IFDEPS

# IFDEPS 2018
# Booklet

## International Forum on Detectors for Photon Science


Udpated on: 8 March 2018

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# Programme overview

**Sunday, 11 March**

- 13:00 — *Bus from Geneva to the IFDEPS venue*
- 16:00 — *Session 1* — **IFDEPS Opening**
- 17:45 — *Guided tour and dinner at Annecy*

**Monday, 12 March**

- 8:30 — *Session 2* — **Update on development activities at photon sources**
- 10:45 — *Session 3* — **Semiconductor sensors for X-ray spectroscopy**
- 12:30 — *Lunch*
- 14:00 — *Session 4* — **Readout architectures for high count rate energy dispersive detection systems**
- 16:00 — *Session 5* — **Advanced multielement and position sensitive energy dispersive detectors**
- 19:30 — *Dinner*

**Tuesday, 13 March**

- 8:30 — *Session 6* — **Detection technologies for high resolution spectroscopy**
- 11:00 — *Session 7* — **First operation experiences with new detectors**
- 12:30 — *Lunch*
- 14:00 — *Session 8* — **Overview of DAQ general strategies at large facilities**
- 16:00 — *Session 9* — **Technologies for high-throughput data acquisition**
- 19:30 — *Dinner*

**Wednesday, 14 March**

- 8:30 — **Session 10** — **Future of photon science detectors**
- 11:00 — *Bus to Geneva*

Legend:

- *Energy dispersive detection*
- *DAQ*
- *Operation experience*
- *Short facility reports*

## Programme contributors and conveners

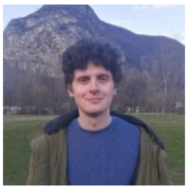
- Peter Denes (LBNL, USA)
- Heinz Graafsma (DESY, Germany)
- Antonino Miceli (APS, ANL, USA)
- Matteo Porro (E-XFEL, Germany)
- Peter Siddons (NSLS-II, BNL, USA)
- Bernd Schmitt (PSI, Switzerland)
- Nicola Tartoni (DLS, UK)

- Gabriella Carini (BNL, USA)
- Takaki Hatsui (SPring-8, Japan)
- Pablo Fajardo (ESRF, France)

## Represented photon sources

- ALBA, Spain (Oscar Matilla)
- APS, US (Antonino Miceli)
- BNL, US (Peter Siddons)
- CLS, Canada (Tom Regier)
- DESY, Germany (Heinz Graafsma)
- DLS, UK (Nicola Tartoni)
- ELETTRA, Italy (Ralf Menk)
- ESRF, France (Pablo Fajardo)
- European-XFEL, Germany (Markus Kuster)
- LBL, US (Peter Denes)
- LNLS, Brazil (Jean-Marie Polli)
- MAX-IV, Sweden (Stefan Carlson)
- NSRRC, Taiwan (Yu-Shan Huang)
- PAL, Korea (HyoJung Hyun)
- Photon Factory, Japan (Shunji Kishimoto)
- PSI, Switzerland (Bernd Schmitt)
- SACLA, Japan (Takaki Hatsui)
- SLAC, US (Jana Thayer)
- SOLEIL, France (Fabienne Orsini)
- SPring-8, Japan (Yasuhiko Imai)
- SSRF, China (Fei Song)

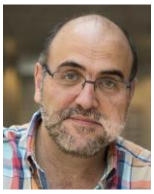
# Local organisers



Paolo Busca
Detector Engineer

Cedric Cohen
Detector Engineer

Anne-Françoise Maydew
Events Coordinator



Pablo Fajardo
Group Leader

Thierry Martin
Detector Unit Head

# Transport

The workshop organisation provides transport by coach from and to Geneva at the beginning and the end of the workshop.

Sunday 11 March: Geneva to Annecy

The coach will depart at 13:00 from Geneva central railway station, "Gare Cornavin", place de Montbrillant. The coach company is FRANCONY. A workshop mini-bus (9 seats) will be waiting for latecomers at the same place, until 14:30.


**Free transport ticket**

When you arrive at Geneva International Airport by plane, you can get an 80 minute ticket for Geneva Public Transport for free. The ticket machine for free ticket is located at the luggage retrieval hall, just before going out on the left, and prints the free ticket without requirements or limitations upon the pressing of the button. Free ticket entitles you to take an airport train (train from the airport to the city center), bus or tram. Ticket is transferable and limited only to 80 minutes.

How to reach Geneva central railway station "Gare Cornavin" from the airport? Go to the airport railway station, situated one level below the airport shopping zone. During daytime, every hour several trains go to Geneva's Central Station (Cornavin) directly. The journey takes 6 minutes.

The arrival time at the workshop venue is estimated around 14h30.

