Session 1: Registration and Welcome Drink

Sunday, 17:00–21:00 Foyer

Registration and Welcome Drink

Session 2: Opening Session and Detector Materials I

Monday, 9:00–10:40 Lecture Hall

Welcome by the Organizers

Invited Talk 2.1 Mon 9:10 Lecture Hall
30 years of innovation in industrial silicon detectors: Contributions by Paul Burger — •Erik H. M. Heijne — CERN-PH Department

Silicon nuclear particle detectors were introduced around 1955, after single crystal manufacturing was mastered. At first, surface barrier detectors proved superior to diffused and ion-implanted devices. This changed around 1978 when technology developments in microelectronics were applied also in detector construction. Joseph Kemmer and Paul Burger played a preponderant role in this revolution. The industrial aspects have been developed in particular by Burger. Setting up with customers the logistics of mask making and production of a wide variety of detectors has been a great achievement. As a result, the penetration of silicon detectors in many new applications has become possible. In the following three decades the development of CMOS technology has continuously been taken into account in the development of new silicon detectors, both through the associated electronics and in the manufacturing itself.

Invited Talk 2.2 Mon 9:20 Lecture Hall
Industrial silicon detectors, advancements in planar technology — •Paul Burger — CANBERRA, General Manager Silicon Detectors

30 years ago, planar technology, was successfully applied to manufacture rugged silicon detectors as an enhanced technique towards surface barrier and diffused junctions. Today, not only nuclear physics and fundamental research requires such types of devices but the industrial market has also become an important user. High performance detectors can be used in health physics, X-Ray fluorescence and diffraction, medical imaging, space applications and photon detection. As an industrial company, we had to develop important features such as ultra-reliable detectors, low leakage current, thin entrance window, thick and thin detectors, low noise devices and position sensitive arrays. A new challenge is the read-out of pixilated devices. Features as integrating the electronics into or onto the detector chip are a topic of current interest.

Contributed Talk 2.3 Mon 10:00 Lecture Hall
GaAs Medipix 2 hybrid pixel detector — •Pasi Kostamo[1], Seppo Nenonen[2], Lukas Tlustos[3], Sami Vähänen[4], Christer Fröjdh[5], and Michael Campbell[3] — [1]Helsinki University of Technology, Espoo, Finland — [2]Oxford Instruments analytical Oy, Espoo, Finland — [3]CERN, Geneva, Switzerland — [4]VTT, Espoo, Finland — [5]Mid Sweden University, Sundsvall, Sweden

High purity epitaxial GaAs has shown good spectroscopic performance as monolithic detectors [1]. GaAs detectors bonded to Medipix1 have also yielded promising results [2]. In this work we present for a first time a GaAs Medipix 2 hybrid pixel detector with detector element of high purity epitaxial GaAs. The GaAs detector element presented in this work is capable of room temperature spectroscopic operation without cooling.

The GaAs detector element manufactured in this work is of mesa type and it is based on a thick epitaxial p-i-n structure grown by hydride vapor phase epitaxy. The mesas were patterned on the p-side of the detector element with inductively coupled plasma reactive ion etching system. The final thickness of 107-113 μm was achieved by removal of the substrate with a lapping and polishing system. The GaAs detector element was designed Medipix2 compatible [3] and it has 256x256 pixels, 55x55 μm^2 each. Total active area of the detector element is 1.4x1.4 cm^2. The detector is flip-chip bump bonded to the read out chip.

Total leakage current of the detector is approximately 10 μA at room temperature with 100 V reverse bias. Technological issues about the manufacturing process are discussed and early results are presented.

References:

[1] A. Owens, et. al., Journal of Applied Physics, 2001 vol 90, issue 10, pp. 5376-5381

[2] A. Owens, et. al., proc SPIE, vol 5501, High-Energy Detectors in Astronomy, Andrew D. Holland, Editor, September 2004, pp. 241-248

[3] X. Llopart, et. al., Nuclear Science, IEEE Transactions on, vol 49, Issue 5, Oct. 2002 pp. 2279 - 2283

Contributed Talk 2.4 Mon 10:20 Lecture Hall
Comparison of charge collection efficiency of segmented silicon detectors made with FZ and MCZ p-type silicon substrates — •Gianluigi Casse and Phil Allport — University of Liverpool, Department of Physics, O. Lodge lab., L69 7ZE Oxford street

High resistivity p-type silicon has emerged as the most promising material for the finely segmented detectors to be used in particle physics experiments where high levels of radiation damage are expected. Beside the standard high purity float-zone (FZ) silicon, relatively high resistivity magnetic Czochralski (MCZ) is now available from industry. This material has been proposed as possibly more radiation hard than the standard FZ. This work shows a comparison of these substrate materials in term of charge collection efficiency measurements performed with 40MHz analogue electronics, before and after irradiation.

Session 3: Applications I

Monday, 11:00–12:40 Lecture Hall

Invited Talk 3.1 Mon 11:00 Lecture Hall
X-Ray Based Methods for Nondestructive Testing and Material Characterization — •Randolf Hanke and Theo Fuchs — Fraunhofer EZRT, Dr.- Mack-Strasse 81, 90762 Fürth

The progress in complexity and miniaturization in the field of new materials as well as in micro production needs improvements and technical advances in the field of micro NDT to provide better quality data and more detailed knowledge about the internal structures of micro components. Nondestructive methods like radioscopy, ultrasound, optics or thermal imaging therefore increasingly gain in importance with respect to ongoing product and material development in the different phases like material characterization, product control or module reliability. Depending on all these different features like application fields, material inspection or characterization, this contribution will give an overview about the radioscopic based methods related to their most important applications.

Radioscopic inspection has become one of the most powerful tools in the field of non destructive testing for industrial material inspection since the discovery of X-rays by Conrad Wilhelm Röntgen in the year 1895 (Nobel Price 1901). Already at this time, C.W. Röntgen had to face the same problems, which are still today regarded as major challenges with respect to advanced research and development for nondestructive testing:

- The high dynamic range of measured intensities caused by exponential attenuation law for radiation in matter
- The superposition of object structures along the radiation beam direction, caused by projective geometrical imaging (projection technique)
- Long exposure times, essential for a reasonable signal to noise ratio (SNR)
- Loss in contrast by diffuse background, generated by scattered radiation which occurs during Compton interaction of photons with electrons of the outer atomic shell
- The strong attenuation by metals compared to weak absorption of human skin, organs and tissue

Today, in modern industrial quality control, x-rays are used in two different ways:

1. Two dimensional radioscopic transmission imaging (projection technique), usually applied to inline inspection tasks in application fields like lightweight material production, electronic component soldering or food production.

2. Computed tomography for generation of three dimensional data, representing spatial information and density distribution of objects. CT application fields are on the one hand the understanding of production process failure or component and module inspection (completeness) and on the other hand the dimensional measuring of hidden geometrical outlines (metrology).

This presentation demonstrates the methods including technical set ups (x-ray source and detector), imaging and reconstruction results and the methods for high speed and high resolution volume data generation and evaluation.

Contributed Talk 3.2 Mon 11:40 Lecture Hall
Material Resolved X-ray Imaging using Spectrum Reconstruction with Medipix2 — •Markus Firsching, Patrick Takoukam Talla, Thilo Michel, and Gisela Anton — Physikalisches Institut, FAU Erlangen, Germany

In conventional X-ray imaging of a composed object only the cumulative attenuation is accessible, but the contribution from different materials can not be resolved. We consider that the object consists of known basis materials. Our method of material reconstruction provides the areal densities of these basis materials in each pixel of the image. This method uses the different energy dependence of X-ray attenuation of the basis materials to distinguish between them. It obviously requires a spectroscopic detector.

Pixelated hybrid semiconductor X-ray detectors as Medipix2 suffer from charge sharing between pixels. This leads to a deteriorated energy response of the detector. To overcome this problem, we present two different methods to reconstruct incident X-ray spectra from threshold scans in each pixel. Both of which, namely spectrum stripping and a linear least squares fit, employ MC-simulated energy response functions to mono-energetic irradiation. Both methods work very well.

The reconstructed incident spectra allow the application of material reconstruction with Medipix2. We present the material resolved images of a phantom containing aluminum, acrylic glass (PMMA) and iodine. Image quality parameters are examined. This method allows new applications in non-destructive testing and medical imaging. This work was carried out within the Medipix-collaboration.

Contributed Talk 3.3 Mon 12:00 Lecture Hall
Radiographic observation of microstructure displacement field — •Daniel Vavrik[1,2], Jan Jakubek[1], and Ivan Jandejsek[2] — [1]Institute of Experimental and Applied Physics, Horska 3a/22, 128 00 Prague 2, Czech Republic — [2]Institute of Theoretical and Applied Mechanics v.v.i., Prosecka 76, Prague 9, Czech Republic

This work reports on results of radiographic observation of 3D displacement field of loaded flat specimen by recognition of its inner grain induced microstructure. Inner material microstructure can be visualized thanks to practically unlimited dynamic range of the used pixelated X ray imager and proper data processing. Quality of the radiograms is significantly improved in our work using the "Direct thickness calibration method" (DTC). A map of equivalent thickness values substituting radiograph intensities is obtained by this method [1]. As X-ray detector we used the single X ray photon counting digital 13 bit Medipix 2 [2] device with a 700 microns thick Si sensor arranged into a matrix of 256x256 square pixels, 55x55 microns each. Inner material microstructure of the observed Al alloy is exhibited in radiogram by attenuation variations which are inducted by differences in chemical composition of individual grains. These variations are in proportion of 50 microns to the average geometrical thickness of 5 mm thick flat specimen in regard to the DTC method used. Grainy microstructure features projected in radiogram have typically dimensions of tens of microns. Consequently, the microfocus X ray source Feinfocus used with spot size of 5 microns and divergent X ray beam serves as adequate instrument for projection of so small structure. In accordance to the radiogram structure scale, a geometrical magnification of 3.6 was used in our experimental setup when a recognizability of details with 15 microns size is reached using the Medipix-2 device. Due to the natural Poisson distribution of the X-ray photon flux, the required signal-to-noise ratio and the radiogram spatial resolution desired, at least a 14 bit dynamic range is required for sufficient contrast radiogram structure. Such high dynamic range is possible thanks to the zero dark current, noiseless counting and absolute linearity of the Medipix 2 device where higher dynamic range can be reached by summing subsequent single radiograms. Assuming a flat geometry for the loaded specimen, the in plane displacement field (in directions of first two space axes) is evaluated from radiographs using the image correlation technique. The grid of control points is generated in the first image. The grid points positions are traced over the all the radiographs taken with subpixel accuracy. Submicron resolution of the control points positions is reachable. The related out-of plane displacement field (in direction of third space axis) is measured as the specimen thickness reduction map using the DTC technique. The resultant 3D displacement field is determined as differences between the actual and first (reference) radiograph.

[1] J. Jakůbek, D. Vavřík, S. Pospíšil, J. Uher, NIMA, Vol. 546, Issues 1-2, 2005, Pages 113-117, available on-line

[2] Medipix collaboration: http://www.cern.ch/MEDIPIX/

Contributed Talk 3.4 Mon 12:20 Lecture Hall

A silicon carbide microstrip detector for radiation spectroscopic imaging — •Giuseppe Bertuccio[1], Stefano Caccia[1], Delia Tosi[1], Claudio Lanzieri[2], and Filippo Nava[3] — [1]Politecnico di Milano, Milano, Italy — [2]Selex Integrated Systems, Rome, Italy — [3]University of Modena, Modena, Italy

The design and performance of a microstrip detector made on Silicon Carbide (SiC) will be presented. The detectors have been manufactured using planar technology on 2 inches 4H-SiC wafers. Two prototypes of detectors (S4, S5) have been manufactured, both constituted by 32 strips with length of 2 mm; the S4 detector have 50 μm wide strips with 100 μm pitch, the S5 have 25 μm wide strips with 55 μm pitch. The strips are Schottky junctions on a 45 μm thick low doped n-type epitaxial 4H-SiC grown on top of a high conductivity SiC wafer.

The two detectors have been fully characterised electrically and with X-rays. It has been observed a very good uniformity in the I-V characteristics of the strips on the whole detector. The Schottky junctions show a barrier height of 1.58 eV with an ideal coefficient of 1.05. The reverse current measured at 27°C on the 32 strips is 4.5fA ± 2.1fA at bias voltage of 100 V (80kV/cm mean electric field). The shot noise of these low currents corresponds to Equivalent Noise Charge below 1 electron r.m.s. up to peaking time of 20μs, so making these detectors practically noiseless even at room temperature with respect of presently available front-end electronics. The reverse current shows a weak dependence on the temperature, being below 20 fA up to 107°C.

The detectors have been characterised with X-rays using Americium 241 and Iron 55. An energy resolution of 330 eV FWHM (18 electrons r.m.s.) on the pulser line has been measured at 23°C for the S5 detector coupled to a low noise JFET input charge preamplifier, which strongly limits the system performance. The spectroscopic characterisation of the detector using a custom designed integrated CMOS preamplifier with an intrinsic noise of 3 electrons r.m.s. is under way.

Session 4: High Resolution Imaging

Monday, 14:00–16:00 Lecture Hall

Invited Talk 4.1 Mon 14:00 Lecture Hall

The use of 2D pixel detectors in micro- and nano-CT applications — •Manuel Dierick[1], Luc Van Hoorebeke[1], Patric Jacobs[2], Bert Masschaele[1], Jelle Vlassenbroeck[1], Veerle Cnudde[2], and Yoni De Witte[1] — [1]Dept. of Subatomic and Radiation Physics, Proeftuinstraat 86, 9000 Gent, Belgium — [2]Dept. of Geology and Soil Science, Krijgslaan 281 S8, 9000 Gent, Belgium

Computed Tomography or CT is a non-destructive imaging technique that uses penetrating radiation (mostly X-rays) to visualize the internal structure of a sample. The best known example is the CAT scanner which has become a standard diagnostic tool in medical science, providing detailed views of the body with spatial resolutions below one millimeter. In recent years another type of CT scanners has been developed for mostly industrial and scientific applications, namely micro-CT scanners. These made spatial resolutions possible of the order of tens of microns to even a few microns.

During 2005 the Radiation Physics research group (Dept. of Subatomic and radiation physics) and the Sedimentary Geology and Engineering Geology research group (Dept. of Geology and Soil science) of the Ghent University jointly developed a modular micro-CT setup. The two main goals were to achieve a spatial resolution of below one micrometer and to have a very versatile tool providing high-quality images. We opted for a so-called dual-head X-ray tube with 1) a transmission type head with a nominal focal spot size of 900 nm below 40 kV tube voltage for high resolution applications and 2) a directional high power head (up to 160 keV, up to 150 Watts) which enables us to scan larger samples. A six-axis sample manipulator system was assembled. The crucial component in this is an ultra high precision air-bearing rotation stage to keep all motion errors during rotation well below 1 micrometer.

Depending on the application we have the choice between a number of detectors, each with their own advantages in terms of size, pixel resolution, energy sensitivity, dynamic range, noise etc. Different detector technologies are available including an amorphous silicon flat panel, a 11 Megapixel CCD camera, CMOS flat panel detectors and an image intensifier. All this results in a wide range of experimental conditions (10-160 kV, sample size from sub-mm up to 20 cm, spatial resolutions from 1 mm down to 1 micrometer). Some applications are: species description of fossil inclusions in amber, statistical analysis of pore size distributions in rocks and soils, providing 3D CAD models of objects for input into finite element tools for simulation of stress or fluid flow, structural analysis of foams etc.

This talk will give a detailed description of the setup, an overview of some typical applications and the available hard- and software-tools. Finally we will describe the potential of future detector technologies in micro-CT applications.

Contributed Talk 4.2 Mon 14:40 Lecture Hall
The LHCb RICH photon detector system — •Kenneth Wyllie — CERN, Geneva 23, Switzerland CH-1211

The LHCb experiment at the CERN Large Hadron Collider will employ two Ring-Imaging-Cherenkov (RICH) detectors for particle identification. The Cherenkov photons will be detected by planes of photon detectors covering a total surface area of 2.6m2. The detector chosen for this task is the pixel hybrid photon detector (HPD). This novel device combines silicon sensors, integrated pixel front-end electronics and high-density interconnects together with vacuum-tube technology to produce an efficient, low-noise detector sensitive to single photons. For the complete photon detector system of the LHCb RICH, 484 such HPDs are required.

This paper describes the HPD system installed in the LHCb RICH experiment. The HPD technology was presented at IWORID 2004 and production was subsequently started on all components for the full complement of 484 HPDs. The difficulties experienced during production and their solutions will be described, with specific emphasis on the integrated silicon sensors and readout electronics. The incorporation of the HPDs within the system will then be presented together with particular aspects of this integration related to the efficiency and lifetime of the detector in the harsh environment of LHCb. Finally, results from tests of the system using a number of different photon sources will be presented.

Contributed Talk 4.3 Mon 15:00 Lecture Hall
High resolution application of YAG:Ce and LuAG:Ce imaging detectors with CCD X-ray camera — •Jan Tous[1], Martin Horvath[2], Ladislav Pina[2], and Karel Blazek[1] — [1]Crytur Ltd., Palackeho 175, CZ-51101, Turnov, Czech Republic — [2]Reflex Ltd., Novodvorska 994, CZ-14221, Prague, Czech Republic

A high resolution CCD X-rays camera based on YAG:Ce or LuAG:Ce thin scintillators is presented. The high resolution of the imaging system in low energy X-ray radiation is proved on several objects. The achieved spatial resolution of the images is better than 1 micron.

The high resolution imaging system is a combination of a high sensitive digital CCD camera and an optical system with a thin scintillator imaging screen. The screen is the YAG:Ce or LuAG:Ce inorganic scintillator. These materials have the advantages in the mechanical and chemical stability and the non-hygroscopicity. The high-resolution imaging system can be used for different types of radiation (X-Ray, electron, UV, and VUV). The objects used for imaging are grids and small animals with parts of several microns in dimension. The resolution capabilities have been tested using different types of CCD cameras and scintillation imaging screens.

Contributed Talk 4.4 Mon 15:20 Lecture Hall
Characterisation of lanthanides-doped LSO epitaxial layers for high-resolution X-ray imaging applications — •Paul-Antoine Douissard[1], Thierry Martin[1], Maurice Couchaud[2], Alexander Rack[3], Angelica Cecilia[3], and Tilo Baumbach[3] — [1]European Synchrotron Radiation Facility, BP 220, Grenoble, 38043, France — [2]CEA Léti MINATEC, 17 rue des Martyrs, Grenoble, 38054, France — [3]Forschungszentrum Karlsruhe ANKA, Postfach 3640, Karlsruhe, 76021, Germany

The SCINTAX projects aims at developing a new thin layer scintillator for high resolution X-ray imaging. Based on LSO layers grown on adapted substrates, these scintillators will radically improve the efficiency of X-ray imaging methods currently used in synchrotron facilities. It also presents interesting features for the non destructive testing market. The major improvement will result from a higher absorption of these crystals with respect to commonly used scintillators, such as YAG:Ce, LAG:Eu, GGG:Eu etc. Another advantage is that the substrate used for the growth presents no emission under X-ray excitation. It is not the case for most substrates used today in synchrotron x-ray imaging [1]. Finally, the emission can be adapted to better match the CCD cameras quantum efficiency by using a right dopant [2].

LSO thin scintillating layers doped with different lanthanides ions were grown using Liquid Phase Epitaxy (LPE) at the French Atomic Energy Commission (CEA). Their scintillating characteristics were then studied: light output, UV/Vis absorption, X-ray absorption efficiency, radiation damage, afterglow, decay time. The line spread function (LSF) was also measured under X-ray radiations from the European Synchrotron Radiation Facility (ESRF). These performances were then compared to thin film scintillators commonly used in synchrotron applications.

This project SCINTAX is funded by the European Community as part of the Sixth Framework Programme (STRP 033 427).

Contributed Talk 4.5 Mon 15:40 Lecture Hall
Microcolumnar ZnSe:Te Scintillator for High Resolution Imaging — •Vivek Nagarkar, Bipin Singh, Valeriy Gaysinskiy, Stuart Miller, and Samta Thacker — Radiation Monitoring Devices, Inc., 44 Hunt Street, Watertown, MA 02472

The advent of large area high-resolution digital readouts has revolutionized digital X-ray imaging technology enabling their use in such important applications as medical imaging, nondestructive testing, and homeland security. Recent outstanding progress in high-speed sensors such as an electron multiplying CCD (EMCCD), has now made it possible to design imaging detectors for several new and exciting applications including time resolved studies and high speed cone beam computed tomography (CBCT) for basic biological and functional studies. Since most current and anticipated future digital detectors rely on indirect detection of X-rays where scintillators act as a light converter, correspondingly brisk progress in high resolution, high light yield, fast scintillator technology is needed to fully exploit capabilities of the digital readouts. Due to their extraordinary properties, selenium based scintillators doped with various activator ions are attractive materials in this regard. Here we report on the growth of one such novel material, ZnSe:Te, in a microcolumnar form suitable for high resolution imaging.

While ZnSe as an IR window material is established, incorporation of an isovalent Te impurity in ZnSe crystals to control its luminescence properties was discovered just a few years ago [1]. ZnSe:Te promises to provide unprecedented scintillation efficiency of over 100,000 optical photons/MeV and has a 610 nm emission which is ideally suited for CCD sensors. Additionally, its high density of 5.4 g/cm^3, fast decay time of ~3 ms with no afterglow, and orders of magnitude higher radiation resistance compared to standard scintillators allows for high efficiency, high speed imaging in harsh radiation environments. Significant work on the crystal growth of ZnSe, and some work on fabricating powdered ZnSe:Te films [2] has since been reported, but no attempts have been made to fabricate it in a columnar form suitable for high-resolution imaging due to the complexities involved in the growth processes. We have successfully fabricated microcolumnar films of ZnSe:Te using vapor deposition process and have evaluated their imaging properties. These films show excellent columnar structure with column diameters as small as 200 nm, bright red emission, and high spatial resolution of 11 lp/mm, which is a factor of 3 higher compared to the powdered ZnSe:Te films of equivalent thickness. A comparative study of the performances of microcolumnar ZnSe:Te and the commercial powdered screens along with the application potential for these new screens in advanced X-ray imaging will be discussed in this paper.

References:

[1] V. Ryzhikov, G. Tamulaitis, N. Starzhinskiy, L. Galchinetskii, A. Novickovas, J. Lumin., 101 (2003) 45.

[2] Bruker AXS Inc., Advanced X-ray Solutions, http://www.bruker-axs.com

Session 5: Device Processing and Front-End Electronics

Monday, 16:20–18:00 Lecture Hall

Invited Talk 5.1 Mon 16:20 Lecture Hall

3D integration technologies for imaging applications
— •Piet De Moor — IMEC, Leuven, Belgium

Radiation detection of both photons and particles has been evaluating during the last decades from fairly large (millimeter to centimeter) size single pixel detectors over one-dimensional arrays to full two-dimensional imaging systems with very small pixel sizes (down to a few micron), having large number of pixels (e.g. several Megapixels) and hence excellent spatial resolution. This evolution happened mainly thanks to the miniaturization capabilities of both advanced CMOS analog (and digital) readout electronics and sensor manufacturing technology. Another enabling technology is hybrid interconnection, e.g. using small solder bumps to connect the individual cells on the read-out chip with the individual pixels of the separately processed sensor array (consisting of e.g. non-Si materials). In line with the further miniaturization potential of the CMOS read-outs, the pitch at which this hybrid interconnection is realized will further decrease to less than 10 micron, thereby shifting to alternative materials and technologies for the interconnects.

A disruptive performance enhancement of these radiation imaging systems will be obtained when three-dimensional stacking of dies or embedding of thin dies is being used. Contrary to the current systems having lateral interconnects (e.g. bonding wires) to the read-out chips, 3D stacking of sensor, read-out chip and read-out system board will allow to tile individual 3D detectors and will enable large area detection combining both high resolution and very small non-sensitive area. Moreover, 3D integration of (e.g. multiple) sensor layers, analog read-out electronics, memory and digital signal processing chips will allow to build intelligent and yet compact imaging sensor nodes.

In order to manufacture these 3D integrated imaging devices, a number of different technologies have to be developed in a manufacturable and reliable way: through (thinned) Si via interconnects for bringing the electrical signals from one side of the chip to the other, and high density microbump interconnects to interconnect two or more different chips each of them having through Si via interconnects. Alternatively, sensor and read-out dies can be aggressively thinned and embedded using thin film technology, enabling very thin flexible, foldable systems. The required technology development and its status today will be discussed along with some imaging system application demonstrators such as backside illuminated active pixels sensors and tilable X-ray detector 3D stacks.

Contributed Talk 5.2 Mon 17:00 Lecture Hall

Development of thin pixel sensors and a novel interconnection technology for the SLHC — Ladislav Andricek, Siegfried Bethke, Joerg Dubbert, Nabil Ghodbane, Hubert Kroha, Oliver Kortner, Hans-Guenther Moser, •Richard Nisius, and Rainer Richter — Max-Planck-Institut fuer Physik, Foehringer Ring 6, D-80805 Muenchen

We present an R&D programme towards a novel pixel module design for the ATLAS experiment at the super LHC based on a radiation tolerant pixel sensor, which will be 50–100 micrometer thin and produced using a wafer bonding technology.

As an option to replace the bump bonding process, the sensor will be connected to the read-out electronics by the novel Solid-Liquid InterDiffusion (SLID) interconnection process developed by the Fraunhofer-Institut IZM, offering finer segmentation and potentially lower cost.

In addition, using ICV-SLID, namely Inter-Chip Vias together with the SLID process, allows for a compact design, i.e. a higher live fraction and the vertical integration of analog and digital electronics made from different chip technologies.

This pixel detector concept opens new possibilities for the optimisation of radiation tolerance, power consumption, speed and complexity.

Contributed Talk 5.3 Mon 17:20 Lecture Hall
Rework of Flip Chip Bonded Radiation Pixel Detectors — •Sami Vähänen, Hannele Heikkinen, Harri Pohjonen, Jaakko Salonen, and Satu Savolainen-Pulli — VTT Technical Research Centre of Finland, PO Box 1000, Tietotie 3, FI-02044 VTT, Espoo, Finland

In this paper some practical aspects of reworking flip chip hybridized pixel detectors are discussed. As flip chip technology is advancing in terms of placement accuracy and reliability, large-area hybrid pixel detectors have been developed. The area requirements are usually fulfilled by placing many chips on single substrate. However, as the number of chips increases, the probability of failure in the hybridization process or chip operation also increases. Because high accuracy flip chip bonding takes time, a significant part of the price of a pixel detector comes from the flip chip assembly process itself. As large detector substrates are expensive, and many flip chip placements are required, the price of an assembled detector can become very high. In a typical case, there is just one bad readout chip (out of several) on a faulty detector to be replaced. Considering the high price of pixel detectors and the fact that reworking faulty chips does not take much longer than placing a new one, it is worthwhile to investigate the feasibility of a rework process.

CERN's ALICE ladder detectors, bumped and flip chipped by VTT, were used as test material for this study. Each ladder detector consisted of five CMOS readout chips bonded onto a silicon sensor chip. Each readout chip had 32x256 array of 25-μm diameter solder bumps at a pitch 50 μm /425 μm.

Contributed Talk 5.4 Mon 17:40 Lecture Hall
Spectral characterisation and noise performance of Vanilla - an Active Pixel Sensor — •Andrew Blue[1], Andrew Laing[1], Dzmitry Maneuski[1], Val O'Shea[1], Renato Turchetta[2], Andy Clark[2], Mark Prydderch[2], Sarah Bohndiek[3], and Costas Arvanitis[3] — [1]Dept. Of Physics & Astronomy, University of Glasgow, Scotland, UK — [2]CCLRC, Rutherford Appleton Laboratory, Oxfordshire, UK — [3]Dept. of Medical Physics and Bioengineering, University College London

A UK consortium (MI3) was formed in 2004 under an RC-UK Basic Technology Programme to develop CMOS active pixel sensors for a broad range of scientific applications including space science, particle physics and medical imaging

This work will report on the characterisation of Vanilla, the most recent MI3 produced APS (Active Pixel Sensor). The Vanilla APS comprises of 512x512 (25um square) pixels. The sensor has a 12 bit digital output for full frame mode, although it can also be readout in analogue mode. It can also be read in a fully programmable Region-Of-Interest (ROI) mode. In full frame, the sensor can operate at a readout rate of more than 100 Frames/Second, while in ROI mode, the speed depends on the size, shape and number of the ROI. For example, six ROIs of 6x6 pixels can be read at 10,000 frames per second in analogue mode.

The use of flushed reset - a method proposed to reduce KTC noise - has been fully examined. Using PTC (Photon Transfer Curve) measurements allowed for the calculation of the read noise, shot noise, full well capacity and camera gain constant. Spectral response measurements detailed the QE of the detector through the UV and visible region. Comparisons were also made using hard and soft reset modes.

Optimisation of the sensor was made through variation between readout modes (analogue and digital), frame rates, integration times and on-chip biases and voltages, helping determine whether or not such sensors are - along with biomedical and space applications - suitable for use in particle physics experiments.

Session 6: Social Event

Monday, 18:00–23:00

Beer Garden

Session 7: Gamma Ray Imaging

Tuesday, 9:00–10:40 Lecture Hall

Invited Talk 7.1 Tue 9:00 Lecture Hall
Construction and ground tests of the Large Area Telescope of the GLAST space mission — •Alessandro Brez — INFN, Pisa, Italy

The Gamma-ray Large Area Space Telescope (GLAST) is an international, multi-agency satellite mission with a vast and ambitious physics program in gamma-ray astronomy, particle astrophysics and cosmology and will be launched in December 2007. The Large Area Telescope (LAT) is the main instrument onboard GLAST. The LAT is a unique pair conversion telescope with a very large energy band (20 MeV - 300 GeV) point spread function down to arcmin level and very large effective area (9000cm^2). The LAT was implemented making use of the most advanced particle detectors, like a 74m^2 silicon strip tracker, full custom readout electronics and stiff, light structural mechanics mostly based on composite materials.

Highlights of the LAT instrument performance and of the main calibration phases are discussed here, as well as their impact on the mission discovery potential.

Contributed Talk 7.2 Tue 9:40 Lecture Hall
Performance of the gamma-ray camera based on scintillator array and PSPMT with an ASIC readout system — •Kazuki Ueno, Kaori Hattori, Chihiro Ida, Satoru Iwaki, Shigeto Kabuki, Hidetoshi Kubo, Shunsuke Kurosawa, Kentaro Miuchi, Hironobu Nishimura, Atsushi Takada, Toru Tanimori, and Kenichi Tsuchiya — Department of Physics, Graduate School of Science, Kyoto University, Kitashirakawa, Sakyo, Kyoto, Japan

We have studied the performance of a readout system with ASIC chips for our gamma camera based on 64 channels multi-anode PSPMT(Hamamatsu flat-panel H8500) coupled to a GSO(Ce) scintillator array. The GSO array consists of 8×8 pixels of $6\times6\times13$mm^3 with the same pixel size as the anode. This camera is intended for absorber of an Electron Tracking Compton gamma-ray cammera[1]. We need a readout system with low power consumption in order to make a camera which has 64×108 readout channels for a balloon-borne experiment.

We have already studied the performance of two different types of readout systems. One is based on ASIC(IDEAS VA32_HDR14 ,32ch) chips. All 64 channels are preamplified, shaped, sampled, and held by two chips and these signals are digitized by an ADC. The other is based on discrete preamplifiers with wide dynamic range, and chained resistors to reduce readout channels. The power consumption are about 1.3W and 8W per 64 channels, respectively. Typical energy resolution are 13.0% and 10.5%(FWHM) at 662keV, respectively. The former system has the bad energy resolution because input dynamic range is narrow($\geq$-15pC) and therefore the anode gain needs to be as low as 10^5[2,3].

At this conference, we report the following improvement of the readout system. We adopted other ASIC chips with wider input dynamic range($\geq$-35pC)(IDEAS VA32_HDR11) and developed an attenuator board in order to have a high HV operation. The board has 64 singular resistors adjusted to the anode gain and uniforms variation of the anode gain of H8500(min:max$\sim$1:3) before inputs to ASIC chips. Using the board, H8500 was able to operate with the gain of about 10^6(typical gain of H8500) and the output signals after that board had a good uniformity(min:max$\sim$1:1). The system with the new attenuator board has the incident energy dynamic range of 80 to 800keV, the position resolution of less than 6mm, and a typical energy resolution of about 10.0%(FWHM) at 662keV. Furthermore, we made a camera which consists of 16×16 pixels array of $3\times3\times13$mm^3 GSO(Ce). With the new readout system, each pixel was clearly resolved by flood field irradiation of 662keV gamma rays.

Currently we test a LaBr3(Ce) array and a CsI(Tl) array with the new readout system.

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Contributed Talk 7.3 Tue 10:00 Lecture Hall
Real-Time Data Acquisition and Maximum-Likelihood Estimation for a New Generation of High-Resolution Gamma Cameras — •Brian W. Miller, Harrison H. Barrett, Lars R. Furenlid, H. Bradford Barber, and Robert Hunter — Department of Radiology Research, University of Arizona, Tucson, AZ 85724

Modular gamma-ray cameras that use maximum-likelihood estimation (MLE) of the interaction position and energy have been developed at the Center for Gamma-Ray Imaging. Recently, Furenlid et al. have developed a new MLE algorithm based on a contracting grid search which converges to a ML 2D position and energy estimate within six iterations. This fast convergence allows for real-time MLE while data are being acquired.

We have developed a new generation of high-resolution, gamma-ray detectors where real-time data acquisition and MLE are desirable. The detector, called Bazooka SPECT, is a gamma camera based on columnar CsI(Tl) directly coupled to an image intensifier. Individual gamma-ray interactions are seen as clusters of signal (˜10-20 pixels in diameter). When the detector is operated in photon-counting mode, the resolution can be improved by estimating the interaction position using ML techniques, thus yielding an intrinsic detector resolution of ˜70 μm FWHM at 1:1 magnification.

In columnar CsI(Tl) scintillators, we have demonstrated that a correlation of cluster signal versus crystal depth exists. We can use the depth-dependent information to estimate the 3D position and energy of individual gamma-ray interactions using ML estimation techniques. Estimation of the depth becomes very important when oblique-incident gamma rays are imaged, as can be the case with pinhole imaging.

Our CCD frame grabber is capable of receiving approximately 0.6 gigabits of image data per second (assuming 640x480 pixels operating at 120 fps). Storing frame data from long and multiple acquisitions becomes problematic and involves a lengthy post-processing step. Therefore, it is advantageous to have real-time estimation of 3D position and energy of gamma-ray interactions.

Real-time processing is done by converting image data into a list-mode acquisition. As each image arrives from the frame grabber, a smoothed version is generated in a graphics processing card (GPU) to decrease processing time. The smoothed image is then thresholded above the noise, and contiguous regions of signal are identified as gamma-ray interactions. The raw-image data of these regions are then sent on for further processing but can also be stored to disk for future processing if desired, thus resulting in significant data reduction.

To perform MLE of 3D position and energy, two techniques are currently under investigation. The first technique involves a calibration process where a mean cluster template is generated for each depth within the crystal and for multiple gamma-ray energies. Comparing any given gamma-ray event against the templates (using a GPU) and then selecting the best match will yield a MLE of 3D position and energy. The second proposed technique is to implement a Bazooka SPECT version of the contracting grid search.

Contributed Talk 7.4 Tue 10:20 Lecture Hall
Investigation of pixellated TlBr gamma-ray spectrometers with the depth sensing technique — •Keitaro Hitomi[1], Toshiyuki Onodera[1], Tadayoshi Shoji[1], and Zhong He[2] — [1]Tohoku Institute of Technology, Sendai, Japan — [2]University of Michigan, Ann Arbor, USA
Pixellated thallium bromide (TlBr) gamma-ray spectrometers have been investigated using the depth sensing technique. The TlBr crystal was grown by the traveling molten zone method with zone-refined material. In order to fabricate TlBr detectors, the crystal was cut into wafers with a diamond wire saw. The wafers were then polished mechanically. The thickness of the resultant wafers was around 4 mm. The device had a continuous cathode and 4 pixellated anodes (1 mm x 1 mm) surrounded by a guard ring. Negative bias voltage of 1000 V was applied to the planar cathode and all anode electrodes were electrically grounded. The cathode surface was irradiated with 137Cs and 60Co sources. All measurements were performed at room temperature. An energy resolution of 1.22% FWHM at 662 keV was recorded with the device after the depth correction and rejection. Full-energy peaks of 1.17 and 1.33 MeV gamma-rays from the 60Co source were obtained with the detector. An energy resolution of 1.11% FWHM at 1.33 MeV was measured with the detector after the depth correction and rejection.

Session 8: Detectors and Applications

Tuesday, 11:00–12:40 Lecture Hall

Invited Talk 8.1 Tue 11:00 Lecture Hall
Signal transport in Computed Tomography detectors — •Björn Heismann[1], Stefan Wirth[1], K. Pham-Gia[2], W. Metzger[2], and Daniel Niederlöhner[1] — [1]Siemens Medical Solutions, Germany — [2]Siemens Corporate Technology, Germany

In Computed Tomography (CT) X-ray intensities are measured by large-scale solid-state detectors. The standard signal generation chain comprises a scintillator pixel array attached to a matrix of photo sensors which in turn is read out by analog-to-digital conversion electronics. Both the physics of signal generation and transport as well as the analog-to-digital conversion define the performance of the detectors and have to be studied carefully to optimize it.

We have developed and validated a broad system model describing the multi-stage physical process. The first step comprises a Monte Carlo (MC) tracking of the primary X-ray quanta energy deposition, taking into account the relevant fluorescence and scattering processes. The second step models the transport of optical photons in the scintillator pixels formed by a solid-state bulk with surrounding back-scattering TiO2 walls. In a third step the individual events are integrated to a read-out signal and analyzed for their statistical properties. A multi-pixel set-up is used for the simulation to take into account the signal transfer between adjacent pixels. The system model is verified by a comparison to optical measurements. A scintillator array is excited by a) a flat-field and b) a needle beam X-ray source. The emitted light-field is read out by a high resolution CCD sensor. A good agreement between simulation and experiments is found, with a typical deviation in the range of 5%. We use the model to evaluate several macroscopic figures of merit of a CT detector. This includes signal cross-talk and system modulation transfer function as well as the variance increase due to X-ray scattering and optical transport. We finally calculate the energy weighting function D(E). It is an important figure of merit for dual-energy spectral CT, telling us how much a quantum of energy E contributes to the overall detected signal. Significant deviations from the expected linear behavior are observed. They are explained by and linked to specific properties of the signal transport.

Contributed Talk 8.2 Tue 11:40 Lecture Hall
Imaging of biological samples with pixel detectors — •Chiara Cappellini[1], Massimo Caccia[1], Antonio Bulgheroni[3,4], Fabio Risigo[1], Marcin Jastrzab[1,5], and Emanuele Scopelliti[2] — [1]University of Insubria, Como, Italy — [2]University of Milano, Milano, Italy — [3]University of Roma 3, Roma, Italy — [4]Infn Roma 3, Roma, Italy — [5]University of Science and Technology, Cracow, Poland
Beta autoradiography is a well established technique to measure the distribution of macromolecule concentration in biological samples. The potential of Silicon pixel detectors for imaging Tritium radio labelled samples has already been demonstrated. In the following a direct comparison between two general purpose sensors, mimosa5 and medipix2, characterised by complementary technologies and architectures is reported. The mimosa5 is a high granularity monolithic active pixel detector with full analog output while the medipix2 is a hybrid device with moderate granularity and a counting architecture. The comparison is based on two main figures: the effective activity and the dark counting rate. Tests were performed relying on Tritium standards for autoradiography, with specific activities comparable to radio labelled proteins in daily use; a biological sample was imaged and analysed as well. Different algorithms were developed and tested to discriminate against stochastic noise and cosmic rays. The results do confirm the advantage of real time granular sensors against films and Phosphor imaging screens and set the base for an optimised, customised development.

Contributed Talk 8.3 Tue 12:00 Lecture Hall
Study of the charge sharing in silicon pixel detector by means of alpha particles interacting with a Medipix2 device — Michael Campbell[1], Erik Heijne[1], Tomas Holy[2], John Idarraga[3], Jan Jakubek[2], Celine Lebel[3], Claude Leroy[3], Xavier Llopart[1], •Stanislav Pospisil[2], Lukas Tlustos[1], and Zdenek Vykydal[2] — [1]CERN, CH-1211 Geneve 23, Switzerland — [2]Institute of Experimental and Applied physics, Czech Technical University in Prague, Horska 3a/22, CZ-12800 Praha 2 - Albertov, Czech Republic — [3]Universite de Montreal, Montreal (Quebec), Canada H3C 3J7

The energy deposited in a silicon detector by a heavy charged particle, such as an alpha-particle, creates a large amount of electron-hole pairs. Under the influence of an electric field, the carriers drift towards the corresponding electrode. Due to diffusion, the charge carriers are spread isotropically. The processes of charge collection and signal induction in a detector continues to be studied. Lateral spreading will depend on the collection time hence it is expected to be smaller for larger fields. In the case of pixellated detecting structure, this lateral spread will cause a sharing of the charge between the electrodes and many pixels have a signal. The signal formation depends also on the characteristics of the front-end circuit, which in our case can integrate the charge over a long period, > microseconds. Also influencing the charge collection and its spread is the large amount of electron-hole pairs generated locally by the alpha particle, which creates distortions of the electric field along the ionizing path, giving rise to the plasma effect and the so-called funneling effect. The results of the charge sharing effect measured in the Medipix2 pixel detectors of two different thicknesses (300 μm and 700 μm) will be shown as a function of alpha particle energy and applied bias voltage since the charge carriers give a signal in cluster of multiple pixels. The carrier distribution within the cluster is determined using the variation of the cluster size with energy threshold. A model describing the effects of funneling, plasma and diffusion on the charge collection and its sharing will be also presented.

This work was carried out within the CERN Medipix Collaboration

Contributed Talk 8.4 Tue 12:20 Lecture Hall

Characterization of an epitaxial GaAs/Medipix2 detector using fluorescence photons — •Lukas Tlustos[1], Christer Fröjdh[3], Pasi Kostamo[4], and Seppo Nenonen[2] — [1]CERN, Geneva, CH — [2]Oxford Instrum. Analytical Oy, Finland — [3]Mid-Sweden University, Sweden — [4]Helsinki University of Technology, Finland

A high purity GaAs sensor of 110 μm thickness has been bump bonded to a Medipix2 readout chip [1]. In this work the room temperature spectroscopic response of this device to fluorescence photons in the energy range from 8 to 28 keV is presented and compared to the response of a 300 μm thick Si sensor also bonded to a Medipix2. The measured photopeak responses are used to energy calibrate both detectors, giving a threshold step size of ~40e-/ threshold DAC value in both detectors. The spectral response as a function of the applied detector bias is shown. The depth of depletion of the GaAs sensor is estimated to be 50 μm from measurements made using the 8 keV Kα line of a Cu target X-ray tube. First images using the GaAs device are also presented and compared with those of Si.

[1] X. Llopart, et al., Nuclear Science, IEEE Transactions on, vol. 49, Issue 5, Oct. 2002 pp. 2279 - 2283

Session 9: Poster - Imaging Theory and Processing

Tuesday, 14:00–16:20 Poster Hall

Poster 9.1 Tue 14:00 Poster Hall

The detective quantum efficiency (DQE) for evaluating the performance of a small gamma camera system with a uniformly redundant array (URA) collimator — •Hosang Jeon and Gyuseong Cho — Korea Advanced Institute of Science and Technology, Daejeon, South Korea

The gamma scintillation camera is widely used in various industrial, environmental and medical diagnostic fields. We developed a gamma camera system using Hamamatsu's 5-inch diameter R3292 Position-sensitive PMT (PSPMT), a single NaI(Tl) crystal scintillator. The uniformly redundant array (URA) multi-hole collimator was used for the improvement of sensitivity. The URA is one coded aperture imaging technique. The imaging performance of an imaging system can be described by its detective quantum efficiency (DQE). For the calculation of DQE, the modulation transfer function (MTF) calculated from measured line spread function and the normalized noise power spectrum (NNPS) calculated from uniformly flood images were acquired.

Measurements were made with a 5 cm line and a 25 cm^2 square planar source using 99mTc. The output images for the calculation of DQE were acquired using a general pinhole collimator and a URA multi-hole collimator, respectively. In the result, the URA system showed higher sensitivity and lower NNPS than the pinhole system. A difference was found in MTF between two collimators with a slightly better result for the pinhole. It is observed that DQE of the URA system is obviously better than that of the pinhole system. The purpose of this study is to evaluate the performance of the URA-based collimator gamma camera system using DQE concept. Details of this study will be presented.