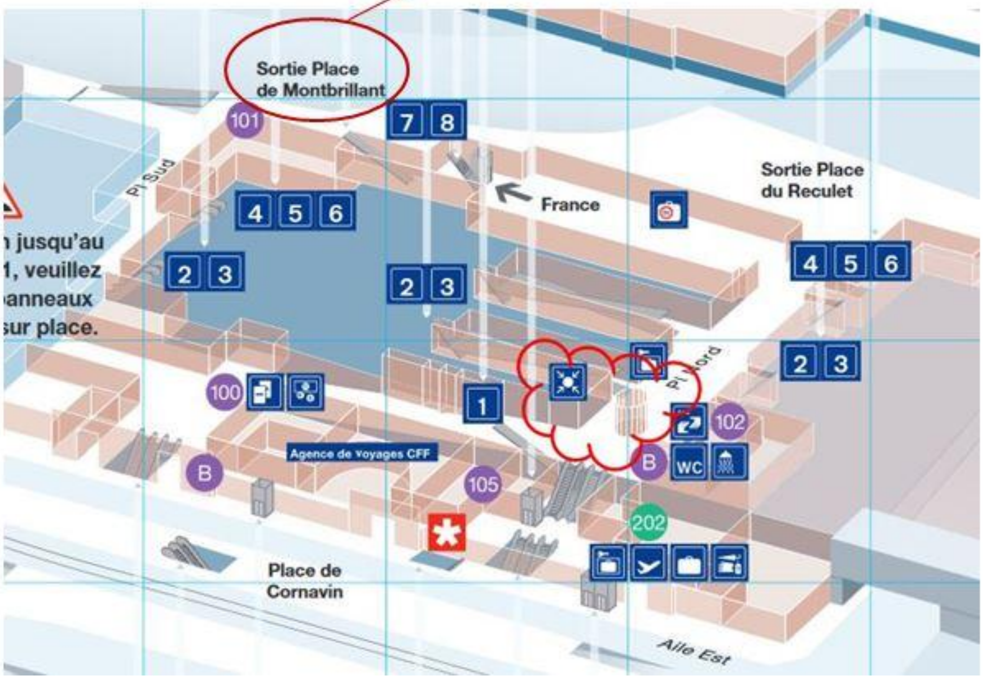
Once at "Gare Cornavin", take the exit "Place de Montbrillant" where the workshop bus, from the transport company "Francony", will be waiting for you.

GENEVE CENTRAL TRAIN STATION
GARE CORNAVIN EXTERNAL VIEW

Exit Place de Montbrillant
Workshop bus
Transports Francony


GENEVE CENTRAL TRAIN STATION
GARE CORNAVIN INTERNAL VIEW

Exit Place de Montbrillant
Workshop bus
Transports Francony




Wednesday 14 March: Annecy to Geneva.

The coach will depart around 11:00 from the workshop hotel directly to Geneva Airport.

# Venue

The Forum will take place at Les Trésoms Hotel.

This charming 1930’s building was renovated in 2015. It is located on the heights of Annecy Lake, in the heart of the Semnoz forest and just a 20-minute walk from the old town.

Useful info: free WiFi, breakfast time 7:00-10:30

## Once upon a time…

In 1930, the boarding house "Les sapins" in La Puya was converted and expanded to become, one year later, a hotel with growing prestige named "Hôtel des Trésoms et de la forêt". The hotel soon welcomed many stars and personalities. It was one of the three 4-stars hostels of Lake Annecy.
It was there that the famous chef, Marc Veyrat, took on his first role as chef de cuisine.

## The word "Trésoms"

The number "trēs" ("three" in Latin) is a reference to the Trinity. The Visitandines sold off their land and the construction of the hotel took the name reported in the land registry. The Latin word "trésums" (three men) became "Les Trésoms" in the local Savoyard dialect.

## The chef: Eric Prowalski

He has been the head of the hotel's kitchens since 2011. Trained alongside Alain Solivérès and Philippe Etchebest, his background has given him solid technical expertise to express the tastes and flavours of contemporary cuisine. To honour the original ingredients, his menu celebrates regional and seasonal produce. He knows how to enliven flavours, while remaining unpretentious. His recipes are tasty and each dish is a hymn to the produce.

# An evening in Annecy

**Visit to Annecy**

After the opening session of the workshop, the coach will take the participants to Annecy for a 2-hour pedestrian guided visit of the old town, in English.

**Dinner in Annecy**

After the visit, dinner is organised in a typical restaurant from the Haute-Savoie region, Le Sarto.

After dinner, the coach will take the participants back to the hotel.

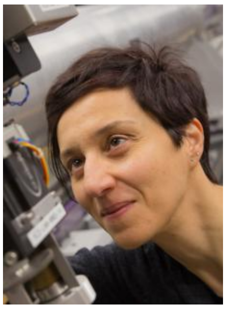
# Participant profiles

## Douglas Bennett


- *e-mail:* Douglas.Bennett@nist.gov
- *Position:* Physicist
- *Affiliation:* National Institute of Standards and Technology
- *URL:* http://www.nist.gov/people/douglas-alan-bennett


- *Professional profile:*

  Dr. Bennett is a member of the Quantum Sensors Group, part of NIST's Physical Measurement Laboratory. The Quantum sensors group advances the detection of photons and particles in a variety of application areas using superconducting sensors and readout electronics. Dr. Bennett focuses on designing and testing low-noise detectors, low-noise readout, and low-noise amplifiers for precision measurement applications. He has over a decade of experience designing transition-edge sensor (TES) micro-calorimeters and integrating them into deployed instruments. He is an expert on the superconducting physics underlying TES operation. Recently Dr. Bennett has been leading efforts to develop frequency domain multiplexers with gigahertz of bandwidth to enable larger arrays of TES microcalorimeters.



## Gabriella Carini


- *e-mail:* carini@bnl.gov
- *Position:* Deputy Division Head of Instrumentation
- *Affiliation:* Brookhaven National Laboratory
- *URL:*


- *Professional profile:*

  Gabriella Carini is a senior scientist with experience in detectors for x- and gamma rays. She worked at the National Synchrotron Light Source and led the Linac Coherent Light Source Detector Department before joining the Instrumentation Division at Brookhaven National Laboratory.