Poster 9.2 Tue 14:00 Poster Hall

Pattern recognition of tracks induced by individual quanta of ionizing radiation in Medipix2 silicon detector — •Tomas Holy[1], Erik Heijne[2], Jan Jakubek[1], Stanislav Pospisil[1], Josef Uher[1], and Zdenek Vykydal[1] — [1]Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horska 3a/22, CZ-12800 Prague 2, Czech Republic — [2]CERN, CH-1211 Genève 23, Switzerland

Medipix2 [1] is a semiconductor pixel detector (256x256 square pixels, 55x55 μm^2 each) which can register individual quanta of radiation. The detector will respond differently for different types of radiation. If the acquisition time is short enough with respect to radiation intensity one can see characteristic tracks of individual quanta in image taken (e.g. curved lines for electrons, round shaped clusters for alpha particles, heavy ions and slow neutrons, cone shapes for fast neutrons, simple dots for low energy X-rays etc.). By analyzing these patterns it is possible to distinguish individual tracks and classify them into predefined categories. For each "cluster" detected the features, (such as parameters describing the shape and energy deposition estimation), can be extracted and used to distinguish radiation type. The energy deposited can be estimated by using calibration measurements with different types of radiation and variation of the discrimination threshold.

The possibility to automatically distinguish different types of radiation and estimate the energy deposited brings a lot of applications including charged particle spectroscopy [2], real-time fission fragment spectroscopy [3] and dosimetry (once the number of interaction, radiation type and energy deposition estimation is known, the equivalent dose can be calculated by incorporating weight factors for the different type of radiation).

References:

[1] - X. Llopart, M. Campbell, R. Dinapoli, D. San Segundo, E. Pernigotti, "Medipix2 - a 64 k pixel readout chip with 55 μm square elements working in single photon counting mode", Proc. IEEE NSS/MIC, San Diego (2001), IEEE Trans. Nucl. Sci. 49 (2002) 2279, see also http://www.cern.ch/medipix

[2] - Z. Vykydal, J. Jakubek, S. Pospisil, "USB interface for Medipix2 enabling energy and position detection of heavy-charged particles", Nuclear Instruments and Methods in Physics Research A563 (2006) 112-115

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Poster 9.3 Tue 14:00 Poster Hall

FPGA implementation of 2D signals encoder/decoder using QMF based dyadic DWT fast wavelet mallat's algorithm: application to radioisotopes images and neutron tomography projections

— Saadi Slami[1,2], Touiza Maamar[2,2], and •Guessoum Abderrezak[3] — [1]Nuclear Research Centre of Birine (crnb), Bp180, AinOussera,17200, Algeria. — [2]Nuclear Research Centre of Birine (crnb), Bp180, AinOussera,17200, Algeria. — [3]University Saad Dahleb of blida, Signal Processing and Imaging Laboratory (LATSI), Route de Soumaa b.p.270 blida 09000, Algeria.

In this work, we present an Implementation on FPGA of 2D signals Encoder/Decoder using dyadic Discrete Wavelet Transform based on quadrature mirror filters, by applying fast wavelet Mallat*s algorithm. The wavelet coefficients will be encoded by Huffman code in order to be transmitted progressively through an Ethernet TCP/IP based connection. The proposed work is implemented and synthesized in VHDL for Xilinx Virtex-IIV2MB1000 FPGA device using ISE 8.1 and simulated on Modelsim PE 6.0d. The synthesis results are presented in detail. The proposed design can substantially accelerate the DWT and the possible reconfiguration can be exploited to reach a higher performance in the future. The system is designed to be integrated as an extension to the nuclear imaging system implemented around our nuclear research reactor. Assuming a Pentium4 processor with clock frequency of 3.3 GHz for the Matlab software implementation, a speed up of over 5 times for a picture size of 256x256 was achieved. Keywords: FPGA, encoder/decoder, DWT, images, research reactor,tomography.

Session 10: Poster - Applications

Tuesday, 14:00–16:20 Poster Hall

Poster 10.1 Tue 14:00 Poster Hall

Gallium Arsenide detectors in medicine and nondestructive testing

— •Mikhail Polkovnikov and Alexander Vorobiev — Institute of High Energy Physics, Pobeda st. building 1, Protvino, Russia

Institute of High Energy Physics (IHEP) Russia, laboratory of detecting systems provides work with a gallium arsenide strip and pixel detectors.

Main goal are to develop and to construct detecting systems, which include readout electronics (mostly integrating , detectors itself and software to analyze result pictures.

Applications of these detectors are in medicine, nondestructive testing and custom control.

Also laboratory will perform work with open detectors in clean rooms.

Poster 10.2 Tue 14:00 Poster Hall

Characterisation and comparison of direct and indirect converting x-ray detectors for NDT (Non Destructive Testing) in low energy and high-resolution applications.

— •Norman Uhlmann, Michael Salamon, Frank Sukowski, and Virginia Voland — Fraunhofer Institute for Integrated Circuits, Development Center X-Ray Technology EZRT, Dr-Mack-Str. 81, 90762 Fürth, Germany

Recent developments of direct converting x-ray detectors with good efficiency from low (10 keV) to higher (>200 keV) energy range will be of major interest for applied non destructive testing purposes. In this publication we present different tests for characterisation and comparison of detectors used in low-energy and high-resolution radioscopic and computed-tomography application. The characterisation and application tests were performed on the direct converting x-ray detector Ajat DIC100TL (Oy AJAT Ltd.) and the indirect converting x-ray detector C9311DK (Hamamatsu). We present results of different characterisation criteria that is valid for all detector types and applications like basic-spatial-resolution, MTF, SNR, efficiency and other criteria for NDT in the designated application field (low contrast and high resolution applications). We also analyse and discuss the results for the two detectors with respect to the application field.

Poster 10.3 Tue 14:00 Poster Hall

Realisation of a Computed Tomography setup to achieve resolutions below 1 micron. — •Michael Salamon, Peter Krüger, Norman Uhlmann, and Ingo Bauscher — Fraunhofer Institute for Integrated Ciruits, Development Center X-Ray Technology EZRT, Dr.-Mack-Str. 81, 90762 Fürth, Germany

The extension of the resolution of present x-ray imaging systems, especially in computed tomography, below 1 micron necessitates very precise equipment details such as the manipulators, focus size and stability, and detector adjustment. In this publication we present an experimental setup of a Computed-Tomography system with sub micrometer resolution. The requirements on and characteristics of the components and their influence on the measurements are discussed and exemplary results of different test objects in the field of non destructive testing with sub micrometer resolution are presented.

Poster 10.4 Tue 14:00 Poster Hall

Comparison of different methods for determining the size of a focal spot of microfocus x-ray tubes, according to the EN 12543-5, using DDA's. — •Michael Salamon, Peter Krüger, Norman Uhlmann, Frank Sukowski, and Virginia Voland — Fraunhofer Institute for Integrated Ciruits, Development Center X-Ray Technology EZRT, Dr.-Mack-Str. 81, 90762 Fürth, Germany

The EN 12543-5 describes a method for determining the focal spot size of microfocus x-ray tubes up to a minimum spot size of 5 micron. The wide application of X-Ray tubes with even smaller focal spot sizes in Computed Tomography and radioscopy applications requires the evaluation of existing methods for focal spot sizes below 5 micron. In addition new methods and conditions for determining submicron focal spot sizes have to be developed. For the evaluation and extension of the present methods to smaller focal spot sizes, different procedures in comparison with the existing EN 12543-5 were analysed and applied, and the results are presented.

Poster 10.5 Tue 14:00 Poster Hall

Optimum design of detector structure and arrangement for NMDS — •Kwang Hyun Kim[1], In Sub Jun[2], Sung Woo Kwack[3], and Ho Sik Yoo[3] — [1]Chosun University, Gwang Ju, South Korea — [2]RadTek, Daejeon, South Korea — [3]KINAC, Daejeon, South Korea

Recent events have increased the need for locating radiation sources such as Cf-252, Co-60, Cs-137, Ir-192 in a wide variety of locations and situations, particularly those that might be used for terrorizing the public. Therefore, Nuclear Material Detection System (hereafter "NMDS") for this is needed to search and detect neutron, gamma ray emitting nuclides during their road transport. However, since these materials are shielded generally with high density material, high detection sensitivity is required. So, existing NMDS uses a large volume NaI detector for the gamma rays and moderated He-3 tubes for the neutron detectors.

In this work, to enhance detection sensitivity, we have employed four GM tubes with four different energy cut-off filters, respectively. Optimal filter characteristics have been determined by Monte Carlo simulation code, MCNPX. For the purpose of obtaining spectroscopy of gamma-ray from radioactive or nuclear material, new algorithm which uses information obtained from GM tubes covered with the filters has also been described. Also, we have simulated detection efficiency by activity, energy and position of radiation source and arrangement of each detector using Monte Carlo simulation code, MCNPX and optimized detector composition for nuclear material detection. Simulation condition and results will be announced in detail.

Poster 10.6 Tue 14:00 Poster Hall

signal and noise performance of large area pin photodiode and charge sensitive preamplifier for gamma radiography — •Kwang Hyun Kim[1], Young Soo Kim[1], Hwa Yeon Yeo[1], and Jung Sik Kim[2] — [1]Chosun University, Gwang Ju, South Korea — [2]KINAC, Daejeon, South Korea

Fast neutron/gamma-ray radiography (FNGR) method is used for the detection of explosives in aircraft container etc. By combining 14 MeV fast-neutron and 60Co gamma-ray radiographic measurements, images are produced that represent both the density and composition of the contents of a container. Particularly, for the gamma radiography, it is importance for gamma detection system based on photodiode to have high signal and low noise.

So in this work, we performed experiments and analyzed the results concentrating on the characteristics of signal and noise with combination of mono type detector module and several Charge Sensitive Preamplifiers (CSA) for gamma radiography using 60Co gamma rays (1.17 and 1.33 MeV). Detector module has been consisted of CsI(Tl) scintillator coupled with large area PIN photodiode of 1 cm x 1 cm fabricated in the process of ETRI. Noise measurements were performed with several candidate CSAs having low noise characteristics such as eV 5091, eV 5093 of eV Product Company and A250, A250F of Amp-Tek Company.

In the process of each design, we optimized the scintillator geometry for 60Co gamma rays using Monte Carlo simulation code, MCNPX, DETECT-2000. Also for the design of the PIN photodiode, ATLAS device simulation tool was used. System construction including CSA and their performance test results will be announced in detail.

Poster 10.7 Tue 14:00 Poster Hall

Survey of historical monuments and art objects using silicon detectors — •Tomáš Trojek, Tomáš Čechák, Ladislav Musílek, and Jiří Martinčík — Czech Technical University, Břehová 7, 115 19 Praha 1, Czech Republic

Semiconductor Si(Li) or Si-PiN detectors are recently frequently used in investigation of various old objects such as manuscripts, paintings, pottery, and metallic items from archaeological excavations. These silicon detectors are mainly applied to spectrometry of characteristic X-rays that are emitted from the object when X-ray fluorescence (XRF) analysis is performing. It plays an important role in determination of chemical compositions of any valuable objects, because the analyses are nondestructive, multielemental, relatively cheap and easy to done. In addition, portable instruments enable in-situ analysis without sampling. The accurate results of X-ray fluorescence analyses are required especially by restorers and conservators who take care of the monuments.

The common XRF instruments contain a radionuclide source or an X-ray tube as a source of primary X-rays. The photon beam of primary radiation induces emission of characteristic X-rays that are then scored with a suitable detector. The choice of a proper detector is a crucial matter affecting the results of the analysis. Firstly, the detector should achieve high detection efficiency in the energy range from 1-2 keV to about 30 keV. Secondly, since the spectroscopic information is required, the energy resolution of the detector must be good enough to distinguish X-ray lines of two elements with close atomic numbers. For example, an atomic number of a lot of important and prolific chemical elements is about 20-30 (chromium, iron, manganese, copper, zinc, etc.) In this region, the energy difference of K-alpha lines of 2 nearby elements is approximately 500 eV. But taking into account the unfavorable overlapping with K-beta lines, energy resolution of the detector should be better than 200 eV for X-ray energy of 5.9 keV.

XRF instruments with silicon detectors make us possible to identify pigments applied to old paintings and wall paintings, or pigments and inks used in mediaeval manuscripts. Furthermore, excellent results are achieved in classification of metallic sculptures, coins, tools, ceramics and others archaeological finds. The XRF analysis is mostly performed by means of focusing of a beam of primary radiation to desired point. Thus, the local chemical composition or chemical composition averaged over larger area is obtained. With respect to lots of heterogeneities in composition and structure, it would be very important to develop a new XRF instrument with a position sensitive detector that would be able to determine surface distribution of all important elements during one measurement.

Poster 10.8 Tue 14:00 Poster Hall

X-ray fluorescence imaging with pixel detector — •Vladimir Tichy, Tomas Holy, Jan Jakubek, Vladimir Linhart, Stanislav Pospisil, and Vykydal Zdenek — Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horska 3a/22, CZ-12800 Praha 2, Czech Republic

X-ray fluorescence (XRF) is a well established method for material elemental analysis. Usually, high quality spectroscopic detectors are used which provide precise element analysis. However it is difficult to obtain imaging information about spatial distribution of the given elements.

To image the spatial distribution of elements in the specimen we used the Medipix2 semiconductor detector. Medipix2 is a pixel detector which has a matrix of 256x256 pixels of 55x55μm with a total area of 2cm^2. Each pixel is connected to its own electronics containing a double discriminator allowing full noise suppression and selection of desired energy range (single channel analyser).

In our setup, the X-ray source illuminates the tested sample which in turn looks at the detector through a pinhole geometry. The energy resolution of the Medipix2 device is 3-5keV, hence it does not allow precise element analysis. It is necessary to know qualitatively which elements are contained in the sample. A precise calibration of Medipix2 response to the spectra of these elements has to be performed. The complex spectrum of the specimen can be decomposed into spectra of individual components. Thus, we are able to determine quantitatively the amount content of the elements in the sample and their position (spatial image distribution).

Medipix2 detects photons with energy above 5keV. Thus, it is possible to detect only elements with atomic number $Z \geq 26$ (iron). It is possible to resolve elements with atomic number difference of 1.

This work was carried out within the CERN Medipix Collaboration.

Poster 10.9 Tue 14:00 Poster Hall

Detection of Fast Neutrons with the Medipix2 Pixel Detector — •Josef Uher[1], Jan Jakubek[1], Ulli Koester[2], Celine Lebel[3], Claude Leroy[3], Andreas Van Overberghe[2], Stanislav Pospisil[1], Radek Skoda[4], and Zdenek Vykydal[1] — [1]Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horska 3a/22, CZ-12800 Prague 2, Czech Republic — [2]Institut Laue Langevin, 6 rue Jules Horowitz, F-38042 Grenoble Cedex 9, France — [3]Universite de Montreal, Montreal (Quebec), Canada H3C 3J7 — [4]Department of Nuclear Reactors, Faculty of Nuclear Sciences and Physical Engineering, Czech Technical University in Prague, V Holesovickach 2, CZ-180 00 Prague 8, Czech Republic

Neutron radiography using thermal and fast neutrons is becoming increasingly important for scientific, technical, security and other applications. In the past, the Medipix2 imaging detector was successfully adapted for thermal neutron imaging in our group by adding a 6LiF neutron converter. Recently, the Medipix2 detector was modified for fast neutron imaging. The Medipix2 device consists of a silicon pixel detector (256 x 256 square pixels, 55 μm x 55 μm each) which is bump-bonded to a readout chip. Fast neutrons are detected through proton recoil from a 1 mm thick polyethylene layer placed on the detector surface. Basic detection and imaging properties of the detector were calculated, simulated and measured. The measurements were done using an AmBe neutron source, as well as external neutron beams of the Sparrow reactor at the Czech Technical University in Prague and of the high-flux reactor at Institut Laue-Langevin (ILL) in Grenoble, respectively. The detector provided a reasonable signal to background ratio of about eight at the neutron beam of ILL's Neutrograph neutron radiography and tomography station. The estimated spatial resolution was at a level of 100 μm. A demonstrational image of a sample taken with fast neutrons will be presented as well.

The work was carried out within the CERN Medipix Collaboration. Neutrograph is collaboration between ILL and the University of Heidelberg.

Poster 10.10 Tue 14:00 Poster Hall

Energy calibration measurements of Medipix2 — Michael Fiederle[1], Dominic Greiffenberg[1], John Idarraga[2], Jan Jakubek[3], Vlastimil Kral[3], •Celine Lebel[2], Claude Leroy[2], Stanislav Pospisil[3], and Michal Suk[4] — [1]Freiburger Materialforschungszentrum, Albert-Ludwigs-Universitat Freiburg, Stefan-Meier-Strasse 21, D-79104 Germany — [2]Universite de Montreal, Montreal (Quebec) H3C 3J7, Canada — [3]Institute of Experimental and Applied Physics of the CTU in Prague, Horska 3a/22, CZ-12800 Praha 2 - Albertov, Czech Republic — [4]Faculty of Mathematics and Physics, Charles University in Prague, V Holesovickach 2, CZ-18000 Praha 8, Czech Republic

Medipix 2 detector modules consist of a semiconductor detector bonded to the photon counting readout electronics

Medipix2. These modules were successfully used in spectroscopic radiation measurements. This position-sensitive device is composed of a pixellated semiconductor detector bump-bounded to a readout chip. The semiconductor detector consists of silicon with a thickness of 300 μm. The Medipix2 offers the possibility to adjust the energy thresholds, thus creating an energy window, which allows a selection of the energy of the detected radiation.

Measurements with the Medipix device will be carried out in the ATLAS experiment to determine the composition and the spectroscopic characteristics of the radiation field inside the detector and the cavern. In view of its application for the high-energy physics, it is necessary to perform a calibration of the energy thresholds. Therefore a method of evaluation has been developed. The calibration has been done by photons of low energies, using ^{55}Fe and ^{241}Am sources and X-rays. X-ray measurements were performed at the Czech Metrology Institut. Using X-ray tubes with filters, photons of energies between 8 keV and 250 keV were obtained and the efficiency of the Medipix device to this radiation was determined. It was also possible to see the exponential decrease of the photon intensity as a function of depth, illuminating the detector with the beam almost parallel to the surface.

This work was carried out within the CERN Medipix Collaboration

Poster 10.11 Tue 14:00 Poster Hall

The CDF RUN II Silicon Detector: Aging Studies — •Ignacio Redondo on behalf of the CDF Collaboration — CIEMAT, Madrid, Spain

The CDF Run II silicon detector is the largest operating silicon detector in High Energy Physics. Its 750,000 channels spread over 6 m^2 of silicon sensors allow precision tracking and vertexing. The CDF silicon detector is fundamental for all branches of the CDF physics program. It played a critical role in the discovery of B_s mixing and is used extensively for the current Higgs Boson searches.

Over the last 5 years, the detector efficiency has remained stable at 95 % after the Run II commissioning period. The observed effects of aging will be presented followed by the expected performance to the end of Run II where 5–8 fb^{-1} is expected to be delivered. The impact of radiation damage upon the performance of the detector will be shown, in particular the status and expectations of the innermost silicon layers including the inverted beam pipe layer (L00).

Poster 10.12 Tue 14:00 Poster Hall

The ATLAS Beam Conditions Monitor — •Harris Kagan[1], Vladimir Cindro[2], Irena Dolenc[2], Helmut Frais-Kolbl[3], Andrej Gorisek[2], Erich Griesmayer[3], Gregor Kramberger[2], Igor Mandic[2], Michael Niegl[2], Heinz Pernegger[4], Shane Smith[1], and William Trischuk[5] — [1]Ohio State University, Columbus OH, USA — [2]Josef Stefan Institute, University of Ljubljana, Slovenia — [3]Fotec, Weiner Neustadt, Austria — [4]CERN, Geneva, Switzerland — [5]University of Toronto, Toronto, Canada

All LHC experiments are presently planning beam conditions monitoring systems to protect their innermost tracking devices from beam anomalies. The ATLAS Beam Conditions Monitor (BCM) solution consists of two rings (forward and backward) of detectors each with four modules. These are required to be radiation hard (50 Mrad). Each module includes two diamond pad sensors read out in parallel. The rings are located symmetrically around the interaction point at z=*183.8 cm and r=55 mm (a pseudo-rapidity of about 4.2). Equipped with fast electronics (2 ns rise times) these stations measure time-of-flight and pulse height to distinguish events resulting from beam anomalies from those normally occurring in proton-proton interactions. The BCM also provides a coarse measurement of bunch-by-bunch luminosities in ATLAS by counting in-time and out-of-time collisions. Eleven detector modules have been fully tested and assembled. Testbeam results in the CERN PS show a module signal to noise of 14*2 for minimum ionising particles. The best eight modules have been installed on the ATLAS pixel support frame that will be installed in ATLAS during the summer of 2007. The final BCM system will be described together with the beam test results and simulation studies.

Poster 10.13 Tue 14:00 Poster Hall

The LHCb VErtex LOcator (VELO) — •Paula Collins — PH Department, CERN, CH1211 Geneve 23

LHCb, the CP violation experiment at the LHC, is currently finalising installation and preparing for the LHC engineering and pilot runs. At the heart of the triggering and reconstruction strategy is the silicon VErtex LOcator (VELO), which consists of of 42 double-sided silicon modules within a thin-walled chamber enclosing a secondary vacuum within the LHC primary vacuum. The VELO will identify the displaced vertices which will enable the experiment to trigger on and reconstruct B hadrons. The module construction has recently been completed, and the integration of the silicon into the experiment is underway. The double sided silicon modules are designed to resist very high and inhomogenous radiation levels. They have been built in n-in-n technology, and demonstrator modules for a possible n-in-p upgrade have also been developed. The system splits into two retractable halves, so during injection the silicon can be moved to a distance of 3 cm, while still fully powered and operational. During stable beam operation the modules move in and approach to within 7 mm of the LHC beams. Due to this unique feature the VELO will be able to monitor the beam at all times, and even measure the absolute luminosity, by making use of a novel method based on vertex reconstruction of beam gas interactions. The production and performance of the silicon modules, and commissioning of this system will be described, along with the strategy employed during the pilot runs to monitor the LHC beams and move the VELO.

Poster 10.14 Tue 14:00 Poster Hall

Optimal geometrical configuration of a double-scattering compton camera for maximum imaging resolution and sensitivity — •Hee Seo[1], Se Hyung Lee[1], So Hyun An[2], Ju Hahn Lee[3], Chun Sik Lee[3], and Chan Hyeong Kim[1] — [1]Department of Nuclear Engineering, Hanyang University, Seoul 133-791, Korea — [2]Korea Atomic Energy Research Institute, Daejeon 305-353, Korea — [3]Department of Physics, Chung-Ang University, Seoul 156-756, Korea

A novel type of Compton camera, which is called Double-scattering Compton Imager (DOCI) and consists of two position-sensitive scatterer detectors and one absorber detector, is under development for nuclear medicine and molecular imaging applications. Two double-sided silicon strip detectors, which has 16 orthogonal strips on each side and has dimensions of 5x5x0.15 cm^3, are employed as scatterer detectors and one cylindrical 3"x3"NaI(Tl) scintillation detector is employed as absorber detector. In this Compton camera, the effective event is defined as an event in which the gamma ray successively scatters in the first two scatterer detectors and absorbed in the subsequent absorber detector. The track of the gamma rays, and thereby the origin of the gamma rays, are determined by Compton scattering kinematics from the information of interaction positions and deposited energies in the scatterer and absorber detectors. In this study, the optimal geometrical configuration of the Compton camera detectors is determined to maximize the performance of the Compton camera in terms of imaging resolution and sensitivity. For this, the Compton camera is simulated very realistically, with the Geant4 detector simulation toolkit, including various detector parameters such as energy resolution, spatial resolution, energy discrimination, and Doppler energy broadening. The geometrical configurations considered in this study include the inter-detector distance (IDD) of 1, 3, 6, 8, 10, 15, and 20 cm and the inter-detector angle (IDA) of 0, 30, 45, 60, and 90 degrees. According to the results of our simulation studies, the Compton camera is expected to show its maximum performance when the two scatterer detectors are placed in parallel with ∼8 cm of separation (i.e., IDD = ∼8 cm, IDA = 0 degree). Our additional simulations also show that the Compton camera will show its maximum performance when the energy of the gamma rays is about 500 keV, which strongly suggests that the Compton camera is a suitable device to image the distribution of positron emission tomography (PET) isotopes in the human body.

Poster 10.15 Tue 14:00 Poster Hall

Continuous DOI resolution measurement and error analysis with LYSO and two APDs — •Chaehun Lee and Gyuseong Cho — Radiation detection and medical imaging Lab., Department of Nuclear and Quantum Engineering, KAIST, Daejeon

PET is a nuclear imaging technique that measures the spatial and temporal distribution of compounds labeled with a positron emitting radionuclide introduced into a patient to be examined non-invasively. Spatial resolution degradation occurs at the edge of Field Of View (FOV) due to parallax error. To improve spatial resolution at the edge of FOV, Depth-Of-Interaction (DOI) PET has been investigated and several methods for DOI positioning were proposed. One method is to analyze the electronic pulse signal shape from a detector made of stacked two different scintillation crystals having different decay times and another is to split and measure light photons in a single long scintillation crystal with two photosensors attached at its ends. The latter can be a highly accurate and cost effective method due to the rapid progress of silicon photosensor technology such as PIN, avalanche photodiodes (APD) or Si photomultiplier (SiPM).

In this paper, a DOI-PET detector module using two 8*4 array APDs (Hamamatsu, S8550) and a 3cm long LYSO scintillation crystal was proposed and their DOI characteristics was investigated experimentally. Before the fabrication of the sample detector module, a Monte Carlo simulation was carried out in order to determine the surface condition and it was found out that the split light signal is attenuated inside the crystal linearly as the distance between the DOI position and the photosensor location increases while the ground surface it does nonlinearly. So, the side surfaces of LYSO crystal were polished and wrapped with VM2000 radiant mirror film having 98% specular reflection efficiency. BC600 optical cement was used for coupling of APD to LYSO end surfaces. Charge sensitive preamplifiers, CR-110 (cremate, Inc), of which equivalent noise charge (ENC) is ˜ 200 electrons in RMS, was used. Collimated gamma ray was exposed to the crystal onto its side surface to localize and vary the DOI position. In order to measure DOI position, signals from two APDs were compared. Energy resolution was obtained from the sum of two APDs* signals and DOI positioning error was calculated. Other parameters such as APD gain fluctuation due to temperature and voltage variation, and preamp output noise to affect DOI positioning were also investigated. Finally, an optimum DOI step size in a 3 cm long LYSO were suggested to help to design a DOI-PET. This study was supported by Radiation and Nuclear Medical Engineering Research Center, KAIST.

Poster 10.16 Tue 14:00 Poster Hall

Study of DOI Resolution with Solide-State Photomultipliers — •Hyunduk Kim, Gyuseong Cho, and Chaehun Lee — Korea Advanced Institute of Science and Technology, Daejeon, Korea

Position Emission Tomography(PET) is powerful tool comparing with other medical imaging modalities such as CT, US and MRI etc., since it can provide the functional information of brain or other organs on the basis of molecular imaging techniques. Unfortunately the parallax error, spatial resolution degradation at the edge of Field of View(FOV) causes an unwanted effects such as uncertainties in the parameterization of the line of response(LOS) and a poor quality image. For improving the image quality, several Depth-Of-Interaction(DOI) measurement methods were proposed such as light sharing, phoswitch detector, multi pixel layer technique et al.. In addition, a novel sensitivity photosensor, such as avalanche photodiode(APD) and silicon photomultiplier(SiPM), was investigated as a PET detector in order to improve the image quality.

In this study, a PET module was composed of the new solid-state photosensor, SiPM, and a widely used Lutetium Yttrium Oxyorthosilicate(LYSO) crystal of 2.3 × 2.3 × 30 mm^3 in order to obtain the time and energy information. The energy resolution of a LYSO(60 %) is poorer than that of a LSO(46 %), but the radiation length of a LYSO (1.2 cm) is almost similar to a LSO(1.1 cm). The DOI capable gamma-ray detector was constructed with two geometries. A simple method of light sharing technique and a more complex method of double layer technique for DOI determination were studied for comparison. We studied the DOI resolution with LYSO scintillator and SiPM to measure 511 keV photons from the 22Na. These results were compared with the simulation by GEANT4/GATE.

We will expect that this study results give the more decreased parallax error for obtaining the good quality image. This study was supported by Radiation and Nuclear Medical Engineering Research Center, KAIST.

Poster 10.17 Tue 14:00 Poster Hall

Performance evaluation of a table-top compton camera for various detector parameters — •Se Hyung Lee[1], Hee Seo[1], So Hyun An[2], Jae Sung Lee[3], and Chan Hyeong Kim[1] — [1]Department of Nuclear Engineering, Hanyang University, Seoul 133-791, Korea — [2]Korea Atomic Energy Research Institute, Daejeon 305-353, Korea — [3]Department of Nuclear Medicine and Interdisciplinary Program in Radiation Applied Life Science, Seoul National University, Seoul 110-744, Korea

The imaging resolution and sensitivity of a Compton camera depend on various detector parameters including the photon energy of the source (of interest), the energy resolution and interaction position resolution of the component detectors, and the geometrical configuration of the detectors such as inter-detector distance and inter-detector angle. The performance of a Compton camera must be quantitatively determined as a function of each prameter to maximize its performance. A prototype table-top Compton camera, which consists of two plane-type position-sensitive semiconductor detectors, i.e., double-sided silicon strip detector (5x5x0.15 cm^3) as scatterer detector and 25-segmented germanium detector (5x5x2 cm^3) as absorber detector, is under development in Korea. In this study, the performance of the table-top Compton camera was evaluated for various detector parameters by using the GEANT4 detector simulation toolkit. Considered parameters are the photon energy of the source, the inter-detector distance and inter-detector angle of the component detectors, and the interaction position resolution of the absorber detector. Our results show that the imaging resolution of the Compton camera significantly improves with the increase of the photon energy of the source up to 364 keV. Considering both the imaging resolution and sensitivity, the optimal energy for Compton imaging was found 364 keV for the table-top Compton camera in this study. With the increase of inter-detector angle, both the imaging resolution and sensitivity get worse. With the increase of inter-detector distance, the imaging resolution of the Compton camera improves, but the imaging sensitivity significantly decreases. The optimal value of the inter-detector distance was found about 10 cm. Finally, the interaction position resolution of the absorber detector was found the limiting factor for the imaging resolution of the Compton camera.

Session 11: Poster - Detector Devices and Concepts

Tuesday, 14:00–16:20 Poster Hall

Poster 11.1 Tue 14:00 Poster Hall

Novel Neutral Particle Analyser for JET Fusion Research — •Juha Kalliopuska[1], Simo Eränen[1], Tapani Vehmas[1], and Marko Santala[2] — [1]VTT, Espoo, Finland — [2]JET, Oxford, England

Joint European Torus (JET) is currently the largest experimental research facility to study the fusion reactions and aims at harnessing fusion energy to produce electricity on Earth. If successful, this will offer a viable alternative energy supply with significant environmental, supply and safety advantages over present energy sources. The fusion takes place in carefully controlled plasma at very high temperatures and fuel ion densities. Condition of the plasma during the fusion reactions is partly monitored with Neutral Particle Analyser (NPA) setup. The current detector relies on a scintillator-phototube combination that converts the incoming ions into light which is then detected using phototubes. The detector mostly suffers from the background radiation from electrons and gamma-rays and the particle identification is possible only for the energetic ions.

Our idea is based on matching the detector thickness close to the ranges of the observed particles in silicon. The ions to be detected, such as hydrogen, deuterium and alpha, have range from 1 to 25 μm depending on their energy. The background radiation has an order of magnitude larger range in silicon and thus causes a minor effect in a thinned silicon detector. The benefits of the novel approach are manifold: a good signal-to-background separation, a direct conversion of ion energy to current pulse, better statistics than with previous solution, a good radiation tolerance, no need for signal amplification and low-voltage operation. Only uprising problem is the thin wafer handling which requires a support wafer to be used. Prototypes are currently being manufactured and the first test structures should be delivered in early summer this year.

Representation comprises the idea, process steps, outcome of the process and preliminary characterization results of manufactured sensors.

Poster 11.2 Tue 14:00 Poster Hall

The study of digital radiation detector based on plasma display panel — •Cho SungHo[1], Yun MinSuk[1], Kang SangSik[1], Nam SangHee[1], and Lee HyungWon[2] — [1]radiation image lab, obang-dong, kimhae, kyungnam, korea — [2]school of computer aided science, obang-dong, kimhae, kyungnam, korea

In this paper, plasma display panel(PDP) is being applied for the first time to a radiation detector. We have developed a prototype of a new type of hybrid X-ray detector based on plasma display panel. It contains a gas, dielectric layer, barrier rib and photoconductor layer. The operation of these converters was studied in a wide range of X-ray energies from 60 to 150Kvp. Also we were studied in a various method such as gas ratio, gas pressure and design structure. The developed detector may open new possibilities for medical imaging, for example in mammography, portal imaging, radiography including security devices)and many other applications.

Poster 11.3 Tue 14:00 Poster Hall

GaAs Detectors with LiF Layer for Detection of Thermal Neutrons — •Andrea Sagatova-Perdochova, Milan Ladziansky, and Vladimir Necas — Department of Nuclear Physics and Technology, Slovak University of Technology, Ilkovicova 3, Bratislava, Slovakia

The radiation resistance of GaAs material to photons [1] as well as the first results of its resistance to neutrons [2] predestine this material to be suitable for neutron detectors preparation. The SI (semi-insulating) GaAs detectors were successfully modified by 6LiF converter layers to de-

tectors of thermal neutrons. The first spectra measured by these detectors when irradiated by neutrons from 239Pu-Be source decelerated by polyethylene show the evidence of 6Li (n, alpha) 3H reaction. Two different surface densities of the neutron converter layers were deposited onto the SI GaAs detectors: 2.9 and 8.8 mg/cm2. Higher neutron detection efficiency (5.2 %) was achieved by the later layer. The observed influence of layer surface density on the detection efficiency was in accordance with the results published in [3], obtained by Si detectors. The 239Pu-Be neutron source used is also the source of gamma rays of various energies. However, their parallel detection with neutrons was suppressed by adjusting the detector active area depth by bias voltage applied. The influence of the surface density of the converter layer on the current-voltage characteristics of the investigated detectors was studied as well. The results show that higher surface density of 6LiF layer reduced the reverse current in comparison with the detector without any coating more considerably than the lower surface density.

Comments: [1] T. Lu Anh et al.: Nuclear Physics B (Proc. Suppl.) 150 (2006), p. 402.

[2] M. Morvic et al.: Nucl. Instrum. and Meth. in Physics Res., B 197 (2002), p. 240.

[3] J. Jakubek et al.: Nucl. Instrum. and Meth. in Physics Res., A 531 (2004) p. 276.

Poster 11.4 Tue 14:00 Poster Hall

On the detection performance of semi-insulating GaAs detectors coupled to multichannel ASIC DX64 for X-ray imaging applications — •Bohumír Zaťko[1], František Dubecký[1], Pavol Boháček[1], Pavol Ščepko[2], Pawel Gryboś[3], Ján Mudroň[4], Piotr Maj[3], and Robert Szczygiel[3] — [1]Institute of Electrical Engineering, Slovak Academy of Sciences, Dúbravská cesta 9, SK-841 04 Bratislava, Slovakia — [2]T&N System, Ltd., Severná 5, SK-974 01 Banská Bystricy, Slovakia — [3]Faculty of Physics and Applied Computer Science, AGH University of Science and Technology, Al. Mickiewicza 30, 30-059 Cracow, Poland — [4]Department of Natural Science, Academy of Armed Forces of General M. R. Štefánik, SK-031 01 Liptovký Mikuláš, Slovakia

Bulk semi-insulating (SI) GaAs seems to be one of the most important candidates for fabrication of semiconductor X-ray detectors applicable in digital radiology instrumentations [1, 2]. Detectors based on SI GaAs show higher detection efficiency and satisfactory energy resolution for modern digital imaging applications. Another key feature of GaAs is smooth dependence of linear absorption coefficient in the photon energy ranging from 11 to 150 keV by comparison with CdTe and confimed formation of the depletion space charge region under reverse bias blocking electrode with ability of its extension into full volume of SI GaAs base [1].

Monolithic line detector array based on bulk SI GaAs were fabricated and coupled to the input of multichannels (64 and 24) readout chip by wire bonding. The detectors have Ti/Pt/Au Schottky blocking and In/Au quasi-ohmic electrode. First resuts of operation of the bulk SI GaAs monolithic radiation detectors coupled to the DX64 ASIC (technology CMOS 0.35 um) are demonstrated. The system allows operation in single photon counting regime applicable in new generation "quantum" digital X-ray imaging and foreseen so called "color" imaging applications. The main features includes low noise (operation with threshold below 5 keV), good spatial resolution (using strip detectors of size 220 x 200 x 2500 μm^3 edge-on oriented), almost 100 % detection efficiency (up to 50 keV photons energy) and acceptable high counting rate capability (20 bits counters with count rate nearly up to 1 MHz per channel, peaking Tp=160 ns).

[1] Dubecký F., et al., Nucl. Instr. Met. in Phys. Res. A (2007) in print. [2] Zaťko B., et al., Nucl. Instr. Met. in Phys. Res. A (2007) in print.

Poster 11.5 Tue 14:00 Poster Hall

Role of new ohmic electrode metallizations in detection performance of bulk semi-insulating GaAs imaging radiation detectors — Pavol Boháček, František Dubecký, •Bohumír Zaťko, and Mária Sekáčová — Institute of Electrical Engineering, Slovak Academy of Sciences, Dúbravská cesta 9, SK-841 04 Bratislava, Slovakia

In this work, we concentrate to the study of the role of ohmic electrode metallization of radiation imaging detectors based on bulk semi-insulating (SI) GaAs. Alietti pointed out the non-optimal standard alloyed AuGeNi ohmic metallization applied in SI GaAs radiation detectors with the surface Schottky barrier [1]. He demonstrated better detection performance using a new non-alloyed ohmic contact technology realized by implantation of Si+ ions at two different doses and energies [2]. Detectors with this new type of ohmic contact reached more than 5 times higher breakdown voltage, lower saturation current and overall better detection performance. Present understanding of observed progress is related to the limitation of holes injection from the ohmic contact, hence "non-injecting" contact. The aim of present study is to find another or simpler technology of "non-injecting" ohmic contact using metal with low Pauling electronegativity (or work function). We fabricated SI GaAs radiation detectors with different electrodes (Mg/Au, Ca/Au and Gd/Au) using metals with enough low electronegativity (1.3 eV, 1.0 eV and 1.2 eV for Mg, Ca and Gd, respectively) to form hole barrier contact considering non-injecting effect as non-alloyed ohmic of Alietti. Current-voltage and noise characteristics, long-term operation stability and detection performance of detectors with the new kind of ohmic contact are measured and evaluated. Observed results are discussed and compared with the ones using standard ohmic metalllization.

[1] Alietti M. et al., NIM in Phys. Res. A 362 (1995) 344. [2] Bertuccio G. et al., IEEE Tran. on Nuc. Sci. Vol. 44, No. 2 (1997) 117.

Poster 11.6 Tue 14:00 Poster Hall

Fast polycrystalline CdTe detectors for Bunch-by-bunch luminosity monitoring in the LHC — •Andrea Brambilla[1], Sebastien Renet[1], Muriel Jolliot[1], Guy Feuillet[1], Enrico Bravin[2], Edda Gschwendtner[2], Massimo Placidi[2], and Hermann Schmickler[2] — [1]CEA grenoble - LETI MINATEC, France — [2]CERN, CH-121, Geneva 23

The luminosity at the four interaction points of the Large Hadron Collider must be continuously monitored in order to provide an adequate tool for the control and optimisation of the beam parameters. Polycrystalline CdTe detectors have previously been tested showing their high potential to fulfil the requirements of luminosity measurement in severe environment the LHC interaction regions. Further the large signal yield and the fast response time should allow bunch by bunch measurement of the luminosity at 40 MHz with high accuracy. Four luminosity monitors with two rows of five polycrystalline CdTe detectors each have been fabricated and will be installed at both side of the low intensity interaction points ALICE and LHC-b. A detector housing was specially designed to meet the mechanical constraints in the LHC. A series of elementary CdTe detectors were fabricated and tested of which 40 were selected for the luminosity monitors. A sensitivity of 10000 electrons/MIP and a pulse width better than 5 ns FWHM are currently achieved.

Poster 11.7 Tue 14:00 Poster Hall

Space Charge Effects on Gas Gain in Non-Uniform Field Argon-Based Detectors — •Nilgun Demir and Ilhan Tapan — Uludag Universty Fen-Edebiyat Faculty Gorukle Kampusu 16059 BURSA

The charge carriers in the detector volume created in the gas amplification process cause a space charge effect. The fluctuation in gas amplification process is one of the main factor in the energy resolution of proportional counters. At low bias voltages only a very small number of charge carriers are generated and so the space charge effect is negligibly low. However, as bias voltage increases so does the gas amplification factor and the number of the secondary charge carriers grows, reducing the electric field strength between space charges and the anode wire.

In the present work, a Monte Carlo simulation code [1] has been used in order to investigate the influence of space charge effect on the gas gain and its fluctuation for Argon based gas mixtures as a function of the applied voltage between cathode and anode at atmospheric pressure for wide range component concentrations.

[1] - I. TAPAN and N. DEMIR, Simulation of gain fluctuation for non-uniform field argon based gas detector, Nuclear Instruments and Methods in Physics Research A 525 (2004)p53

Poster 11.8 Tue 14:00 Poster Hall

X-ray response properties of flat panel gas detector — •Minseok Yun[1], Sungho Cho[1], Sangsik Kang[1], Kyungjin Kim[2], Jongbae Shin[2], and Sanghee Nam[1] — [1]Radiation image laboratory of biomedical engineering, inje university, ubangdong, kimhae, Korea — [2]LG micron Ltd, Gyeonggi-do, Korea

Large area matrix-addressed image detectors are a recent technology for x-ray imaging with medical diagnostic and other applications. In this paper, a new flat panel gas detector for diagnostic x-ray imaging is proposed, and its characteristics are investiagted. To estimate the x-ray signal of gas detector, we simulated the space distibution of the x-ray induced charges by Monte Carlo simulations. Most simulations of such detectors simplify the setup by only taking the conversion layer into account neglecting behind. The Monte Carlo code MCNPX has been used to simulate the complete interaction and subsequent charge transport of x-ray radiation. The experimental measurements, the transparent electrodes, dielectric layer, and the MgO protection layer were formed in fron glass. And, the x-ray phosphor layer and address electrodes are formed in the rare glass. The dark current, the x-ray sensitivity and linearity as a function of electric field were measured to investigate the electrical properties. From the results, the stabilized dark current density (<250 pA/cm2) and the significant x-ray sensitivity (* 2.3 nA/cm2-mR) were obtained. And the good linearity as a fuction of exposure dose was showed in wide diagnostic energy range. These results means that the pasive matrix-addrresed flat panel gas detector can be used for digital x-ray imaging.

Poster 11.9 Tue 14:00 Poster Hall

The effect of gas pressure on the performance of a MSPC detector — •Okla Al-Horayess[1] and Martin Turner[2] — [1]KACST, PO Box 56260, Riyadh 11554, KSA — [2]University of Leicester, Leicester LE1 7RH, UK

In contrast with the conventional proportional counters detectors, the electrodes of the Micro-Strip Proportional Counter (MSPC) are deposited by photolithographic techniques onto a rigid substrate. In this study, a 10*m anode MSPC detector filled with Xe+5%CO2 has been investigated at gas pressures of up to 5 atm. The results, in terms of gas gain, energy resolution and operating voltage are presented. The effect of gas pressure on gas gain and energy resolution is described. As a result of the fine structure of the counter, i.e. the very small anode width and anode-cathode spacing, the gas gain and energy resolution were expected to improve compared to that of conventional proportional counters. As expected, the gas gain was remarkably improved but not the energy resolution. At high pressures, the energy resolution of the counter was found to be worse and degraded fast. The results obtained show a noticeable degradation in the counter performance at high gas pressures. The main suspect factors causing this unexpected behaviour are discussed.