## Stefan Carlson

- *e-mail:* stefan.carlson@maxiv.lu.se
- *Position:* Researcher
- *Affiliation:* MAX IV Laboratory
- *URL:* http://www.maxiv.lu.se

- *Professional profile:*

  I'm the leader of the Sample Environment and Detector Support (SEDS) team at MAX IV. We give support to all beamlines at MAX IV with cryostats, furnaces, and other sample environments, as well as detector installations, and development of experiment stations. The team consists of me and a research engineer (Dörthe Haase), two electronics engineers (Mikael Johansson and Bertil Svensson), and a technician (Mathieu Leme).

## Andrea Castoldi

- *e-mail:* Andrea.Castoldi@polimi.it
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- *Affiliation:* Politecnico di Milano and INFN, Italy
- *URL:* http://www.deib.polimi.it/ita/personale/dettagli/132798

- *Professional profile:*

  M. Sc. and Ph.D. degrees in Electronic Engineering from Politecnico di Milano, Italy. In 1992-93 visiting scientist and staff engineer at Brookhaven National Laboratory, Instrumentation Division (USA). In 1993 Assistant Professor at Universita' degli Studi, Milano. Since 2005 Full Professor of Electronics at Politecnico di Milano. His research interests are in the fields of radiation detectors for scientific applications, low-noise readout electronics and signal processing techniques, simulation and characterization of semiconductor devices. He is co-inventor of a novel semiconductor detector for spectroscopic imaging of X-rays.

## Peter Denes

- *e-mail:* pdenes@lbl.gov
- *Position:* Senior Scientist
- *Affiliation:* Lawrence Berkeley National Laboratory
- *URL:*

- *Professional profile:*

  From 1985 to 2000, Peter Denes was a senior research physicist at Princeton University. At Lawrence Berkeley National Laboratory in Berkeley, California, where Denes has been since 2000, his work focuses on high-speed electron and soft X-ray imaging detectors for in-situ microscopies. His group focuses on monolithic (CCD, CMOS active pixels) direct detection silicon sensors, together with the corresponding ASIC and data acquisition development.

## Graham Dennis

- *e-mail:* graham.dennis@diamond.ac.uk
- *Position:* Senior Electronics Engineer
- *Affiliation:* Diamond Light Source
- *URL:* http://diamond.ac.uk

- *Professional profile:*

  An Electronics Engineer with 14 years of experience in Synchrotron Science. Initially at the UK STFC Daresbury Laboratory (Synchrotron Radiation Source) then the Rutherford Appleton Laboratory, before joining the Detector Group at Diamond Light Source in 2009. My main area of research is the development of Advanced Digital Pulse Processors for Spectroscopy Detectors, specializing in hardware design, algorithm development and data analysis. Heavily involved in the hardware design of Xspress2 at STFC, Xspress3mini for Quantum Detectors and recently lead the development of the latest Xspress DPP - Xspress4 - for Diamond Light Source with the latter achieving very high performance high count rate spectroscopy when coupled to Canberra Monolithic Segmented HPGe Detectors.

## Sebastian Dittmeier


- *e-mail:* dittmeier@physi.uni-heidelberg.de
- *Position:* PhD candidate
- *Affiliation:* Physikalisches Institut, Heidelberg University
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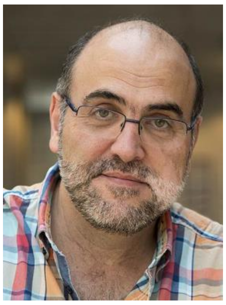
- *Professional profile:*

  Sebastian Dittmeier is currently a PhD candidate at Heidelberg University. Sebastian works on the development of the streaming data acquisition system for the Mu3e experiment. His work focuses on the study of high speed communication with optical, electrical and wireless links, for the use in Mu3e and beyond in future high energy physics experiments. Sebastian knows that any experiment relies on a proper data acquisition. Thus, he believes that technological advancements in readout architectures are as important as sensor developments for successful future experiments.

## Pablo Fajardo




- *e-mail:* fajardo@esrf.eu
- *Position:* Head of the Detector & Electronics Group
- *Affiliation:* ESRF – The European Synchrotron
- *URL:* http://www.esrf.eu


- *Professional profile:*

  Background in solid-state physics and electronics engineering and a PhD in instrumentation. More than 25 years of experience with beamline operation and synchrotron radiation instrumentation since joining the ESRF in 1991. Design and construction of various types of scientific instruments, in charge of the X-ray detector program and responsible for data acquisition and instrument control electronics at ESRF.

## Carlo Fiorini

- *e-mail:* carlo.fiorini@polimi.it
- *Position:* Full professor
- *Affiliation:* Politecnico di Milano and INFN, Milano, Italy
- *URL:* http://www.deib.polimi.it/eng/people/details/194086

- *Professional profile:*

  Carlo Fiorini is full professor at Politecnico di Milano, Dipartimento di Elettronica, Informazione e Bioingegneria. His primary research interests concern the development of radiation detectors and related applications, and the readout electronics for the detector signals. He has participated to several national projects (MIUR, INFN, CNR, ASI) and international projects funded by European Community and European Space Agency, also as coordinator. He has been committed in research activities by companies like Siemens Medical Solutions (USA), Ion Beam Applications (IBA, Belgium), Canberra (USA). He is author and co-author of more than 300 papers in international reviews and conference proceedings, and co-author of 6 patents.

## Andreas Fleischmann

- *e-mail:* Andreas.Fleischmann@kip.uni-heidelberg.de
- *Position:* Senior Scientist
- *Affiliation:* Heidelberg University
- *URL:* http://www.kip.uni-heidelberg.de

- *Professional profile:*

  Head of research group Quantum Sensors at the Kirchhoff-Institute for Physics, Heidelberg University, developing detector systems based on arrays of metallic magnetic calorimeters for precision experiments in atomic, nuclear and particle physics.