Poster 11.10 Tue 14:00 Poster Hall

Electro-optic Properties of X-ray Detector using Phosphor-Light Modulator — •Sangsik Kang, Bungyul Cha, Jungwook Chin, Sungwook Hea, and Sanghee Nam — radiation image laboratory of biomeidcal engineering, inje university, ubangdong, kimhae

In this paper, the novel x-ray detector which incorporates the x-ray phosphor and the amorphous selenium light modulator. In this detection method, since the x-ray detector is electrostatic and the photo charge is strongly coupled to the light modulator, high resolution imaging is possible. The a-Se film of 20 * thickness was fabricated by a vacuum thermal evaporation for application as liquid crystal light modulator. the light absorption in visible range of 400 ˜ 630 nm was over 95 %, and the light transmittance rapidly increased at an infrared range over 650 nm. The low dark current density of 2.5 nA/cm2 was obtained at 10 V/um. Also, The x-ray sensitivity of the 270*-Gd2O3:Eu film coupled 20*-Se film was 7.31 nC/cm2-mR. Finally, the light modulator, which was consisted of the a-Se and the TN-LC layer, was fabricated. To investigate the light modulation characteristics of the fabricated light modulator, the T-V(Transmission-Voltage) curve and the optical response were measured. The experimental results were that the light modulator exhibited the conventional T-V curve of liquid crystal and the light transmittance was 12% (at 50V) and 86% (at 100V).

Poster 11.11 Tue 14:00 Poster Hall

Photo-readout choices for a large lead-scintillator-sandwich detector array — •Athanasios Hatzikoutelis — Physics Dept. Lancaster U. , Lancaster, UK

Light-yield measurements along with the results and the technique are reviewed here for a photon-veto detector of the KOPIO experiment. The operational conditions for the array, rough vacuum, high magnetic field, fast response and hermetic coverage, made the choice for an optimal readout scheme difficult. Tests were performed on a prototype detector with various combinations of fibers, couplings and integration times. A cosmic trigger setup was used in measuring absolute light output and the time resolution from each configuration

Poster 11.12 Tue 14:00 Poster Hall
Performance studies of a monolithic scintillator-CMOS image sensor for x-ray application — •Bo Kyung Cha, Jun Hyung Bae, Byoung-Jik Kim, Hosang Jeon, and Gyuseong Cho — Dept. of Nuclear and Quantum Eng., Korea Advanced Institute of Science and Technology,Daejeon 305-701, Korea

In recent years, electric imaging detectors for digital X-ray radiography are replacing the conventional image acquisition method such as film-screen technology. These have the advantages of real time image acquisition, availability of post-processing of image data, and efficient image storage and retrieval. Many direct and indirect imaging detectors have been developed for medical and/or industrial applications in the last decade. Nevertheless, novel or advanced 2-dimensional detectors are still required for better image performance with higher resolution, higher sensitivity, and higher quantum efficiency at the same time with lower manufacturing cost. In our research, a scintillator-coupled CMOS (complementary-metal-oxide semiconductor) image sensor was proposed. CMOS technology has advantages of easy design, low cost, low power consumption, high system integration and high resistance to radiation damage in comparing with charge-coupled devices (CCD). The developed CMOS sensor is a sample device for feasibility test and it consists of 128 x 128 photodiode arrays and pixel circuits with a pixel size of 50*m and the pixel fill factor of 78 %. In order to avoid light signal loss and other coupling difficulties normally appearing in lens- or fiber optic-coupled system between the scintillator plate and the image sensor chip, a thallium-doped CsI scintillator film of thickness 50 *m was directly deposited on the CMOS photodiode array by thermal evaporation method. Finally the sensor was tested by X-ray with 50˜80 kVp energy range and their imaging performance in terms of the signal to noise ratio (SNR), the modulation transfer function (MTF), the noise power spectrum (NPS), and the detective quantum efficiency (DQE) were analyzed.

Poster 11.13 Tue 14:00 Poster Hall
Construction and Temporal Property of a-Se coupled liquid crystal — •Byungyul Cha, Sangsik Kang, Jikoon Park, Jungwook Shin, and Sanghee Nam — radiation image laboratory of biomeidcal engineering, inje university, ubangdong, kimhae

Currently most radiographic imaging systems in clinical use rely on the use of a phosphor screen and thus require conversion of light to an electronic signal. In such conversion process there will be some signal loss due to inefficiencies in coupling between the screen and the later light detection components. The aim of this work is to experimentally investigate the feasibility of a radiographic x-ray imaging to verify and supplement theoretical understanding as described. The cell transmission versus potential characteristic was measured to determine how well the LC cell transmission model represents a real cell. And the temporal properties of the LC cell were examined with response time measurements. From the x-ray induced switching measurements, the light transmittance of liquid crystal was 68.6% at 0.5 mR and 87.8% at 2.5 mR, respectively. These results means that the novel imaging detector which incorporates the Gd2O3:Eu fine phosphor and the amorphous selenium light modulator is possible the operation at the low x-ray dose, therefore, the application as medical imaging detector.

Poster 11.14 Tue 14:00 Poster Hall
Measurement of the effective inter-strip capacitance of p-type 3D stc strip detectors with different strip isolation techniques using an IR laser set-up and LHC front-end electronics — •Simon Eckert[1], Karl Jakobs[1], Susanne Kühn[1], Ulrich Parzefall[1], Gian-Franco Dalla Betta[2], Andrea Zoboli[2], Alberto Pozza[3], and Nicola Zorzi[3] — [1]Albert-Ludwigs University, Freiburg, Germany — [2]University of Trento, Trento, Italy — [3]ITC irst, Trento, Italy

Design and construction of a prototype module comprising ATLAS SCT front-end electronics and 3D stc p-type strip sensors with different strip isolation techniques will be shown. Employing an IR laser and automated xy stages with micrometer resolution we characterised these 3D stc p-type sensors in terms of their effective inter-strip capacitance and noise behaviour before irradiation using ATLAS SCT front-end electronics.

Poster 11.15 Tue 14:00 Poster Hall
Development of a multifunctional particle spectrometer to support future planetary exploration — •Erik Maddox[1], Alex Palacios[1], Dimitiris Lampridis[1], Stefan Kraft[1], Alan Owens[2], and Peter Falkner[2] — [1]cosine Research B.V., Leiden, The Netherlands — [2]ESA/ESTEC, Noordwijk, The Netherlands

For future exploration of the solar system missions to Mercury (BepiColombo), the Sun (SolarOrbiter) and the moons of Jupiter and Saturn are being planned or under study. The expected intensity of radiation during these mission is hazardous for the scientific instruments of the satellite. To extend the lifetime of the satellite payload a multifunction particle spectrometer (MPS) is being developed.

The MPS is a radiation monitor and will send an alarm signal to the satellite control system during periods of high radiation. In addition the MPS is a scientific instrument that will unfold the composition of the different contributing particles on-line by the dE/dx versus E method. The energy spectrum and angular distribution will be recorded as well.

This article describes the main requirements for an MPS. The base line design to fulfil the requirements consists of two segmented silicon tracker planes on top of a scintillator crystal. The read out electronics should have low power consumption and cope with count rates up to 1 MHz (particle identification mode) and 10 MHz particle count rate. A readout scheme consisting of 32 channel readout from IDEAS is proposed and the signal filtering algorithm will run on a digital signal processor based on a FPGA. Subsequently results from the detector characterisation studies, electronic tests and prototype tests with a proton beam are shown.

Poster 11.16 Tue 14:00 Poster Hall

ingle Photon Imaging at ultra-high resolution — •R. Bellazzini[1], G. Spandre[1], M. Minuti[1], L. Baldini[1], L. Latronico[1], N. Omodei[1], C. Sgro'[1], J. Bregeon[1], M. Razzano[1], M. Pinchera[1], A. Tremsin[2], J.V. Vallerga[2], and O. Siegmund[2] — [1]INFN, Pisa,Italy — [2]SSL,Berkeley,USA

We present a single photon counting photodetector with imaging capability at ultra-high resolution.The detector is made by coupling very fine pitch Micro-Channel Plates (MCP) to a large area, custom, analog ASIC with high pixel granularity (105 k pixels at 50 micron pitch in a honeycom arrangement, corresponding to 470 pixels/mm2). The Micro-Channel plates have pore size of 4 , 6 and 12 microns at a pitch of 5.5, 8 and 15 microns, respectively.When the MCP is illuminated by a UV lamp, a single electron is extracted at the surface thanks to the residual photosensitivity of the MCP itself. The electron is multiplied inside a channel and the charge cloud extracted at the bottom by a suitable electric field and finally collected by the fine arrangement of metal pads on the top surface of the ASIC. The ASIC samples the charge cloud allowing to measure with high precision the charge centroid on a event by event basis. Collection of million of photons allows to build a high resolution image. As a matter of fact, the detector is able to resolve (see) the MCP pores down to 4 microns, indicating that the intrinsic resolution of the readout t system is much better than 4 microns (we estimate 2 microns FWHM or better). When working with 4 microns pore diameter MCPs we were able to resolve close to 100 line pairs/mm.

Session 12: Poster - Front-End Electronics, Readout and Interconnect Technologies

Tuesday, 14:00–16:20 Poster Hall

Poster 12.1 Tue 14:00 Poster Hall

The RELAXd project: development of four-side tilable photon counting imagers — •Zdenek Vykydal[1,2,3], Jan Visschers[2], Deniz Sabuncuoglu Tezcan[3], Koen De Munck[3], Tom Borgers[3], Wouter Ruythooren[3], and Piet De Moor[3] — [1]Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horská 3a/22, 12800 Praha 2, Czech Republic — [2]The National Institute for Nuclear Physics and High Energy Physics (NIKHEF), Kruislaan 409, 1098 SJ Amsterdam, The Netherlands — [3]IMEC vzw, Kapeldreef 75, B-3001 Leuven, Belgium

The feasibility of using hybrid single photon counting imaging chips for many applications working with X-rays, neutrons or other types of the radiation (like material sciences, biology, etc.) has been already well demonstrated. The Medipix2 readout ASIC is an example of such a device. With an appropriate sensor chip on the top, it can count single X-ray photons, without any noise or dark current, at high fluxes (several Gigaphotons per cm^2 per second). It also offers an excellent radiation resistance and good position resolution (256 x 256 pixels of 55 x 55 μm^2).

The limiting factors for more widespread usage of these devices in bio-medical applications (i.e. mammography, small animal imaging) are the small size of the active area (about 2 cm^2) and the low frame rate. The aim of the RELAXd project (high REsolution Large Area X-ray Detector) is to develop a high frame-rate 3D microsystem, consisting of four readout chips bump-bonded to one sensor chip. These so called "quad-modules" should be four-side tilable with minimal dead spaces, to construct matrices of these modules covering a large area.

Standard wire-bond technique used to connect I/O pads of the Medipix2 chip to the printed circuit board (PCB) carrier board requires additional dead space. This work describes a process flow and first tests in approaching the goal of four-side tilability of the Relaxd quad module, by avoiding the wire-bond connections. We are using newly developed technology of through silicon via (TSV) to interconnect the front side and back side of the chip. Additional copper layer on the back side of the chip will be used to redistribute all necessary I/O signals uniformly, forming ball grid array (BGA) of 8 x 17 balls with pitch of 850 μm, respectively 1700 μm. Compared to other TSV approaches this technique is not application specific and can be performed at low temperature (< 280°C) on standard CMOS wafers.

Poster 12.2 Tue 14:00 Poster Hall

Preliminary results of the complete ppc readout system for the Medipix2 quad — •Roberto Marzeddu[1,2], Viviana Fanti[1,2], and Paolo Randaccio[1,2] — [1]Università di Cagliari, Cagliari, Italy — [2]INFN sez. di Cagliari, Cagliari, Italy

We are developing a readout system based on the Medipix2 [1] quad ASIC in the framework of the PPC project (Pixel Detector with Parallel Optical Readout for Computed Tomography) supported by the INFN institute. The PPC readout system was designed for tomographics imaging applications. It exploits the parallel readout of the chip Medipix2 and a G-Link standard optical link for data acquisition in order to reach a frame-rate high enough (20 frame/s) with respect to the final application. The DAQ project foresees four electronic cards. The first one, named Chipboard, houses the Medipix2 quad and the front-end control logic. The second board; named Motherboard, supports and manages the Chipboard. The third one (Hub) is devoted to the optical interconnect. The whole acquisition system is interfaced to a standard PC through a custom PCI card.

As a first step, a test setup based on a flat cable interconnect - instead of the foreseen optical fibre link - was builted and tested [2]. Now we present preliminary results on the performances of the complete setup, showing some characterization measurements and X-rays test images. All tests were performed using one Medipix2 quad chip coupled with a 300 μm Silicon sensor.

References

[1] - http://medipix.web.cern.ch/MEDIPIX/ [2] - V. Fanti, R. Marzeddu, P. Randaccio *Optical Link Based Readout System for Medipix2 Quad X-rays Detector*; NIM A (2007), Elsevier Science In press

Poster 12.3 Tue 14:00 Poster Hall

Signal processor controlled USB2.0 interface for Medipix2 detector — •Michal Platkevic, Viktor Bocarov, Jan Jakubek, Stanislav Pospisil, Vladimir Tichy, and Zdenek Vykydal — Institute of Experimental and Applied Physics, Czech Technical University in Prague, Horska 3a/22, CZ 12800 Prague 2, Czech Republic

Advanced digital detecting systems of the Medipix family [1] are available and make possible real time imaging with high sensitivity and broad dynamic range. The hybrid silicon pixel detector device Medipix2 consists of a sensor chip with 256 x 256 square pixels of 55μm size each. The read-out chip contains an amplifier, two discriminators and a 13-bit counter for each pixel. Currently, the acquisition controlling and data reading can be realized via devoted interface MUROS2 (Medipix2 re-Usable Read Out System version 2) or USB1.0 interface device.

MUROS2 need a universal data acquisition card for PCI computer slot, external power supplies and external detector bias. Due to large dimensions of these external devices and limited lengths of cables the applicability of the detector is reduced.

USB1.0 interface [2] extends the applicability [3] of the Medipix2 device and make it more portable, but its transfer rate is limited to 5 frames per second.

With the new interface the drawbacks and limitations are eliminated. To make the Medipix2 system more efficient we developed a novel read-out system using advantages of the USB2.0 (Universal Serial Bus) interface - transfer rate of 480 Mb/s and ease of operation. Medipix serial output is used, data are then de-serialized in devoted circuitry and taken by processor. The new interface is controlled by digital signal processor providing high level of flexibility and high performance for online data processing. It is equipped with large memory allowing stand alone operation.

This work was carried out within the CERN Medipix Collaboration.

Poster 12.4 Tue 14:00 Poster Hall

Bandwidths of micro twisted-pair cables and fusion spliced SIMM-GRIN fiber and radiation hardness of PIN/VCSEL arrays — •KK Gan — Department of Physics, The Ohio State University, 191 W. Woodruff Ave., Columbus, OH 43210, USA.

The SLHC is designed to increase the luminosity of the LHC by a factor of ten. In the present ATLAS pixel detector, the electrical signals between the pixel modules and the optical modules (opto-boards) are transmitted via ˜ 1 m of micro twisted-pair cable. The optical fiber ribbons consist of 8 m of rad-hard/low bandwidth SIMM fibers fusion spliced to 70 m of rad-tolerant/medium bandwidth GRIN fibers. We currently transmit optical signals at 80 Mb/s and expect to transmit signals at ˜ 1 Gb/s at the SLHC. The design of the present pixel optical links has several nice features: 1) Since the optical components are mounted on patch panels instead of directly on the pixel modules, the radiation exposure is much reduced. 2) The separation of the opto-boards from the pixel modules decouples the production of both components and greatly simplifies their design and fabrication. 3) An optical package on a pixel opto-board couples to a removable and robust fiber ribbon terminated with an MT connector. For the SLHC, we would like to take advantage of the many years of R&D effort and production experience. If the present architecture can transmit signals at the higher speed, the constraint of requiring no extra service space is automatically satisfied. We have measured the bandwidths of the transmission lines and the results indicate that the micro twisted-pair cables can transmit signals up to ˜ 1 Gb/s and the fusion spliced fiber ribbon can transmit signals up to ˜ 2 Gb/s. We have irradiated PIN and VCSEL arrays with 24 GeV protons and find at least one candidate PIN and one VCSEL array that can survive to the SLHC dosage.

Poster 12.5 Tue 14:00 Poster Hall

An MT-Style Optical Package for Optical Data Transmission — •KK Gan — Department of Physics, The Ohio State University, 191 W. Woodruff Ave., Columbus, OH 43210, USA.

An novel optical package for mounting a VCSEL or PIN array for transmitting and receiving optical signals has been developed. The package is fabricated using BeO as the substract for efficient removal of heat produced by the array. The array is connected to the driver or receiver chip using three dimenional traces together with wire bonds. Each array couples to a fiber ribbon terminated in a commercial MT connector. The package is quite compact with its physical size significantly smaller than that of the MT connector. This design simplifies the testing and assembly of the optical components because the MT connector with the long fibers attached can be remounted with ease while preserving good light coupling efficiency. This non-magnetic package can be used in the high radiation environment such as the SLHC.

Poster 12.6 Tue 14:00 Poster Hall

Optimization of CMOS Active Pixels with High Signal-to-Noise Ratio for High Resolution X-ray Imaging — •Young Soo Kim[1] and Gyuseong Cho[2] — [1]Chosun University, Gwangju 501-759, Republic of Korea — [2]Korea Advanced Institute of Science and Technology, Daejeon 305-701, Republic of Korea

The CMOS active pixel sensors (APSs) are increasingly being used in digital X-ray imaging applications as well as in commercial cameras due to their advantages such as on-chip integration of the signal processing circuitries and low manufacturing cost etc. Nowadays, according to requiring the high spatial resolution imaging system, the pixel size of the CMOS APSs should be minimized as soon as possible. However, in this case, the generated signal level is very low compared to the noise and it is very important to reduce the noise level.

In this study, we developed our theoretical noise model to account for the temporal noise in active pixels, and then found out the optimum design parameters such as fillfactor, each size of the three transistors (reset transistor, source follower, row selection transistor) comprising active pixels with 3T structure, bias current, and load capacitance that can have the maximum signal-to-noise ratio. To develop the theoretical noise model in active pixels, we considered the integration noise of the photodiode and the readout noise of the transistors related to readout. During integration, the shot noise due to the dark current and photocurrent, during readout, the thermal and flicker noise were considered. The developed model can take the input variables such as photocurrent, capacitance of the photodiode, integration time, transconductance of the transistors, channel resistance of the transistors, gate-to-source capacitance of the follower, and load capacitance etc.

And, to validate our noise model, test structures have been realized. The size of the designed pixels is 20 μm for high resolution X-ray imaging. The pixel type is the n+/p and the fillfactor is around 30 ~ 37 % according to the transistor sizes. In these test structures, AMIS 0.5 μm (2P/3M) CMOS process was used for fabrication and different values for design parameters (including optimum design parameters extracted from the developed model) were considered. The results of the noise measurement were agree well with model calculations, and the optimum values of in-pixel components can be extracted using this developed noise model.

Poster 12.7 Tue 14:00 Poster Hall

Simulation of the charge transfer inefficiency of column-parallel CCDs. — •Dzmitry Maneuski[1] and LCFI Collaboration[2] — [1]Department of Physics & Astronomy, University of Glasgow, Scotland, UK — [2]On behalf of the Linear Collider Flavour Identification (LCFI) Collaboration

Charge-Coupled Devices (CCDs) have been successfully used in several high energy physics experiments over the past two decades. Their high spatial resolution and thin sensitive layers make them an excellent tool for studying short-lived particles. The Linear Collider Flavour Identification (LCFI) collaboration is developing Column-Parallel CCDs (CPCCDs) for the vertex detector of the International Linear Collider (ILC). The CPCCDs can be readout many times faster than standard CCDs, significantly increasing their operating speed. The results of detailed simulations of the charge transfer inefficiency of a prototype CPCCD chip are reported. The influence of the gate voltage on charge transfer inefficiency (CTI) is presented. The effects of the radiation damage on the CTI of a Si-based CCD particle detector are studied by simulating the effect of two electron trap levels Ec - 0.17 eV and Ec - 0.44 eV at different concentrations and operating temperatures. The dependence of the CTI on different occupancy levels (percentage of hit pixels) and readout frequencies is also studied. The optimal operating temperature - where the effects of the trapping are at a minimum - is found to be ~230 K for the range of readout speeds proposed for the ILC.

Session 13: Poster - Detector Materials

Tuesday, 14:00–16:20 Poster Hall

Poster 13.1 Tue 14:00 Poster Hall

Temporal performance of various semiconductor detectors for X-ray fluoroscopy imaging — •Chiwon Chi[1], Sangsik Kang[2], Sungho Cho[2], Sungkwang Park[3], and Sanghee Nam[4] — [1]Department of Medical Imaging Science, InjeUniversity, Gimhae City, 621-749, South Korea — [2]Department of Biomedical Engineering, InjeUniversity, Gimhae City, 621-749, South Korea — [3]Dept of Radiation Oncology, Paik Hospital Pusan, South Korea — [4]Medical Imaging Research Center, InjeUniversity, Gimhae City, 621-749, South Korea

As studied in the field of video imaging system and analog radiation detector, many semiconductors about image lag and ghost effect in the digital radiography have been studied. Lag is the carryover of signal from a previous image, whereas ghosting is the reduction of sensitivity caused by previous exposure history of the detector. This two concepts in the fluoroscopy system have been measured as a very important factor. In this paper, semiconductor materials such as PbI2, HgI2, PbO, TlPbI3, and InI were used in a experiment and all samples were fabricated 2cm*2cm size on the substrate with particle in binder method. It was coated ITO electrode on semiconductor surface through thermal evaporation system. Also, for increasing lag performance, polymer materials were deposited semiconductor with PVD method. The kVp, irradiation dose, and irradiation time for the lag measurements were used as important parameters. Also, experimental results were compared and evaluated through previous method used for analog system and new method that could easily use in the digital radiography. Signal lag in the most materials was considerably confirmed the different results when compared with previous literature, while that at HgI2 film was acquired a good result as low as 5%. It was confirmed changing lag performance of semiconductor material through experiments conducted with the important parameters such as the kVp, irradiation dose, and irradiation time. We developed new measurement process that could easily acquire image lag and a evaluation of image lag about many semiconductor materials was successfully carried out.