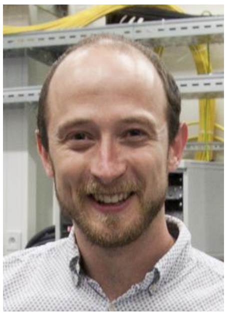
## Heinz Graafsma


- *e-mail:* heinz.graafsma@desy.de
- *Position:* Head Photon Science detector Group
- *Affiliation:* DESY
- *URL:* http://photon-science.desy.de/research/technical_groups/detectors


- *Professional profile:*

  I have a background in solid state physics and crystallography, using synchrotron radiation. After obtaining a PhD based on work at the NSLS at Brookhaven, I became PostDoc at the ESRF in 1992, where I was in charge of the end-station of the materials-science Beamline. In 1997 I became head of the Instrument Support Group, as well as senior scientist. In 2006 I moved to DESY, to create a Photon Science Detector group, and define the detector program and structure of the European XFEL. In the group, we are developing state of the art detectors for photon science, and we are involved in their use in innovative experiments.

## Matthew Hart




- *e-mail:* Matthew.hart@stfc.ac.uk
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- *Affiliation:* Rutherford Appleton Lab, STFC
- *URL:* http://www.technologysi.stfc.ac.uk


- *Professional profile:*

  Based within the Application Engineering Group at RAL my role is to lead cross-disciplinary detector projects through to delivery. I have a background in Physics and Microelectronics, now my focus is on System Engineering and Project Management. I have worked on the LPD system for XFEL.eu for over 10 years. More recently I have been working on next generation electron microscope detectors.

## Takaki Hatsui

- *e-mail:* hatsui@spring8.or.jp
- *Position:* Team Leader for Data Acquisition Team
- *Affiliation:* RIKEN SPring-8 Center, RIKEN
- *URL:* http://xfel.riken.jp/organization/xrdd_blrdg_dat.html

- *Professional profile:*

  Takaki Hatsui received B.S. and M.S. degrees from Kyoto University, Kyoto Japan, in 1994 and 1996, respectively, and PhD degree in science in the field of physical chemistry from the Graduate school for Advanced Studies in Japan in 1999. After working as a postdoctoral fellow at the University of Tokyo and Uppsala University, he was with Institute for Molecular Science as a research associate and an assistant professor for soft x-ray spectroscopy. During that period, he has developed sub pixel resolution soft x-ray detector for resonant x-ray inelastic spectroscopy, which is later commercialized by the co-investigator Andrew Holland. In 2007, he joined RIKEN, and has been leading the data acquisition team that covers developments of detectors, data acquisition, and analysis platform at the XFEL facility SACLA. So far the team has developed multi-port CCDs, and SOPHIAS detectors. In 2013, he has also started the development of detectors toward SPring-8-upgrade.

## Tomasz Hemperek

- *e-mail:* hemperek@uni-bonn.de
- *Position:* Lead ASIC Designer
- *Affiliation:* Physics Institute of Bonn University
- *URL:* http://linkedin.com/in/hemperek

- *Professional profile:*

  Tomasz Hemperek completed his M.Sc. degree in Electronic Engineering at the AGH-UST UST-University in Krakow and his Ph.D. in Experimental High Energy Physics at the University of Bonn. His Ph.D. thesis focused on introducing new types of radiation tolerant CMOS Monolithic Pixel Sensors. In his research, he  lead the designing of various readout chips for ATLAS, CMS and Belle II experiments mainly focusing on digital design, verification and top-level integration. He has developed multiple DAQ systems for chip testing and characterization. In his career, he has also worked at IPHC Strasbourg and the Mentor Graphics Corporation.

## Yu-Shan Huang

- *e-mail:* jade@nsrrc.org.tw
- *Position:* Associate Scientist
- *Affiliation:* National Synchrotron Radiation Research Center, Taiwan
- *URL:* https://www.nsrrc.org.tw/english/personal.aspx?ID=00136&Dept_UID=28&Type=M

- *Professional profile:*

  I am interested in research topics of coherent X-ray imaging and X-ray Optics. Currently, I serve as Head of the Experimental Facility Division at NSRRC and in charge of beamline construction and operation.

## Simo Houtari

- *e-mail:* simo.huotari@helsinki.fi
- *Position:* Professor of Physics
- *Affiliation:* University of Helsinki
- *URL:* http://www.helsinki.fi/people/simo.huotari

- *Professional profile:*

  Professor in experimental materials physics, main focus in use of x-ray methods in characterization of complex matter. Main tools are various x-ray spectroscopies, scattering, and x-ray imaging. Recent interests include in situ catalysis and electrochemistry and biological physics. Our x-ray physics laboratory in Helsinki has an active x-ray imaging group with microtomography facilities and we are currently building a grating-interferometry based phase-contrast imaging setup. We use wavelength-dispersive x-ray optics for high-resolution x-ray spectroscopy (meV to eV resolution) at synchrotrons and recently also eV-resolution spectroscopy in our university's "home" laboratory. I have a large interest in the development of high resolution detectors (in all aspects) for both x-ray imaging, spectroscopy, and those to be used in conjunction with wavelength dispersive spectrometers.

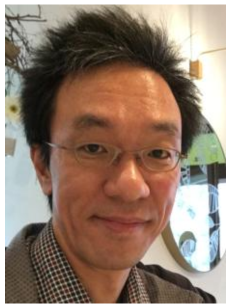
## HyoJung Hyun

- *e-mail:* hjhyun@postech.ac.kr
- *Position:* Staff Scientist
- *Affiliation:* Pohang Accelerator Laboratory
- *URL:*

- *Professional profile:*

  I am working in the detector group of PAL-XFEL. My works are to support detector operation and to contribute the collaboration of PERCIVAL detector development. And, I am involved at the beam diagnostics TFT of PAL-XFEL beamline department. My research experiences during the graduate course and post-doctoral course were originated at the development of silicon detector for high energy physics such as elementary particle physic and astro-particle physics. So, I am familiar with testing and characterization of the silicon detectors.

## Yasuhiko Imai



- *e-mail:* imai@spring8.or.jp
- *Position:* Team Leader, Senior Scientist
- *Affiliation:* Japan Synchr. Rad. Research Institute (JASRI), SPring-8
- *URL:* https://nrid.nii.ac.jp/en/nrid/1000030416375

- *Professional profile:*

  Yasuhiko IMAI has been working at SPring-8 as a beamline staff scientist for 18 years. He is in charge of a high-resolution nano-beam X-ray diffraction system for the last 11 years. He has experience in using synchrotron facilities; Photon Factory (PF), PF-AR at KEK, SPring-8, and Taiwan Photon Source (TPS) as a user.
  His current position is a team leader of nano-materials structure team, which takes care of three public beamlines at SPring-8; BL04B2 (high-energy X-ray diffraction), BL13XU (surface and interface structure), and BL28B2 (multi-purpose white X-ray). He is also a leader of a detector support working group to promote optimized usage of detectors, especially hybrid pixel detectors, at SPring-8.

## Shunji Kishimoto

- *e-mail:* syunji.kishimoto@kek.jp
- *Position:* Professor
- *Affiliation:* Inst. of Materials Structure Science, KEK
- *URL:*

- *Professional profile:*

  Since 1987, Mr. Kishimoto has been responsible for managing X-ray beamlines at Photon Factory, including BL-14A. He has developed fast X-ray detectors for synchrotron radiation science, e.g., Avalanche Photodiode detectors for nuclear resonant scattering and X-ray diffraction experiments.

## Michael Krisch

- *e-mail:* krisch@esrf.fr
- *Position:* Head of the Instrumentation Division (ISDD)
- *Affiliation:* ESRF – The European Synchrotron
- *URL:*

- *Professional profile:*

  Michael K. holds a PhD in Physics and has more than 30 years of experience in synchrotron radiation research, working at DESY, Brookhaven National Laboratory, and the ESRF. His field of expertise comprises the investigation of the electronic and magnetic structure and dynamics of condensed matter and high-pressure science and techniques. He was previously responsible scientist for beamlines ID20 and ID28 and led the Dynamics and Extreme Conditions Group of the ESRF Experiments Division from 2009 to 2015. Since June 2015 he is Head of the Instrumentation Services and Development Division. He is member of the ATTRACT Project Consortium Board.

## Markus Kuster


- *e-mail:* markus.kuster@xfel.eu
- *Position:* Head of the detector group
- *Affiliation:* European XFEL GmbH, Germany
- *URL:*


- *Professional profile:*

  Markus Kuster has a background in theoretical and experimental astro- and astroparticle physics. Since his graduation at the University Tübingen he was involved in various detector development projects for terrestrial and space experiments. He is leading the detector group at the European XFEL, which is responsible for high-speed large and small area X-ray detectors required by European XFEL's scientific instruments for imaging, monitoring, veto and spectroscopic applications.

## Sang Jun Lee


- *e-mail:* sangjun2@slac.stanford.edu
- *Position:* Physicist
- *Affiliation:* SLAC National Accelerator Laboratory
- *URL:*


- *Professional profile:*

  Sang Jun Lee received his Ph.D. from Seoul National University in 2012. He was a postdoctoral fellow at NASA Goddard Space Flight Center and at Stanford University from 2012–2015 and 2015–2017, respectively. He joined SLAC National Accelerator Laboratory as a physicist in 2017. His research has been concerned with the development of start-of-the-art cryogenic particle detectors and their applications. At SLAC, his research interests focus on the application of transition-edge sensor (TES) X-ray spectrometers to fundamental and applied physics including the study of 2d materials and high Tc superconductors.

## Oscar Matilla Barceló

- *e-mail:* omatilla@cells.es
- *Position:* Electronics Section Head
- *Affiliation:* ALBA Synchrotron
- *URL:* http://www.cells.es

- *Professional profile:*

  Oscar Matilla is the head of the Electronics Section in ALBA Synchrotron (CELLS) Computing and Control Division. His section provides electronics support to accelerators and beamlines, for instance, designing custom electronic devices, specifying systems, instrumentation and giving X-Ray detectors support.
  Oscar holds an Electronic Engineering degree as well as MSc in Physics from Universitat de Barcelona, a double domain education that secures him with solid ground to provide electronics services to physical experimentations. Finally he has completed his studies with a Master's degree in Industrial and Services Project Management.
  Before joining to ALBA project 11 years ago, Oscar spent some years wandering around different R&D departments; being the longest working in SONY for five years in digital video signal processing.

## Thierry Martin

- *e-mail:* tmartin@esrf.fr
- *Position:* Head of the Detector Unit
- *Affiliation:* ESRF – The European Synchrotron
- *URL:* http://www.esrf.eu

- *Professional profile:*

  Thierry Martin is the Head of the Detector Unit at the ESRF. The unit is in charge of providing advice, support and development capabilities in X-ray detection. He completed the ENSICAEN engineering school and an M.Sc degree in Instrumentation at Caen. In 1998, he received his PhD degree from the University of Caen. After his graduation he spent 18 months as a physicist at Smiths-Heimann. In 2000, he joined the ESRF as an engineer in charge of high-spatial resolution detectors mostly based on scintillators, optics and imaging sensors, and also X-ray beam monitors.