Poster 13.2 Tue 14:00 Poster Hall

Annealing studies of a silicon microstrip detector irradiated at high neutron fluences — •Mercedes Miñano[1], Carmen García[1], Sergio González[1], Carlos Lacasta[1], Vicente Lacuesta[1], Manuel Lozano[2], Salvador Martí i García[1], Giulio Pellegrini[3], Joan Marc Rafí[2], and Miguel Ullán[2] — [1]Instituto de Física Corpuscular,IFIC (CSIC-UVEG), Edificios de Investigación, Aptdo de correos 22085,46071 Valencia, Spain — [2]Centro Nacional de Microelectrónica, CNM-IMB (CSIC) Campus Universidad Autónoma de Barcelona. 08193 Bellaterra, Barcelona, Spain — [3]Departamento de Electrónica, Informática y Automática, Universidad de Girona. E-17071 Girona, Spain

silicon p-type detectors are being investigated for the development of radiation tolerant detectors for the luminosity upgrade of the CERN large hadron collider (super-LHC).

microstrip detectors have been fabricated by CNM-IMB with a n-side read-out on p-type high resistivity float zone substrates. They have been irradiated with neutrons at the TRIGA Mark II nuclear reactor in Ljubljana. The irradiation fluxes match with the expected doses for the inner tracker at the sLHC (up to 10^{16} equivalent 1 MeV neutrons cm^{-2}). The macroscopic properties of the irradiated prototypes after irradiation were characterized at the IFIC-Valencia laboratory. The charge collection studies were carried out by means of a radioactive source setup as well as by an infrared laser illumination.

The annealing behavior was studied in detail on a microstrip detector irradiated with a flux of 10^{15} equivalent 1 MeV neutrons cm^{-2}. Collected charge measurements have been done after accelerated annealing times at 80°C up to an equivalent annealing time of several years at room temperature. This note will report the recorded results from the annealing of the irradiated p-type microstrip sensor.

Poster 13.3 Tue 14:00 Poster Hall
Lithium Drifted Silicon Detectors for Harsh Radiation Environments — •James Grant[1], Craig Buttar[1], Mike Brozel[1,2], Aissa Keffous[2], Abdelhak Cheriet[3], Karima Bourenane[3], Faouzi Kezzoula[3], and Hamid Menari[3] — [1]Department of Physics and Astronomoy, University of Glasgow, Glasgow, Scotland, United Kingdom, G12 8QQ — [2]School of Chemistry, University of Bristol, Bristol, BS8 1TS, England, United Kingdom — [3]Unit of Silicon Technology Development, 02 Bd Frantz Fanon, Algiers 16000, Algeria

The drifting of lithium ions in silicon was first demonstrated in the 1950s and early 1960s by Pell [1] and others and the technique has been used to compensate nominally p-type silicon to realise thick, internally passivated, 2-5 mm thick silicon particle detectors.

This paper presents a preliminary investigation of the drifting of Li in Si and whether this can be used to passivate radiation-induced acceptors. This would have applications in any area where Si detectors are exposed to high levels of radiation fluence e.g. in space missions and particle physics experiments. Lithium ions (which are donors in Si) that are diffused and drifted through the silicon bulk are predicted to compensate radiation induced acceptor states in a similar way to the passivation of grown-in acceptors in melt-grown Si. This should reduce the voltage required for full depletion and other effects resulting from the introduction of acceptor centres during radiation. In essence, the Si/Li detector is predicted to be partially or fully self-repairing as long as there is a supply of lithium at the n+ contact which can act as a diffusion source.

Si/Li devices were fabricated at the Unit of Silicon Technology Development in Algeria. These devices exhibited excellent current-voltage (I-V), capacitance-voltage (C-V) and charge collection efficiency (CCE) properties after fabrication in 2003. However, when these devices were characterised in early 2007 they showed significantly degraded dc electronic properties indicating that there was some out-diffusion of the lithium ions in the intervening years. By reverse biasing the Si/Li devices to 600 V at 120^{o}C for a number of hours it was possible to recover the excellent electronic properties of the detectors that were measured directly after fabrication. Thus, the full depletion voltage extracted from C-V measurements of a 2.2 mm thick re-drifted Si/Li device was reduced from 600 V to 50 V while the device exhibited a 100% CCE at a reverse bias of only 200 V.

These preliminary results demonstrate that Li ions can be drifted after storage of the device for extended times and that they can still act as passivating centres for electrically active acceptors. This suggests that Si/Li detectors may show great promise for radiation hard applications, the continuous drifting of Li atoms passivating irradiation-induced acceptor damage centres as they are produced. The next step of this study is to irradiate Si/Li devices with 24 GeV/c protons and 1 MeV neutrons and show that not only do the lithium ions passivate the radiation-induced acceptor levels but also that the lithium drift process occurs quickly enough to protect the detectors when used under room temperature operation.

[1] E.M. Pell, J. Appl. Phys. Volume 31, Number 2, 291-299, 1960

Poster 13.4 Tue 14:00 Poster Hall
Influence of high energy X-ray exposure on mechanical properties of SiOx - containing amorphous DLC structures — •Diana Adliene[1], Jurgita Laurikaitiene[1], Vitoldas Kopustinskas[2], and Asta Guobiene[2] — [1]Kaunas University of Technology, Physics Department, Studentu g.50, LT-51368 Kaunas Lithuania — [2]Institute of Physical Electronics, Kaunas University of Technology, Savanoriu 271, LT-3009 Kaunas Lithuania

Diamond and diamond like carbon (DLC) are widely used for the constructing of radiation detectors for medical applications, due to the material equivalency to the soft tissue. Properties of CVD diamonds and their behaviour in radiation field are well investigated, however there are only few studies on the properties of amorphous carbon (a-C:H) films synthesized in room temperature by direct ion beam deposition. Amorphous DLC films have a smooth surface and are defined by the excellent mechanical properties (high hardness, adhesion, stability, low mechanical stress), depending on sp3/sp2 ratio, content of the hydrogen in the films and co-doping. These mechanical properties may be of advantage when developing radiation detector structures for medical applications (i.e. contacts with electrodes). The aim of this work was to investigate the mechanical properties of silicon doped amorphous hydrogenated DLC films irradiated with high energy (medical range) photons. Silicon and silicon oxide doped a-C:H films deposited onto Si wafers from hexamethyldisiloxane vapour and hydrogen gas mixture using direct current ion beam deposition method [1] were irradiated (single exposure and irradiation in sequences) with high energy photons (1.25 MeV) from medical 60Co source and X-ray photons (6 MV and16 MV) generated in medical linear accelerator Clinac (VARIAN). Mechanical stress in irradiated samples was investigated by laser interferometry. Surface morphology and thickness were characterized by scanning electron microscopy (SEM), model JEOL JSM-5600, and atomic force microscope (AMS), model Nanotop 2006. Chemical bonding structure of DLC films was characterized using Fourier transform infrared (FTIR), model Spectrum GX FT-IR, Perkin Elmer) and Raman scattering (RS) spectroscopy. It was found, that the adhesion*s properties and stability of DLC was not affected significantly by high energy photon irradiation. However some changes in surface morphology and increased hardness in investigated samples as compared to not irradiated samples, due to the changes in chemical structure of DLC film under radiation, were observed Mechanisms of radiation induced changes in the DLC film structure and properties are discussed on the base of the obtained results.

References 1. V.Kopustinskas, Š. Meškinis, S.Tamulevičius, M.Andrulevičius, B.Čižiute, G.Niaura. Sythesis of the silicone and silicone oxide doped a-C:H films from heksamethyldisiloxane vapor by DC ion beam, Surface and Coatings technology, 200, 2006, p 6240-6244.

Poster 13.5 Tue 14:00 Poster Hall

Synchrotron X-ray topography and electrical characterization of epitaxial GaAs p-i-n structures — •Pasi Kostamo, Aapo Lankinen, Antti Säynätjoki, Harri Lipsanen, and Turkka Tuomi — Helsinki University of Technology, Espoo, Finland

High purity epitaxial GaAs is one of the most promising new materials for semiconductor radiation detectors capable of spectroscopic detector operation at room temperature. GaAs provides theoretically very low leakage current levels due to the relatively wide bandgap. However, achieving low leakage current levels necessary for high-resolution energy dispersive operation sets strict demands for the material quality. One most important factor affecting the material quality is the electrically active dislocations in the depleted region. These dislocations may provide channels for leakage current and thus increase the leakage current level of the detector diode several orders of magnitude.

Synchrotron X-ray topography results are presented of high purity gallium arsenide p-i-n structures grown by hydride vapor epitaxy. A comprehensive set of large area transmission, large area back-reflection and transmission section topographs are analyzed. The X-ray topography results are compared to electrical performance of detector diodes. A good agreement is found with x-ray topographs and electrical measurements.

The results show that wafer uniformity and crystal quality play a significant role when epitaxial high purity material is used for manufacture of detector diodes. The uniformity issue is highlighted when detector components with large area are manufactured. It is also shown that synchrotron X-ray topography provides valuable information in the viewpoint of process development.

Poster 13.6 Tue 14:00 Poster Hall

Performance of semi-insulating GaAs radiation detectors: Role of electrodes metallizations — •František Dubecký[1], Pavol Boháček[1], Bohumír Zaťko[1], Tibor Lalinský[1], and Andrea Šagátová[2] — [1]Institute of Electrical Engineering, Slovak Academy of Sciences, Dúbravská cesta 9, SK-84104 Bratislava, Slovak Republic — [2]Department of Nuclear Physics and Technique, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovičova 3, SK-81219 Bratislava, Slovak Republic

The physics and technology of structures based on semi-insulating (SI) GaAs seems to be insufficiently understood and developed. SI GaAs due to its physical properties coupled with recent progress in radiation detector technology became one of the most important candidates for fabrication of monolithic systems for applications in new digital X-ray imaging applications (F. Dubecký, et al., Nucl. Instr. Meth. A 2007, in press).

In present work, we continue in a comparative study of electrode technology in SI GaAs-based radiation detectors with different blocking (Schottky) and ohmic contact metallizations (F. Dubecký, et al., Nucl. Instr. Meth. A 2007, in press). Four different detector structures with Ti/Pt/Au and Au/Zn blocking combined with AuGeNi eutectic alloy and In/Au ohmic metallizations are fabricated in a high vacuum system. Detectors are based on detector-grade undoped bulk SI GaAs and characterized by current-voltage, noise and long-term operation stability measurements. Detection performance is evaluated from pulse height spectra of Am-241 and Co-57 gamma radionuclide sources. Results observed with different metallizations are compared and discussed in the light of observed experimental data. Importance of the following study and optimization of electrodes technology of SI GaAs detector with good performance is demonstrated.

Poster 13.7 Tue 14:00 Poster Hall

Deep level photoluminescence in semiinsulating CdTe(In) and CdTe(Sn) — Jan Franc, Pavel Hlídek, Eduard Belas, •Hassan Elhadidy, and Roman Fesh — Institute of Physics, Charles University, Ke Karlovu 5, CZ-121 16, Prague 2, Czech

CdTe and (CdZn)Te have been intensively studied due to their applications in detection of X-ray gamma ray radiation at room temperature. The transport of generated photocarriers is substantially influenced by presence of deep levels, which act as recombination and trapping centers. We concentrate on photoluminescence (PL) results from spectral range 0.3-1.3eV, that includes also signal from deep levels near the mid-gap.

The high-resistivity (10^9-5×10^9 Ωcm) CdTe crystals investigated in this study were prepared by vertical gradient freeze method in the crystal growth laboratory of the Institute. The CdTe was synthesized from 6N purity Cd and Te in the same ampoule.

Two groups of samples were investigated. One group was doped with Sn. This dopant is known to have a deep level near the middle of the forbidden gap The second group was doped with In, which acts as a shallow donor. The nature of deep levels in CdTe(In) is not well known so far.

A very intensive PL luminescence on deep levels is observed in case of CdTe(Sn) samples. The intensity of the peaks is approximately two orders of magnitude higher, than in In doped samples. Comparison of the integral photoluminescence activity through deep levels (0.3-1.2eV) with the total PL signal (0.3-1.6eV) shows approx. one order of magnitude higher radiative recombination activity through deep levels in case of CdTe:Sn samples compared to CdTe:In samples.

A qualitative correlation between the mobility-lifetime product of electrons and the integral PL intensity at deep levels was observed. A correlation between integral PL intensity of A-centers and deep levels in CdTe:In samples was found out. This finding supports the idea, that deep levels in these samples are primarily complexes formed together with A-centers. The integral PL in the spectral range of deep levels can therefore serve as an indicator of sample quality from the point of view of its suitability for fabrication of detectors of gamma and X-ray radiation.

Poster 13.8 Tue 14:00 Poster Hall

Correlation of CdTe:In properties with annealing at Cd/Te pressures — •Eduard Belas[1], Roman Grill[1], Jan Franc[1], Pavel Hlídek[1], Vladimír Linhart[2], Tomáš Slavíček[2], and Pavel Höschl[1] — [1]Institute of Physics, Charles University, Prague 2, CZ-121 16, Czech Republic — [2]Institute of Experimental and Applied Physics, Czech Technical University, Prague 2, CZ-128 00, Czech Republic

The effect of the annealing under various Cd/Te pressures on the electrical, optical and spectroscopic properties of semi-insulating In-doped CdTe is investigated. The correlation between various annealing conditions and the resistivity, free carrier concentration, low-temperature photoluminescence and gamma- and alpha-ray spectroscopy measurements is used for the determination of specific annealing conditions for the preparation of the high quality detector grade material. The dominant ionization level is determined by temperature dependence of Hall effect measurement and compared with low-temperature photoluminescence (PL). The ratio between excitonic and deep or shallow defect-related PL intensity is compared, as well. The charge collection efficiency (CCE) of as-grown and annealed samples is measured by alpha spectroscopy.

Deep donor ionization level $E_D \sim 0.7$ eV is determined in as-grown high resistive material. PL spectra show the correlation of the detector response and the intensity ratio of the emission peaks at 0.75 eV and 1.45 eV related to the deep level of Cd vacancy and A-centers, respectively. The lower intensity of the emission at 0.75 eV implies better CCE. Slightly-compensated high conductive n-type material with dominant donor ionization level $E_D = 10$ meV was prepared by Cd-saturated annealing followed by slow cooling. Donor bound exciton emission increased together with broad emission peak at 1.1 eV obviously related to Te vacancies. After Te saturated annealing followed by quenching non-compensated p-type material with dominant acceptor ionization level $E_A = 180$ meV was formed. PL spectra show dominant acceptor bound exciton recombination together with intensive broad deep level peak at 0.75 eV similar to as grown sample. Te-rich annealing followed by slow cooling is used to search the way for the restoration of the semi-insulating material. Consequently, specific annealing conditions are used to enhance the detector quality.

Poster 13.9 Tue 14:00 Poster Hall

Surface Leakage Current Control with Heterojunction-type Passivation in Semi-insulating CdZnTe Material — KiHyun Kim[1,2], •ShinHang Cho[2], JongHee Suh[2], JaeHo Won[2], JinKi Hong[2], and SunUng Kim[2] — [1]Divisions of Medical Sensor, Samil-Pharm, Seoul, 137-061, South Korea — [2]Dept. of Display and Semiconductor Physics, Korea University, ChungNam, 339-700, South Korea

Surface play an important role in the overall performance of CdTe or CdZnTe X-ray and gamma-ray detector. Surface conduction increases the leakage currents and surface traps make $1/f$ noise currents. A passivation that reduces the dc leakage currents does not necessarily reduce the $1/f$ noise currents since it can contribute surface traps. A proper passivation reduces both the dark currents as well as the $1/f$ noise currents.

The effects of passivation on leakage currents and surface trap were investigated both the semi-insulating polycrystalline CdZnTe:Cl thick films and the single CdZnTe:Sn crystals. Polycrystalline CdZnTe:Cl samples were prepared by thermal evaporation methods and single CdZnTe:Sn crystals were grown by vertical Bridgman method. Both samples have the resistivity in the order of 5×10^9 Ωcm. The etching of CdTe or CdZnTe in Br-MeOH solutions make Cd^{2+} ions partially transfer into the solution with the formation of $CdBr_2$ and remained Te^{2-} ions reduced to Te^0. Thus, the cation site is partially eliminated from the surface while the anion site with dangling bonds remains. Due to the presence of water traces in the Br-MeOH solution as well as due to oxidation in air, the film consists of TeO_2 and CdO is formed on the CdTe surface. The electron states at the surface can trap and accumulate the majority carriers, thereby forming the potential barrier at the surface. Passivation in $(NH_4)_2S$ reconstructs the surface owing to the effective removal of CdO and TeO_2 and saturation of dangling bonds with the formation of CdS and CdTeS. The thin CdS and CdTeS layer forms heterojunction with CdZnTe and thereby surface barrier which prohibits surface leakage currents.

Quantitative analysis of surface passivation was made of surface recombination velocity, sheet resistance of CdZnTe films and noise spectrum analysis.

Poster 13.10 Tue 14:00 Poster Hall

X-ray Sensitivity of Semi-insulating Polycrystalline CdZnTe Thick Films — KiHyun Kim[1,2], •JongHee Suh[2], ShinHang Cho[2], JaeHo Won[2], JinKi Hong[2], and SunUng Kim[2] — [1]Divisions of Medical Sensor, Samil-Pharm., Seoul, 137-061, South Korea — [2]Department of Display and Semiconductor Physics, Korea University, ChungNam, 339-700, South Korea

The X-ray sensitivity of a detector is considered as one of the important performance measures for a superior image. High sensitivity increases the dynamic range of the image and permits low patient exposure dose. In the present research, we have studied the X-ray sensitivity of semi-insulating polycrystalline CdZnTe thick films as a function of electric field, mean photon energy, semiconductor thickness, and charge transport parameters, i.e., drift mobility and carrier lifetime or trapping time determined by transient photoconductivity measurement.

Semi-insulating polycrystalline CdZnTe:Cl thick films were deposited on graphite substrate and CMOS sensor by thermal evaporation method. The substrate temperature was kept below 350 °C. The resistivity and thickness of CdZnTe layers is 5×10^9 Ωcm and 300 μm,respectively. The gold and indium was used as a top electrode depends on the injecting or non-injecting layer formation.

The X-ray sensitivity of polycrystalline CdZnTe is about 2.3 $\mu C/cm^2/R$ and 1.0 $\mu C/cm^2/R$ in the electron and hole collection mode with 65 kVp and 50V, respectively. In addition, the spatial uniformity of the sensitivity in polycrystalline CdZnTe materials was also investigated in 10×10 cm^2 size sample.

Poster 13.11 Tue 14:00 Poster Hall

Improvements on Leakage Current of Mercuric Iodide X-ray Detector — Sang Sik Kang, •Sungho Cho, Soyeong Kim, Daewoong Chon, and Sanghee Nam — radiation image laboratory of biomeidcal engineering, inje university, ubangdong, kimhae

Mercuric iodide (HgI2) have been widely used as direct x-ray devices. But, a difficult challenge of mercuric iodide is the higher than desired leakage current. Leakage currents are generally influenced by factors such as applied field, film thickness, material type and structure. In this work we report new studies of the leakage currents of the mercuric iodide based x-ray devices, which were incorporated by depositing various blocking materials (a-Se, PbI2, CdS, etc.) on HgI2 film. The x-ray devices which incorporate multilayer structure is vacuum deposited by physical vapor deposition and particle-in-binder method. The structure and the surface morphology of the fabricated film was investigated by scanning electron microscopy. The leakage current and the output charge density of the films as a function of applied voltage were investigated. Experimental results show that a-Se rectifying layer on HgI2 film reduced the leakage current and improved the signal to noise ratio significantly. And the current instability versus time was closely related to the accumulation of a charge on trapping centers and the injected charge from external electrode during application of the bias. In addition, the surface treatment was found to improve substantially the leakage current characteristics of a variety of HgI2-based x-ray devices.

Poster 13.12 Tue 14:00 Poster Hall

The Evaluation of Semiconductor Performance of Mercuric Iodide Film Fabricated with new Particle In Binder Method for Large Area X-ray Imaging — •Chiwon Choi[1], Chol Kwon[1], Sangsik Kang[2], Yunsuk Kim[2], and Sanghee Nam[3] — [1]Department of Medical Imaging Science, InjeUniversity, Gimhae City, 621-749, South Korea — [2]Department of Biomedical Engineering, InjeUniversity, Gimhae City, 621-749, South Korea — [3]Medical Imaging Research Center, InjeUniversity, Gimhae City, 651-749, South Korea

As a semiconductor for digital radiography, HgI2 among various materials has reported easy fabrication with screen printing method. But, in case of screen printing method, it is difficult to fabricate thick semiconductor layer. In this paper, the new particle-in-binder (PIB) method was developed, and the study results were compared with polycrystalline HgI2 films fabricated with screen printing methods. We investigated the structural and morphological properties of the films with scanning electron microscopy (SEM) and their electrical properties. Film sample was fabricated 2cm*2cm and was coated thickness ranging between 200 * and 250 *. The SEM analysis results demonstrated the applicability of the new PIB method to high-density structures. The x-ray sensitivity of the HgI2 film fabricated with new PIB method was 21nC/cm2/mR and the dark current was 0.8nA/cm2 at applied field of 1 V/μm. Also, it was shown in good linearity. The signal lag measured for 33ms after x-ray exposure was 5.4 %. This study provides the first performance data of new deposition method for digital x-ray detector.

Poster 13.13 Tue 14:00 Poster Hall

Annealing Effects on X-ray Detection Properties of Polycrystalline PbO film — •Kang Sang Sik, Jikoon Park, Byungyul Cha, Chul Kwun, Chiwon Chae, and Sanghee Nam — radiation image laboratory of biomedical engineering, inje university, ubang dong, kimhae, korea

The influence of post-deposition annealing on the characteristics of the lead oxide films was investigated in detail. X-ray diffraction and scanning electron microscopy, and atomic force microscopy have been employed to obtain information on the morphology and crystallization of the films. Also we measured dark current, x-ray sensitivity and linearity for investigation of the electrical characteristics of films. It was found that the annealing conditions strongly affect the electrical properties of the films. The x-ray induced output charges of films annealed in oxygen gas increases dramatically with increasing annealing temperatures up to 500 degree but then drops for higher temperature anneals. Consequently, the more we increase the annealing temperatures, the better density and film quality of the lead oxide. Analysis of this data suggests that incorporation and decomposition reactions of oxygen can be controlled to change the detection properties of the lead oxide film significantly.