## Ralf Menk

- *e-mail:* ralf.menk@elettra.eu
- *Position:* Senior researcher, project leader
- *Affiliation:* Elettra Sincrotrone Trieste & INFN Trieste, Italy
- *URL:* http://www.elettra.eu

- *Professional profile:*

  Ralf Hendrik Menk received his diploma in physics in 1990 at the University Siegen, Germany and in 1993 his PhD in physics at the University Siegen and HASYLAB at DESY, Germany. After detector related postdoctoral stays at HASYLAB (1993 - 1995) and NSLS at BNL, New York, USA (1995 - 1997) he moved to Elettra Sincrotrone Trieste, Italy. Since 2001 he is senior researcher and project leader for photon detector development and imaging applications at Elettra-Sincrotrone Trieste and since 2012 he is associated researcher at the national institute of nuclear physics (INFN) Trieste. In July 2016 he has been appointed as Adjunct Professor in the Department of Medical Imaging at the University of Saskatchewan, Canada.

## Emilio Meschi

- *e-mail:* emilio.meschi@cern.ch
- *Position:* Senior Applied Physicist
- *Affiliation:* CERN
- *URL:* http://meschi.web.cern.ch

- *Professional profile:*

  1988: joins the CDF collaboration (Fermilab, E741)
  1991: MS Physics, University of Pisa: QCD, first evidence of color coherence
  1995: PhD Physics, Scuola Normale Superiore, Pisa: Time-integrated b-mixing with muons
  1994–1998: Design and construction of the Silicon Vertex Trigger for the CDFII upgrade
  1998: joins the CMS collaboration
  1998–2000: CERN research fellow – electron/photon reconstruction, Higgs physics
  2000–today: CERN staff physicist in the CMS Data Acquisition group
  2003–today: Responsible for the CMS High Level Trigger farm
  2007: Senior Applied Physicist
  2012–2015: LHC Program Coordinator
  2016–today: CMS DAQ Upgrade Coordinator

## Antonino Miceli

- *e-mail:* amiceli@anl.gov
- *Position:* Group Leader
- *Affiliation:* Argonne National Laboratory, Advanced Photon Source
- *URL:* https://www.aps.anl.gov/Detectors

- *Professional profile:*

  Antonino Miceli leads APS Detectors Group. The mission of the APS Detectors Group is to deliver cutting-edge X-ray detectors to APS beamlines. Our mission is accomplished in two ways. First, we introduce new commercial detectors to the APS community via the Detector Pool. Second, we are engaged in a number of detector R&D projects to meet the future needs of the APS. We focus our detector R&D efforts in three areas: pixel array detectors, high-energy sensors, and emission detection. We are involved in two collaborations on pixel array detectors. These include the VIPIC detector for ultra-fast XPCS with BNL and FNAL, and the MM-PAD detector with Cornell University. For high-energy sensors, we are collaborating with the BNL NSLS-2 Detector Group on germanium strip detectors for high-energy spectroscopic applications. Finally, for X-ray emission detection, we are collaborating with NIST and SLAC on transition-edge sensors (TES) for high energy-resolution emission detection applications.

## Aldo Mozzanica

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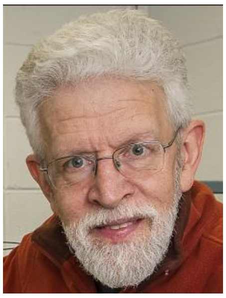
- *Professional profile:*

  Aldo Mozzanica did his Ph. D. in physics at the University of Milan with a thesis on the development of a scintillating fiber particle tracker for Antiproton cross-section measurements.
  In 2008 he started working as a Post Doc in the SLS Detector Group with the task of developing a 1D detector based on charge integration readout with an automatic gain switching preamplifier (GOTTHARD).
  Since 2012 he is the scientist responsible for the JUNGFRAU development; JUNGFRAU is a 2D pixel detector with 75um pixel pitch primarily developed for SwissFEL applications. In this project, he is in charge of the ASIC design, the module production and the project coordination.

## Paul O'Connor



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- *Professional profile:*

  Paul O'Connor received the Ph.D. degree in Physics from Brown University in 1980, served as Member of Technical Staff with AT&T Bell Laboratories from 1980-1990, and has been on the scientific staff of Brookhaven National Laboratory through the present. His research areas are in the application of microelectronics and semiconductor detectors to a diverse range of scientific applications, including astroparticle physics, photon science, and medical imaging.

## Masataka Ohkubo

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- *Professional profile:*

  M. Ohkubo is running two national projects on innovative measurement and analysis for advanced structural materials. They are funded by Cabinet Office, and Acquisition, Technology & Logistics Agency, which cover a wide scale range from molecules to aircraft main wings. He headed the projects on XAFS and Mass Spectrometry (MS), both of which employ superconductor detectors, and initiated the clean room facility for analog-digital superconductor devices (CRAVITY) at AIST.
  There are also activities as IEC convener, IOP Executive Board member, PhD defense opponent, etc. He holds two visiting professorships at University of Tsukuba and High Energy Accelerator Research Organization (KEK). He covers a wide range of metrology, but his particular expertise is advanced analytical instrumentation with superconductivity.

## Fabienne Orsini


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  Senior physicist specialized in detectors for particle physics and photon science applications. Member of AIDA2020 CMOS project.

## Jean Marie Polli


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  Master in Physics and Scientific Instrumentation by the Brazilian Center for Physical Research CBPF. Currently I am Detectors Group leader specialist of Instrumentation at Brazilian National Synchrotron Light Laboratory part of the Brazilian Center for Research in Energy and Materials (CNPEM).

## Matteo Porro


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- *Professional profile:*

  Matteo Porro earned his Master's degree in Electronics Engineering and his Ph.D. in Radiation Science and Technology at Politecnico di Milano. His research interests focus on the development of low-noise silicon detectors and of the associated readout ASICs.
  From 2005 until 2015, he was research scientist at the Semiconductor Laboratory of Max Planck Institute in Munich. He was responsible of the ASIC development activity, focusing on multi-channel chips for DEPFETs and pnCCDs. He coordinated the development of the ASTEROID ASIC for the Mercury exploration mission BepiColombo and the VERITAS ASIC for the upcoming ATHENA mission.
  In 2007 he became the coordinator of the DSSC project, that aims at the development of a 2D DEPFET-based X-ray imager with mega-frame readout capability for the European XFEL GmbH in Schenefeld. Since 2015 he is affiliated with the European XFEL, where he is continuing in his role of project leader of the DSSC detector.

## Tom Regier


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- *Professional profile:*

  Beamline scientist in charge of the Spherical Grating Monochromator beamline at the Canadian Light Source. Primary interests are the application of soft x-ray compatible silicon drift detectors, development of in-situ soft x-ray capabilities and the development of web based data acquisition and analysis infrastructure.

## Rainer Richter

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- *Professional profile:*

  My main interests are related to development of semiconductor sensors. This includes conception, simulation and layout of new devices as well as the study of their technological feasibility. Currently I am involved in the development of the DEPFET Pixel Detector for Belle2, a fast electron detector and in the ATLAS pixel detector upgrade.

## Abdul Rumaiz

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- *Professional profile:*

  Dr. Abdul K Rumaiz obtained his Ph.D in physics from the University of Delaware. He joined the NSLS detector group as a post-doctoral fellow and has moved through the ranks. He is currently a physicist at the NSLS II detector group, where he is involved with several detector projects such as the MAIA, VIPIC and the germanium detectors.

## Bernd Schmitt


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- *Position:* Group leader
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- *Professional profile:*

  Studied physics at the University of Heidelberg. PhD in particle physics at CERN and the University of Bonn. Two/three years as a CERN fellow on the OPAL and CMS experiments. At PSI since 1999 initially as project leader for the Mythen single photon counting detector. Leader of the detector group of the Photon Science Department of PSI (SLS and SwissFEL) since 2008. Experience in all aspects of hybrid detector development, production and operation, including single photon counting and charge integrating strip and pixel detectors.

## Paul Scoullar


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- *Affiliation:* Southern Innovation
- *URL:* http://www.southerninnovation.com


- *Professional profile:*

  Paul Scoullar is the Founder and Technical Director of Southern Innovation, a company developing products for the rapid, accurate detection & measurement of radiation.
  In his role as Technical Director he is primarily focused on technology & product development across a range of industries including scientific instrumentation; homeland security and the mining and mineral processing sectors.
  Paul's commercial experience spans new venture creation, business development, product development, strategic intellectual property management, collaborative partnerships with University and Governments, and fund raising.
  Paul has a Bachelor of Electrical Engineering (Hons.) from The University of Melbourne, has authored a number of peer-reviewed papers, and has a broad portfolio of Patents.

## Paul Sellin

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- *Professional profile:*

  My research interests are the development and characterisation of radiation detectors and detector materials, for applications in nuclear physics, medical imaging, and security detection. My research focusses on the characterisation of semiconductor materials for detector applications, and their use as radiation detection devices. Recent research projects include the development and characterisation of high-Z compound semiconductor materials (eg. GaAs, InP, CdTe, CdZnTe) for X-ray and nuclear medicine imaging detectors, and the characterisation of radiation-hard detector materials (eg. diamond, silicon carbide, gallium nitride) for radiation detection applications where high dose rate and/or high temperature capability is required. I also work on organic materials for use as radiation detectors, including semiconducting polymers and organic crystals.

## D. Peter Siddons

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- *Professional profile:*

  I have worked extensively in the synchrotron radiation field, initially on Bragg reflection crystal optical systems, and more recently on the development of advanced detectors for synchrotron applications.

## Fei Song

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- *Professional profile:*

  Major in Semiconductor Physics and Nanomaterials, research interests mainly focus on the fabrication of thin film and low dimensional nanostructures and their related applications, paying special attention recently to the development of x-ray detectors. In charge of the Energy Materials beamline in SSRF.

## Jolanta Sztuk-Dambietz

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- *Position:* Detector Scientist
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- *Professional profile:*

  I received a PhD in high energy physics from Lodzi University in Poland. Since 2011, I work as detector scientist at the European XFEL GmbH in Schenefeled, Germany. I am responsible for the integration and commissioning of one of the novel fast 2D detectors (i.e. the AGIPD detector) into the scientific instruments and for the coordination of the detector calibration effort at the European XFEL.

## Nicola Tartoni

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- *Position:* Detector Group Leader
- *Affiliation:* Diamond Light Source ltd
- *URL:*

- *Professional profile:*

  Nicola Tartoni joined Diamond Light Source in 2004 as detector scientist and was the first person recruited in the Detector Group at Diamond. After the resignation of the group leader he took the responsibility of the detector group in 2007 and was officially appointed Detector Group Leader in 2012. He has been Visiting Fellow in the Faculty of Engineering and Physical Sciences of the University of Surrey where he lectured in the MSc in Radiation Detection and Instrumentation. Before joining Diamond he was a member of the Plasma Diagnostic Group of the tokamak FTU in Frascati, Italy.