Poster 13.14 Tue 14:00 Poster Hall

Annealing effect on x-ray detection properties of polycrystalline PbO film for x-ray imaging — •Chul Kwun, Sangsik Kang, Chiwon Choi, Byungyul Cha, and Sanghee Nam — radiation image laboratory of biomeidcal engineering, inje university, ubangdong, kimhae

Polycrystalline lead oxide (PbO) film is excellent candidate material for direct conversion x-ray detector. But it has been reported that a thickly and bulky film reduce significantly the charge collection efficiency as well as the electron-hole pair creation due to lower mass density of film. In this paper, firstly, the sub-micron lead-oxide particles, which can use in a novel high efficiency flat panel x-ray detector, were synthesized by a simple solution-combustion method. Field emission scanning emission efficiency (FE-SEM) was used to analyze the component ratio and the morphology of the PbO particles as a function of annealing temperature. Secondly, the lead oxide (PbO) films of 200 micron thickness were deposited on glass substrates using a wet coating process at room temperature. The influences of post-deposition annealing on the x-ray detection characteristics of the PbO films were investigated in detail. The key parameters - the dark current, the x-ray sensitivity and signal to noise ratio - were measured. It was found that the annealing conditions strongly affect the electrical properties of the films. The x-ray induced output charges of films annealed in oxygen gas increases dramatically with increasing annealing temperatures up to 500 degree.

Poster 13.15 Tue 14:00 Poster Hall

Improved process for the TlBr single crystal detector — •Vasilij Kozlov[1], Hans Andersson[2], Vladimir Gostilo[3], Markku Leskelä[1], Mihail Shorohov[3], and Heikki Sipilä[2] — [1]Department of Chemistry, University of Helsinki, P.O. Box 55, FIN-00014, Helsinki, Finland — [2]Oxford Instruments Analytical Oy, PO Box 85, FIN-02631, Espoo, Finland — [3]Baltic Scientific Instruments (BSI, Ltd.), Ganibu dambis 26, P.O.Box 33, Riga, LV-1005, Latvia

Among wide bandgap semiconductor materials a TlBr (2.68 eV) single crystal is a potential gamma-ray detector. Its high stopping power and density (7.56 g/cm^3) makes it unique for space astrophysics, medicine and military applications. Unfortunately, the detector manufacturing process is still far from perfect. Additionally, the material is toxic and soft. As a result, purity and crystal quality of TlBr crystals do not correspond to the requirements of room temperature gamma-ray detectors. In this work, special efforts were put to a purification of TlBr raw material in order to receive the cleanest product-detector.

The procedures included the methods traditionally used in TlBr detector fabrication, but in addition, an ingot grown by Bridgman-Stockbarger method and ready for a manufacturing of detectors was re-crystallised in water at hydrothermal conditions. Then, the powder product was purified several times by a travelling molten zone (TMZ) method. The single crystal was grown with the same TMZ method but with a lower rate.

The further operations (crystal cutting, annealing, polishing, etching) of making the detectors matched to that normally used in practice The samples were characterised by optical and X-ray rocking curve methods. Electrical characteristics were measured at -20°C - 42°C. Spectroscopic prop-

erties, I-V characterisation and the mobility-lifetime product of electrons are reported and discussed.

Poster 13.16 Tue 14:00 Poster Hall
Microstructures, microhardnes and spectrometrical performance of TlBr detector crysrals. — •Mihail Shorohov[1,2], Faina Muktepavela[2], Janis Maniks[2], Larisa Grigorjeva[2], Donats Millers[2], and Vladimir Gostilo[1] — [1]Institute of Solid State Physics, University of Latvia, Kengaraga street 8, LV-1063 Riga, Latvia — [2]Baltic Scientific Instruments, Ganibu dambis 26, P.O.Box 33,LV-1005, Riga, Latvia
TlBr single crystal is a wide band gap material with high densityand high stopping power. It is known that TlBr detectors are useful for X-ray and *-quantum detection at room temperature. For the best TlBr detectors the FWHM is 2.5% forat 59.5 keV. But till now TlBr detectors is far from commercial use due to its non-stability. The main factors affecting the sensitivity and energy resolution of detectors are crystal purity, charge carrier collection efficiency on detector surface, quality of crystal surface and contact electrodes. Therefore the investigations of surface microstructure and morphology of TlBr crystals are actual problems.

The mechanical processing and chemical etching on TlBr crystal surface were studied. The optical microscopy and microhardness methods were used for surface quality controls. The procedures of chemical etching were developed for removing of mechanically destroyed surface layer and surface processing before deposition of contact electrodes. Different types of electrode materials as well as deposition techniques were studied. The quality of crystals presented from different providers was compared. It is shown that microstructure analysis by optical microscopy and microhardness methods can be successfully applied for surface quality characterization and enhancement of detector manufacturing technology. The obtained results were compared with spectrometric performance of detectors.

Poster 13.17 Tue 14:00 Poster Hall
Optical Characteristics of TlBr Crystals — •Nickolai Smirnov, Igor Lisitsky, Mikhail Kuznetsov, Anatolij Govorkov, and Elena Kozhukhova — Institute of Rare Metals, Moscow, Russia
The growth technology of TlBr detector crystals could not provide the required quality for the crystals at present. Its further development requires considerable studies of characteristics of the crystals, grown in various conditions, including optical methods. Optical characteristics were measured for TlBr crystals grown by Bridgman technique in various ambient: vacuum, Ar, air. The growth ambient had a profound influence on short-wave edge spectral transmition and light scattering on length of a wave 0,63 mm. Is established, that the least abrupt border short-wave transmition and greatest light disseminating has the crystal which has been brought up in vacuum. The best optical characteristics have the crystal, received on air. The model of influence of an atmosphere is offered on the optical characteristics of crystals.

Session 14: Applications II

Tuesday, 16:20–18:00 Lecture Hall

Invited Talk 14.1 Tue 16:20 Lecture Hall
Detectors for neutron imaging — •Burkhard Schillinger, Elbio Calzada, Klaus Lorenz, Martin Mühlbauer, and Michael Schulz — Technische Universität München, FRM II - Lichtenbergstr.1, 85748 Garching
While counting detectors are employed for neutron scattering instruments, neutron imaging requires integrating detectors for high fluxes. Counting gas detectors do not have sufficient spatial resolution for good imaging, so scintillation screens are employed, which can be read by camera systems or by amorphous silicon flat panels. This talk will concentrate on the properties of neutron scintillation screens as well as the employed camera systems. Depending on the application, cooled high-resolution CCD cameras are selected for high resolution static imaging, gated interline CCDs or full frame CCDs in combination with image intensifiers are used for stroboscopic short-time imaging, and new CMOS cameras can be employed for high-speed continuous imaging. Imaging artefacts like white spots from gamma radiation directly hitting the camera chip can be removed by software filters. Several examples of different imaging techniques will be presented from the neutron imaging facility ANTARES at he FRM II reactor of Technische Universität München.

Contributed Talk 14.2 Tue 17:00 Lecture Hall
Direct detection devices for single particle electron cryo-microscopy — •A.R. Faruqi, R. Henderson, and G. McMullan — MRC Laboratory of Molecular Biology,Hills road,Cambridge CB2 2QH, UK
The possibility of obtaining atomic resolution structures of single molecules (or single particles) embedded in vitreous ice using electron cryo-microscopy should be theoretically feasible though this has not been achieved in practice. Several improvements in technology are required to obtain the highest resolution in which better detectors is a key element. The great attraction of single particle microscopy is that there is no need to obtain high quality three dimensional crystals of the molecules - essential for x-ray crystallography. The main disadvantage, relevant for the present discussion, is that images need to be recorded, preferably on electronic detectors with high efficiency (DQE) and resolution (MTF), excellent radiation hardness and containing a large number (4kx4k) of independent pixels. Some examples of the typical single particle size and image magnification used in microscopy will be presented to describe the detector requirements.

Film, used traditionally, is an excellent recording medium, containing an adequate number of pixels, but needs processing before results become available and cannot be used in an on-line system; also, the DQE is poor at low electron doses due to intrinsic noise (fog) levels in film. CCDs can be used as indirect detectors (via intermediate phosphor and fibre optics) resulting in a reduced MTF due to light scattering within the phosphor grains and at the fibre optics interface. Due to the rapid advances in CMOS based sensors it is now feasible to consider a direct detection device with better performance.

As previously reported, Medipix2 has excellent imaging properties at 120 keV (and at lower electron energies, which is relevant for other EM applications). Due to the intrinsically noiseless readout in Medipix2 it is an ideal detector for use in those experiments which require the sum of a large number of frames - since only the signal is added without adding noise. An ongoing application at the MRC Laboratory is in the investigation of specimen movement in response to extremely low dose of electrons. Eliminating, or even reducing specimen drift will be extremely helpful in obtaining higher resolution images from single particles. We have also investigated a number of monolithic active pixel sensors, which offer certain advantages over hybrid detectors, particularly at 300 keV. A number of sensors are being evaluated, with different parameters, including epilayer thickness, to find an optimum sensor for 300 kV microscopy.

Contributed Talk 14.3 Tue 17:20 Lecture Hall

Thin silicon strip devices for direct electron detection in transmission electron microscopy — •Grigore Moldovan, Xiaobing Li, Peter Wilshaw, and Angus Kirkland — Department of Materials, University of Oxford, Parks Road, Oxford, OX1 3PH, UK

With the development of nano-materials and nano-devices, our ability to characterise structures on the nano-scale has become critical. An essential role in this has been taken by transmission electron microscopy (TEM), but its application is hindered by a variety of limitations imposed by present electron detection systems. These have arisen primarily because of their indirect detection mechanism and result in poor efficiency and resolution, reduced dynamic range and limited field of view. Detectors based on new concepts are vital in overcoming these limitations. A new generation of directly exposed electron detectors is now emerging, based on a variety of devices designed for position sensitive particle detection, such as hybrid active pixel devices (HAPS) or monolithic active pixel devices (MAPS). This work considers, for the first time, the application of silicon strip detectors (SSD) in TEM.

A set of requirements for detector performance will be proposed first establishing a common framework for analysis. Monte Carlo simulations of the electron-sensor interaction will be used to explore the relationship between sensor geometry, expected modulation transfer function (MTF) and efficiency function (EF). It will be shown that the MTF degrades rapidly with increasing sensor and support thickness, and that a thickness of around 50 microns is needed. This will be discussed as a function of electron energy, up to 400keV. Details of device and process design will then be presented, showing that back-etched silicon on insulator (SOI) wafers can be used to fabricate such thin sensors. Basic device characterisation of one-pixel sensors will be shown, demonstrating the excellent signal-to-noise ratio and radiation hardness of these devices. MTF and EF characterisation of one-dimensional devices will also be presented, showing that a much better resolution and efficiency can be obtained with directly exposed SSD than the present phosphor-charge coupled devices.

These results will be discussed in relation with the set requirements and in the broader context of HAPS and MAPS devices. It will be shown that in counting mode this new generation of sensors allows noiseless detection with a tremendous improvement in efficiency, reaching levels impossible to obtain with existing systems. In addition, counting mode introduces virtually unlimited dynamic range, allowing the production of images with contrast spanning many orders of magnitude. Furthermore, in integration mode these devices have a much increased speed, well beyond the capacity of present indirect-detectors. However which detector type is optimum for a particular application depends on parameters such as field-of-view, speed and costs of ownership. It will be shown that for the case of spectroscopy based methods, the large number of pixels required make the present MAPS and HAPS unattractive and favour SSD. For the case of imaging based methods, the required speed rules out the existing read-out systems for SSD in the favour of MAPS and HAPS, indicating a need for faster read-out electronics.

Contributed Talk 14.4 Tue 17:40 Lecture Hall

A prototype of radiation imaging detector using silicon strip sensors — •Hwanbae Park, Hyojung Hyun, Dongha Kah, Heedong Kang, Hongjoo Kim, Youngim Kim, Sangsoo Ryu, and Dohhee Son — Department of Physics, Kyungpook National University, Daegu 702-701, Korea

The aim of this work is to evaluate the performance of a silicon strip sensor with a single photon counting data acquisition system based on the VA1 read-out chip and to study the feasibility of a silicon detector for medical applications.

The silicon strip sensor is an AC-coupled single-sided and the active area of a sensor is about 30 x 30 mm^2 with a thickness of 380μm. It has 64 strips with a strip pitch of 500μm. The sensors are held at room temperature with a bias of 46 V. Two silicon strip sensors are mounted orthogonally with a 5 mm space gap to get the two-dimensional information.

Two low-noise analog VLSI, VA1 chips are used for signal readout of a strip sensor. The assembly of sensors and readout electronics is housed in Al dark box. A CsI(Tl) scintillation crystal and a 2in. PMT are used to trigger signal events. The data acquisition systems are based on 64MHz FADC and control software for the PC-Linux platform.

Measurements have been performed using a Pb phantom. A ^{90}Sr radioactive source and a 45-MeV proton beam from the MC-50 cyclotron at the Korea Institute of Radiological and Medical Science are used for imaging test. Results of the signal-to-noise ratio and images are presented.

Session 15: Applications of spectroscopic Detectors

Wednesday, 9:00–10:40 Lecture Hall

Invited Talk 15.1 Wed 9:00 Lecture Hall
Bio-medical X-ray Imaging with Spectroscopic Pixel Detectors — •Anthony Butler, Nigel Anderson, Phil Butler, Nick Cook, Tracey Melzer, and Rita Tipples — University of Canterbury, Christchurch, New Zealand

The aim of this presentation is to review the clinical potential of spectroscopic X-ray detectors. The presentation will include spectral images of surgical specimens and human foetuses, obtained with a Medipix-2 detector.

A new breed of X-ray detectors is being developed that individually processes photons interacting with a sensor. These are either known as quantum detectors, photon counting detectors, or for the more advanced systems, photon processing detectors. Many of these detectors, such as Medipix-2, allow thresholds to be selected so that only photons within a specified energy range are recorded. New detectors in development, such as Medipix-3, have multiple thresholds within each pixel. These new detectors will allow for routine use of spectroscopic X-ray systems for bio-medical imaging.

The significance of spectroscopic X-ray detectors is difficult to predict but insights can be gained by examining both image reconstruction artefacts caused by beam hardening, and the current uses of dual energy techniques in bio-medical imaging.

Beam hardening artefact is a CT reconstruction artefact that arises due to the approximation that the spectrum of transmitted X-rays is constant regardless of the material being imaged. This artefact poses significant clinical problems in diverse areas including CT pulmonary angiography and muskuloskeletal imaging around metallic implants. It is hoped that with spectroscopic detectors the artefact can be reduced, thus improving diagnostic capabilities.

Dual energy angiography is a technique where an infused angiographic contrast agent is identified by its k-edge. Within bio-medical imaging iodine and gadolinium contrast are routinely used for vascular studies and tumour characterisation. Both iodine and gadolinium have k-edges within the energy range of diagnostic X-rays making them easily identifiable with spectroscopic detectors. Potential clinical applications include pre- and post-contrast CT imaging and retention of contrast in tumours such as breast cancer.

Different tissues and tumours have different attenuation co-efficients over a range of energies. Spectral imaging will translate to better identification and delineation of tumours compared to conventional imaging. While dual energy techniques are well established for bone diseases, for practical reasons they are rarely used elsewhere. Despite this, spectral information is known to be of benefit for many diseases. Published examples of the use of energy information in mammography include: 1) lower energies provide better soft tissue contrast. 2) ductal carcinoma has a different attenuation spectrum than fibrous tissue. 3) microcalcification can be better identified for early detection of cancer.

In conclusion, spectroscopic X-ray pixel detectors have potential for a wide range of clinical benefits.

Contributed Talk 15.2 Wed 9:40 Lecture Hall
Recent advances in GridPix detectors — •Maximilien Chefdeville — NIKHEF, Kruislaan 409, amsterdam 1098 SJ, The Netherlands

The successful application of the Timepix chip as a highly segmented readout of a small Micromegas chamber is presented. The intrinsicly good single electron detection efficiency of Micromegas-based pixel readout gaseous detector, together with the drift time measurement provided by the Timepix ASIC allow 3-dimensional reconstruction of single electrons from ionizing particle tracks. By means of a coincidence setup, several minimum ionizing cosmic tracks were recorded in He/C_4H_{10} 80/20. The ionization statistics were studied by the analysis of the electron spatial distribution along the tracks. Results on cluster density will be shown.

Micromegas grids were recently integrated (InGrid) onto a Medipix2 wafer by means of post-processing, resulting in increased detection area and improved performance. The alignment between the grid holes and the pixel input pads suppresses the periodic spatial variation of detection efficiency previously observed when mounting manually the Micromegas onto the chip, yielding a uniform spatial response of the detector.

The InGrid technology has now reached a mature level. Several InGrids of various geometries were made on bare silicon wafers and their operational characteristics studied. Simulations involving electric field maps and gas drift and amplification parameters have been used to study how the geometry affects the gain and the energy resolution; results from these will be presented.

Contributed Talk 15.3 Wed 10:00 Lecture Hall
High resolution UV, soft X-ray and neutron imaging with Timepix CMOS readout — John Vallerga[1], Jason McPhate[1], •Anton Tremsin[1], Oswald Siegmund[1], and Bettina Mikulec[2] — [1]Space Sciences Laboratory, University of California at Berkeley, Berkeley, CA 94720 USA — [2]University of Geneva, 24, quai Ernest-Ansermet, 1211 Geneva 4, Switzerland

The latest version of Medipx active pixel readout (Timepix) allows for the measurement of time over threshold. In that mode the amplitude of the signal can be measured in each pixel (currently 55 μm square, 256x256 pixels per chip). For the events spread over a few pixels an accurate event position can be determined by calculating the centroid of the event. Combination of electron multiplying micrichannel plates installed in front of a Timepix readout takes the full advantage of the event cetrnoiding capability. The circular symmetry and a relatively well controlled spread of the electron cloud emitted by an MCP enable imaging with a subpixel resolution. Our first experimental results prove that the spatial resolution can be as high as <10 ∼m FWHM obtained at a relatively low MCP gain of $\sim 5 \times 10^4$, extending the lifetime of an MCP detector compared to other high resolution systems. The penalty for the high spatial resolution is the counting rate capabilities of the device: the charge footprints of individual events should not overlap in a single readout frame. The latter is achieved by a proper selection of the frame acquisition time. The full parallel readout mode (up to a 1000 frames/sec) and a firmware implementation of event cetrnoiding should still allow imaging at ∼100 KHz counting rates.

Contributed Talk 15.4 Wed 10:20 Lecture Hall
Single Quantum Counting Pixel Detectors for Imaging with Heavy Charged Particles and Electrons — •Jan Jakubek, Tomas Holy, Stanislav Pospisil, Josef Uher, and Zdenek Vykydal — Institute of Experimental and Applied Physics, Czech Technical University in Prague

The state-of-the-art single quantum counting pixel detectors offer a large potential for different imaging applications. Pixel detectors of the Medipix family can provide information about position and energy of the detected radiation. The use of the unlimited dynamic range and noiseless integration (counting) of the Medipix device in the field of photon imaging (X-ray, gamma, visible light) and for the neutron radiography was already demonstrated. The energy sensitivity together with the good spatial resolution of the Medipix type pixel detectors can be used also for radiography with charged particles. Heavy charged particles of known initial energy lose their energy partially by going through a specimen material. If the resulting energies of particles passing the specimen are measured, then specimen structure can be revealed. Several sample images taken with Medipix2 and Timepix detectors will be presented. Other advantages of the pixel detector are the noiseless detection and the possibility to work in triggered regime. The application of the pixel detector for triggered electron detection in the field of neutron activation analysis will be shown. This work has been carried out within the Medipix2 collaboration.

Session 16: Active Pixel Detectors

Wednesday, 11:00–12:40 Lecture Hall

Invited Talk 16.1 Wed 11:00 Lecture Hall
Silicon X-ray Detectors and Data Acquisition for the LCLS Science Instruments — •Niels van Bakel — Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, CA 94025, USA

In 2009 the Linac Coherent Light Source (LCLS), a fourth generation light source producing extremely short (100 fs) and ultra bright x-ray pulses, will become operational at the Stanford Linear Accelerator Center. Several experiments are currently under development and will begin acquiring data in 2009. The experiments require large area pixel detectors with small (<100 micrometer) pixel size, 120 Hz readout, high dynamic range (up to 10^4 photons per pixel), low noise ($\ll$ 1 photon) and high quantum efficiency (>90 % at 8 keV). I will present the status of two detector programs initiated by the LCLS project to meet these scientific needs. The first program is a hybrid pixel array detector that is being developed at Cornell University. This detector consists of a Si-diode sensor, bump bonded to a readout ASIC with in-pixel digitization. The second program, currently underway at Brookhaven National Laboratory, will develop two detector systems based on an X-Ray Active Matrix Pixel Sensor concept. Additionally, I will briefly discuss the various data acquisition and data storage challenges and the current architectures that are needed for the LCLS science instruments. The LCLS experiments will generate multi-mega pixel two dimensional images with up to 14 bit resolution. This requires a data acquisition system with at least 5 Gbit/s data streaming with the capability to scale for future experiments with larger detectors.

Contributed Talk 16.2 Wed 11:40 Lecture Hall
XPAD3: a fast hybrid pixel readout chip for X-Ray synchrotron facilities — •Patrick Pangaud, Basolo Stéphanie, Chantepie Benoît, Jean-Claude Clemens, Pierre Delpierre, Bernard Dinkespiler, and Christian Morel — CPPM, Marseille, France

Radiation experiments using X-ray synchrotron facilities, such as diffraction, small angle X-ray scattering or macromolecular crystallography require a large surface, a high rate and integrated count, and a fast readout acquisition with an accurate energy threshold level.

XPAD3 is the third version of the XPAD circuit (X-ray Pixel chip with Adaptable Dynamics), a single photon counting chip based on hybrid pixel technology, with low noise, high dynamics and high speed readout. Its features have been improved to provide a counting rate capability from 0.01 up to 2 10^6 photons/pixel/s, high dynamic range over 40keV, very low noise below 100e, energy selection under 6keV and fast image readout below 2ms/frame.

XPAD3 is designed in submicronic (0.25μm) IBM technology. It contains 9600 pixels (130μm x 130μm) distributed into 80 columns of 120 elements each. The analog part in each pixel gathers a low noise charge sensitive preamplifier, a voltage to current converter, and current comparators. The digital part of each XPAD3 pixel is used to register hits in a 12bit counter, and to configure, calibrate, test and read it out. An innovative architecture has been designed in order to prevent the digital circuits from disturbing the very sensitive analog parts placed in their neighborhood. This makes it possible to read out the chip during acquisition while preserving the precise setting of the thresholds over the pixel arrays.

The XPAD3 circuit can be bump bounded with Si, CdTe or AsGa sensors to match detection efficiency with increasing photon energy. XPAD3 detectors are tiled together to form XPIX modules of 8 x 12 cm. First prototypes have been produced and tested and first results will be presented.

Contributed Talk 16.3 Wed 12:00 Lecture Hall
Measurement of the spatial resolution limitation of single photon counting detectors — •Anna Bergamaschi, Christian Broennimann, Roberto Dinapoli, Eric Eikenberry, Fabia Gozzo, Beat Henrich, Miroslav Kobas, Philipp Kraft, Bruce Patterson, and Bernd Schmitt — Paul Scherrer Institut, CH-5232 Villigen, Switzerland

The MYTHEN detector is a one-dimensional microstrip detector with single photon counting readout optimized for time resolved powder diffraction experiments at the Swiss

Light Source (SLS). The system has been successfully tested for many different synchrotron radiation applications including phase contrast and tomographic imaging, small angle scattering, diffraction and time resolved pump and probe experiments for X-ray energies down to 4 KeV and counting rate up to 3 MHz per channel.

The frontend electronics is designed to be coupled to 50 μm pitch microstrip sensors but interest in enhancing the spatial resolution is arising for imaging and powder diffraction experiments.

A structure with strip pitches in the range 10-50 μm has been tested and the gain and noise on the readout electronics have been measured for the different pitches. The ENC is higher at smaller strip pitches, due to the increased interstrip capacitance.

The amount of photons which produce a charge cloud shared between neighboring channels has been evaluated and for all strip pitches it is in agreement with a region of about 15 μm between the strips where this phenomenon should take place. Moreover, the effect of the charge sharing on the spatial resolution has been quantified by calculating the MTF of the system for the different strip pitches.

Contributed Talk 16.4 Wed 12:20 Lecture Hall
Front-End Counting Mode Electronics — •Danielle Moraes[1], Jan Kaplon[1], and Einar Nygard[2] — [1]CERN, CH-1211 Geneva 23, Switzerland — [2]Interon AS, Ringveien 14, N-1386 Asker, Norway.

The ASIC is a counting mode front-end electronic optimized for the readout of CdZnTe and silicon sensors, for possible use in applications where the flux of ionizing radiation is high. The chip is implemented in 0.25 um CMOS technology. The circuit comprises 128 channels equipped with a transimpedance amplifier followed by a gain shaper stage with 25 ns peaking time and two discriminators. The double discriminator and counter circuit enables the use of two independent threshold voltages, enabling for an offline energy window to be set. Each discriminator includes a 5-bit trim DAC and is followed by an 18-bit static ripple counter. The channel architecture is optimized for the detector characteristics in order to achieve the best energy resolution at counting rates of up to 5M counts/second. The amplifier shows a linear sensitivity of 24 mV/fC with 25 ns peaking time and an equivalent noise charge of about 650 electrons, for a detector capacitance of 10 pF. Complete evaluation of the circuit is presented using electronic pulses, silicon sensors and CdZnTe pixel detectors.

Session 17: Detector Materials II

Wednesday, 14:00–15:00 Lecture Hall

Contributed Talk 17.1 Wed 14:00 Lecture Hall
Crystal growth of detector grade (Cd,Zn)Te crystals — •Michael Fiederle, Alex Fauler, Andreas Zwerger, and Ralf Sorgenfrei — Freiburger Materialforschungszentrum, Freiburg, Germany

CdZnTe is still promising materials for the production of radiation detectors. CdZnTe Crystals with the required material properties are actually grown from the melt using High Pressure or conventional Bridgman method and from solution growth by Travelling Heater Method THM. For the application in medicine or homeland security the improvement of the homogeneity of the electronic properties and the reduction of defects e.g. tellurium inclusions are the subjects of the latest publications.

In this work we are presenting results of the growth of detector grade Cd.9Zn.1Te crystals and material characterization. The crystals were grown by the vertical Bridgman method and doped by indium to obtain high resistivity and high mobility lifetime of the charge carriers. These crystals showed high resistivity from 2-10 GOhmcm . The material properties were obtained by spatial resolved Photoluminescence measurements, Infra-red microscopy, Contactless Resistivity Mappings COREMA and deep level spectroscopy by PICTS. The growth of the detector-grade crystals is discussed regarding the homogeneity of the detector properties, defect concentration and the crystallinty of the material. Radiation detectors were fabricated from the grown material. The detector performance was tested with different radiation sources and x-ray tubes. The product of mobility-lifetime of charge carriers and the energy resolution for different radiation energies were measured for detector thickness from 1 mm up to 5 mm.

Contributed Talk 17.2 Wed 14:20 Lecture Hall
Diffusion of charged native defects in semiconductors: The case of CdTe — •Roman Grill, Eduard Belas, Jan Franc, Pavel Höschl, and Pavel Moravec — Charles University, Faculty of Mathematics and Physics, Institute of Physics, Ke Karlovu 5, Prague 2, CZ-121 16, Czech Republic

Diffusion of atoms in semiconductors is a fundamental process affecting quality and practical application of the material. A sophisticated thermal treatment utilizing diffusion can enable the improvement and tuning of the properties of the system.

The application of CdTe for gamma- and X-ray detectors asks to prepare semi-insulating material with a very low deep level doping [1]. Successful attainment of such quality asks to understand in detail the processes, which occur in the material both at the solidification and also at the cooling of the as grown crystal. Defect reactions and diffusion significantly influence the defect structure and material homogeneity at room temperature [2].

In this paper we study theoretically the diffusion of charged point defects in semiconductors with aim to clarify anomalous effects observed at the measurements of chemical diffusion coefficient and being unexplained yet. We derive general model describing charge defect diffusion and show on respective examples peculiarities incurred by the charge of diffusing species. The generalized diffusion model involves complete charge defect statistics including defect reactions and associate formation. Internal electric field induced by the charged defect gradient is comprised as well.

We show, how extrinsic doping influences the rate of chemical diffusion, which can be both enhanced and restrained. We also extend the model of preparation of semi-insulating Te-saturated CdTe [2] and discuss the proper thermal treatment to heal electrical inhomogeneities in real material in which unavoidable inhomogeneous distribution of impurities exists.

[1] C. Szeles, Phys. Stat. Sol. (b) 241, (2004) 783.

[2] R. Grill, J. Franc, P. Höschl, I. Turkevych, E. Belas, and P. Moravec, IEEE Trans. Nucl. Sci. 52, (2005) 1925.

Contributed Talk 17.3 Wed 14:40 Lecture Hall
Radiation Hard Diamond Pixel Detectors — •Harris Kagan[1], Markus Mathes[2], Markus Cristinziani[2], Lars Reuen[2], Shane Smith[1], William Trischuk[3], Jaap Velthuis[2], and Norbert Wermes[2] — [1]Ohio State University, Columbus OH — [2]Bonn University, Bonn Germany — [3]University of Toronto, Toronto, Canada

Diamond is a promising sensor material for detectors that can operate in high radiation environments. Its radiation hardness and fast signal collection properties make it an ideal choice for the inner layers of a SLHC detector. Sensor grade polycrystalline material of sufficient size to make a full ATLAS pixel module was produced, metalised, bump-bonded and tested. We present here an ATLAS hybrid pixel module that uses CVD diamond as the sensor material. It has an active area of 6 x 2 cm^2, pixelated with 46080 sensitive elements. The module is readout with sixteen ATLAS pixel front-end electronic chips that were successfully bump-bonded by IZM. The module has been characterised with lab measurements and successfully operated in test beams. The results of these tests will be presented and compared with silicon pixel modules using the same readout electronics. We will also present the first results from a single-crystal CVD diamond pixel detector using the same ATLAS readout electronics. Single-crystal CVD diamond is made by the same process as polycrystalline material but has no grain boundaries. As a result it is full charge collecting. The single chip single-crystal CVD diamond pixel device has been characterised with lab measurements and successfully operated in test beams. The results of these tests will also be presented.

Session 18: Social Event

Wednesday, 15:00–23:00

Nuremberg and Conference Dinner

Session 19: Simulations and Data Analysis

Thursday, 9:00–10:40 Lecture Hall

Invited Talk 19.1 Thu 9:00 Lecture Hall
Monte Carlo Simulations in Medical Imaging — •Jürgen Giersch[1] and Jürgen Durst[2] — [1]Ludwig-Maximilians-Universität München, Department für Physik, Schellingstr. 4, 80799 München, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Physikalisches Institut Abt. 4, Erwin-Rommel-Str. 1, 91058 Erlangen, Germany

Monte Carlo simulations have become crucial tools in many fields of medical imaging. First of all they help understanding the influence of physical effects such as absorption, scattering and fluorescence of photons in different materials as silicon, GaAs, Cd(Zn)Te, etc. to image quality parameters like the detective quantum efficiency (DQE). In this context Monte Carlo simulations are often used as the first step in a charge transport simulation in semiconductor X-ray detectors. But besides considering the physics, Monte Carlo simulations allow the study of new concepts like photon counting, energy weighting or material reconstruction.

Furthermore there are important applications of Monte Carlo Simulations in the fields of nuclear medicine like PET, SPECT and Compton Camera. For example it is possible to define virtual setups to find new geometries or image reconstruction algorithms.

Finally, a full implementation of the propagation physics of electrons and photons allows the prediction of the behaviour of (novel) X-ray generation concepts.

This versatility of Monte Carlo simulations will be shown with ROSI as an example of a modern, well proven, object-oriented, parallel computing Monte Carlo simulation.

Contributed Talk 19.2 Thu 9:40 Lecture Hall
Exploring the performance of μSR position-sensitive detectors through numerical simulations — •Toni Shiroka, Robert Scheuermann, Elvezio Morenzoni, and Alexey Stoykov — Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, CH-5232 Villigen PSI Switzerland

The recently proposed improvements of the μSR (Muon Spin Rotation) technique include among others the use of position-sensitive detectors for the revelation of decay positrons. Unlike their high-energy particle counterparts, these detectors present specific peculiarities arising from the need of a relatively fast timing and from significant multiple scattering effects.

Through an extensive use of advanced numerical simulation toolkits, such as Geant4, we explore in detail the expected performance and possible ways for its optimization. Intrinsic detector limits, finite pixel dimension effects, as well as the many parameters influencing the detector performance (distance, extension, angles, etc.) were thoroughly analyzed and quantified, thus providing a valuable guide in prototype building and testing.

References:

Agostinelli S, *et al.* 2003 *Nucl. Instr. and Meth. A* **506** 250.
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Penţia M, Mureşan R, Litvinenko AG 1995 *Nucl. Instr. and Meth. A* **369** 101

Contributed Talk 19.3 Thu 10:00 Lecture Hall
Correction of the charge sharing in photon-counting pixel detectors data — •Cyril Ponchut — European Synchrotron Radiation Facility (ESRF), 6 rue Jules Horowitz, F-38000 Grenoble, France

Although photon-counting pixel detector arrays provide energy discrimination capabilities, their energy resolution is limited by the diffusion of the photoelectric charge between neighboring pixels. This effect often referred to as charge sharing induces a low-energy tail in the measured spectra and is more particularly significant for small pixel sizes. In order to correct this effect an iterative deconvolution method has been developed and applied to data collected with the Medipix2 photon-counting chip. The obtained spectra are corrected from charge sharing and moreover show a better energy resolution than the raw spectra. For instance the K-alpha (22.1 keV) and K-beta (25 keV) emission lines of a Cd-109 source are reconstructed as two well separated peaks. The principle of the method will be exposed. Various results obtained with synchrotron beams, X-ray tubes and radioactive sources will be shown.

Contributed Talk 19.4 Thu 10:20 Lecture Hall
Measurement and detailed simulation of the Modulation Transfer Function (MTF) of the Medipix2-Detector — •Peter Bartl, Alexander Korn, Thilo Michel, and Gisela Anton — Physikalisches Institut IV, Universität Erlangen, Germany

The Modulation Transfer Function (MTF) is an important quality parameter for the description of the spatial resolution of imaging systems. For X-ray detectors, as the Medipix2 is, it depends for instance on the pixel size and the incident spectrum. The detection of single photons in the Medipix2 is influenced by a lower energy threshold, which suppresses the counting of any deposited energy in the sensor below the given threshold. The dependency of the MTF on this threshold and on the incident spectrum has been evaluated in simulations and measurements.

The effect of charge sharing causes energy depositions in fractions of the total energy of a photon. Thus, charge sharing lowers the spatial resolution of pixelated detectors by generating multiple counts per incident photon. Accordingly, the suppression of those counts, by applying a higher threshold, leads to an enhancement of the MTF. Furthermore the spatial resolution of a detector like the Medipix2 is decreased by fluorescence photons, which may not only be produced in the sensor material but also in the material behind or surrounding the detector.

Those candidate materials for the Medipix2 are most importantly Silver and Tin. Some fluorescence photons produced in these materials are absorbed all over the sensor layer due to their relatively large range. The spatial resolution is thereby reduced down to low spatial frequencies. This behaviour has been observed in measurements of the MTF and has been reproduced in detail by simulation calculations.This work was carried out within the Medipix-collaboration.

Session 20: Medical Imaging

Thursday, 11:00–12:40 Lecture Hall

Invited Talk 20.1 Thu 11:00 Lecture Hall
PET imaging for treatment verification of ion therapy — •Katia Parodi — Heidelberg Ion Therapy Center, Im Neuenheimer Feld 450, 69120 Heidelberg

The favourable physical properties of ion beams in comparison to conventional photon and electron external radiation treatment modalities offer improved conformality for the delivery of the prescription dose to the tumour and better sparing of surrounding critical structures and healthy tissues. However, full clinical exploitation of this advantage is still hampered by uncertainties in the localisation of the distal dose fall-off within the patient. Thus, tools for in-vivo confirmation of the actual beam delivery and, in particular, of the ion range in the patient would be highly beneficial.

During treatment, positron emitters like 15O (half-life T1/2=121.8 s) and 11C (T1/2=1223 s) are produced in nuclear interactions between the impinging therapeutic radiation and the irradiated tissue. Detection of this small (around 0.3-1 kBq/Gy/ml) irradiation-induced transient radioactivity via Positron Emission Tomography (PET) may offer a valuable tool for verification of the delivered treatment. In particular, the comparison of the measured activity with its expectation based on the intended dose application serve as an in-vivo, non-invasive range validation method of the whole treatment planning and delivery chain, potentially calling for plan adaptation in case of detected discrepancies. For technical implementation, dedicated PET imaging during irradiation (in-beam) requires the development of customized, limited angle detectors with data acquisition synchronized with the beam delivery. Alternatively, commercial PET or PET/CT devices installed in close proximity to the treatment site may enable detection of the residual activation from long-lived emitters shortly after treatment (offline).

After a brief introduction to the principles of PET monitoring of ion therapy, this talk will review two examples of clinical implementation and results using a customized inbeam PET scanner for verification of carbon ion therapy at GSI Darmstadt, Germany [1], as well as a commercial offline PET/CT tomograph for post-radiation imaging of proton treatments at Massachusetts General Hospital, Boston, USA [2]. Challenges as well as pros and cons of the two approaches will be discussed and, in particular, a quantitative comparison of the measurable PET signal depending on the imaging strategy and ion beam delivery system will be presented.

[1] Enghardt W, Parodi K. et al, Dose quantification from in-beam positron emission tomography Radiother Oncol.

(2004) 73 S96-8. [2] Parodi K., Paganetti et al, Patient study on in-vivo verification of beam delivery and range using PET/CT imaging after proton therapy Int. J. Radiat. Oncol. Biol. Phys. (2007), in press

Contributed Talk 20.2 Thu 11:40 Lecture Hall
Challenges for pixelated scintillators in medical X-ray imaging — •Matthias Simon[1], Klaus-Juergen Engel[1], Bernd Menser[1], Xavier Badel[2], and Jan Linnros[2] — [1]Philips Research Laboratories, Weisshausstr. 2, 52080 Aachen, Germany — [2]Department of Microelectronics and Applied Physics, Royal Institute of Technology, Electrum 229, 16440 Kista/Stockholm, Sweden

Higher spatial resolution in future X-ray detectors is of major interest for applications with the need for fine detail visibility. Smaller pixel sizes of the photo diode do not solve this issue, because the spatial resolution is limited by optical photon diffusion in the scintillator layer of current indirect conversion type detectors, especially for thick layers with high X-ray stopping power. A method to prevent optical photons from reaching neighbouring pixels is the embedding of opaque walls within the scintillator. The realization of a pixelated scintillator for large area X-ray detectors faces several challenges to obtain a good imaging performance, especially a high Detective Quantum Efficiency (DQE).

To maintain a high X-ray absorption, a high volume fill-factor is required, which implies both a high packing density of the scintillator material and a challenging aspect ratio in case of wall or trench-like structures surrounding each pixel. Losses of secondary light quanta, e.g. at the pixel walls, have to be kept to a minimum to maintain an acceptable gain. Moreover, the signal per primary X-ray quanta should have a low variation with the depth of interaction to avoid a high secondary quantum noise (Swank-noise). Light scatter inside the scintillator causes both enhanced light loss and Swank-noise.

For this work, a pixelated scintillator has been built from electrochemically etched silicon pore arrays, which are filled with thallium-doped caesium iodide (CsI:Tl). With a pixel pitch of 50 μm, wall thicknesses of 6.5 μm and pore depths of nearly 400 μm are achieved. The X-ray imaging performance is measured by combination of the pore array with an optical imaging sensor binned to the same pixel pitch.

The Modulation Transfer Function is 40 % at 4 lp/mm and 10-20 % at 8 lp/mm. The ability of the pores to transport light quanta from their origin to the photodiode is expressed in a light guiding efficiency, which is determined as 6.5 % in the better cases. The maximal DQE(0) is 0.28, while the X-ray absorption with the given thickness and fill-factor is 0.57. The difference is explained by high Swank-noise due to optical scatter inside the CsI-filled pores, in agreement to Monte-Carlo simulations of the photon transport inside the pore array structure.

Contributed Talk 20.3 Thu 12:00 Lecture Hall
Preliminary results of an in-beam PET prototype for proton therapy — Francesca Attanasi[1], Nicola Belcari[1], Manuela Camarda[1], Giuseppe Antonio Pablo Cirrone[2], Giacomo Cuttone[2], Alberto Del Guerra[1], Francesco Di Rosa[2], Nico Lanconelli[3], •Valeria Rosso[1], Giorgio Russo[2], and Sara Vecchio[1] — [1]Department of Physics, University of Pisa and INFN Sezione di Pisa, Pisa, Italy — [2]INFN Laboratori Nazionali del Sud, Catania, Italy — [3]Department of Physics, University of Bologna and INFN Sezione di Bologna, Bologna, Italy

Proton therapy can overcome the limitations of conventional radiotherapy due to the more selective energy deposition in depth and to the increased biological effectiveness. Verification of the delivered dose is desirable, but the complete stopping of the protons in patient prevents the application of electronic portal imaging methods that are used in conventional radiotherapy.During proton therapy beta+ emitters like ^{11}C, ^{15}O, ^{10}C are generated in irradiated tissues by nuclear reactions. The measurement of the spatial distribution of this activity, immediately after patient irradiation, can lead to information on the effective delivered dose.

First results of a feasibility study of an in-beam-PET for proton therapy [1] is reported. A prototype of a PET system has been built and has operated at the CATANA 62MeV proton beam-line [2]. The prototype is based on two planar heads with an active area of about 5x5 cm^2. Each head is made up of a position sensitive photomultiplier coupled to a square matrix of same size of LYSO scintillating crystals (2x2x18 mm^3 pixel dimensions). Thanks to a resistive chain after the multi-anodes photomultiplier [3] only 4 signals from each head are acquired through a dedicated electronic board that performs signal amplification and digitization. A 3D reconstruction of the activity distribution is calculated using an expectation maximization algorithm [4]. To characterize the PET prototype detection efficiency and spatial resolution were measured using a point-like radioactive source.

The validation of the prototype was performed using 62 MeV protons at the CATANA beam line and PolyMethylMethAcrylate phantoms. Using the full energy proton beam and different range shifter a good correlation between the activity distal edge and the beam range shifter thickness was found along the axial direction.

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[4] A. Motta et al., Comput. Med. Imag. Grap. 29 (2005) 587-596

Contributed Talk 20.4 Thu 12:20 Lecture Hall
Use of Gafchromic^{TM} films in heavy ion therapy — •Maria Martisikova, Benjamin Ackermann, Swantje Klemm, and Oliver Jaekel — German Cancer Research Center, Medical Physics in Radiation Oncology E040, Im Neuenheimer Feld 280, D-69120 Heidelberg

The first hospital based European heavy ion therapy facility will come into operation in 2007 in Heidelberg. It will offer ideal possibilities to deliver a highly accurate and effective radiotherapy for a variety of tumor diseases.

Currently dosimetry for ion beams is performed using pinpoint ionization chambers. This method is straight forward, but has a very limited spatial resolution (typically 1 cm). However, beam scanning through the tumor volume requires nearly continuous dose determination in space. Therefore we investigated the suitability of Gafchromic EBT films for verification of a dose planned to be applied to a patient.

This new type of radiochromic film released in 2004 for use in external radiotherapy (photon beams) is self-developing and not sensitive to visible light. For the performed studies films were exposed to photons and C^{12} ions. For photon irradiations we used the 6 MV medical linear accelerator (SIEMENS, type Primus). For carbon ions a 250MeV/u beam was provided by GSI, Darmstadt, Germany, equipped with the scanning technology. The films were digitized with a commercial flatbed scanner and the data obtained in this way were used to calculate the net optical density (netOD) distributions. For the analysis programs in C were developed employing the LibTIFF library. The influence of various film scanning parameters and ambient effects was analyzed systematically and used to optimize the handling and scanning protocol. Most of the effects, which cannot be optimized, affect the measured netOD much less than 1%. Among the effects which can change the measurement more than 1% are the light scattering correction and time development correction, where the dependences on various parameters was studied.

Of special interest for dosimetry in heavy ion beams is the dependency of the netOD on the applied dose. Therefore we compared the darkening of the film as a function of the applied dose for photons and carbon ions. We found that for clinical doses and beyond (0.1-30 Gy) the film darkening does not saturate yet and thus provides sufficient resolution in dose.

Based on the investigated properties we found that Gafchromic EBT films can be used in scanning carbon ion beams. However, there are some effects which make the use in routine dose verifications time consuming. The effect of some of the film scanning parameters has to be understood and possible countermeasures have to be found in order to define the optimal film scanning protocol.

Session 21: Summary and Closing

Thursday, 12:40–13:00 Lecture Hall

Summary Talk by Valeria Rosso, Announcements, Closing