## Jana Thayer

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- *Professional profile:*

  Dr. Jana Thayer works for the SLAC National Accelerator Laboratory as the Department Head for LCLS Data Systems. In addition to managing day-to-day operations of the data acquisition, analysis, and data management groups, Jana is leading the development of the Data System for LCLS-II. Prior to LCLS, Jana managed the Fermi Gamma-Ray Space Telescope flight software group. Jana received her Ph.D. in high energy particle physics from The Ohio State University in 2002 for her research on inclusive radiative penguin decays of B mesons at the CLEO experiment and participated in the upgrade to the CLEO data acquisition system. She came to SLAC in 2004 after a Postdoc with the University of Rochester.

## Johannes Treis


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- *Position:* Head of System Integration
- *Affiliation:* Semiconductor Laboratory of the Max-Planck-Society
- *URL:* http://www.hll.mpg.de


- *Professional profile:*

  Having joined the MPG Semiconductor Laboratory in 2002, Johannes Treis is involved in the development of DEPFET and pnCCD based Detectors for more than 15 years. He was involved in the development of instrumentation for spaceborn X-ray spectroscopy missions like XEUS, BepiColombo and ATHENA. Here, he was contributing to the design of detector devices, readout ASICs and readout systems, prototype testing, and, in case of the MIXS instrument on BepiColombo, flight qualification. Recently, the main focus of his work has moved towards the design of detectors and compact camera systems for ground based instrumentation furnished with the next generation of smart pnCCD and DEPFET based monolithic pixel detectors for a variety of applications.

## Matthew C. Veale


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- *Position:* Principle Detector Development Scientist
- *Affiliation:* STFC Rutherford Appleton Laboratory
- *URL:* https://www.researchgate.net/profile/Matthew_Veale


- *Professional profile:*

  My interest in photon detection began during my PhD at the University of Surrey in collaboration with the STFC Rutherford Appleton Laboratory focused on the characterization of CdZnTe. My PhD coincided with the formation of the HEXITEC (High Energy X-Ray Imaging Technology) collaboration and the development of the HEXITEC detector system, a 6.4k pixel fully spectroscopic imaging detector with each channel capable of measuring spectra between 2 – 200 keV with an energy resolution of 0.8 keV. This detector technology is now in use in a wide variety of application areas such as materials science at synchrotrons, lab-based chemical imaging, diffraction imaging at laser-driven radiation sources as well as applications in industrial settings such as illicit material detection.

# Abstracts

## *Detection: from the dark ages to the X-ray detectors for future SR and FEL Photon Sources*

Michael Krisch

European Synchrotron Radiation Facility, 71 avenue des Martyrs, 38043 Grenoble, France

**Abstract**:

All five human senses are related to detection, and it is therefore no surprise that detectors (a word coined around 1540, and of Latin origin, meaning uncoverer, revealer) have been one of the key instruments in Science & Technology since the beginning of mankind.

X-ray detectors entered the scene in 1895 with the famous X-ray image of the hand of Röntgen's wife. Starting from photographic plates and films, we now have a plethora of X-ray detectors, optimised for specific applications. Today, X-ray detector technology struggles to keep pace with the advent of ever brighter storage ring-based X-ray sources, and more recently from the Free-electron-laser (FEL) sources.

The ESRF is leading the way in the construction of a brand new low-emittance storage ring whilst all other major synchrotron radiation facilities in the world shall follow in the quest to deliver even brighter X-rays. Free-electron-laser facilities such as LCLS, SACLA, and the European XFEL, which only recently came into operation, are already planning major upgrades. The extremely high photon flux, combined with a complex time structure, are paramount challenges, which need to be addressed in a concerted fashion rather than by a single entity. As X-ray detectors find applications beyond science in domains such as medicine or homeland security – markets which are orders of magnitude larger than the "research market" – detector R&D needs to involve industrial partners, thus closing the innovation triangle between research infrastructures, academia, and industry. To this end, initiatives such as ATTRACT [1] and LEAPS [2] should play a central role.

Following a short historical analysis, the presentation will give an overview of the present and future landscape of SR and FEL photon sources, introduce the concepts behind ATTRACT and LEAPS, and shall conclude with a few very general considerations. It is hoped that this introductory, pre-dinner presentation will stimulate many fruitful discussions during the workshop.

[1] https://www.attract-eu.org

[2] https://www.leaps-initiative.eu

## *Sensor ideas for photon science detectors developed at the MPG Semiconductor Lab*

Rainer H. Richter, on behalf of the MPG Semiconductor Lab

MPG Semiconductor Laboratory, Otto-Hahn-Ring 8, 81739 Munich, Germany

**Abstract**:

Designing a detector system the perseverative question about S/N, dynamic range and speed has to be answered quite differently for each application field. Photon science detectors usually require high dynamic range and speed. But even if energy resolution is not of importance a high signal to noise compensates the increased white noise at high speed and improves counting precision. Many sensors developed for ultra-low noise applications can be beneficially used in photon science as well. In this context we want to present new sensor ideas developed at the MPG Semiconductor Lab.

The DSSC detector developed for XFEL at Hamburg has DEPFET pixels with internal signal compression. They provide high gain for small signal charge and continuously reduced gain for larger charge. This allows single photon detection and high dynamic range operation simultaneously. With readout rates of about 4.5MHz the XFEL sets the highest speed requirements, what necessarily implies a direct connection of each pixel to its readout channel by a bump bonded sensor/readout-chip package. However, many other photon science facilities can be equipped with classical sensor arrays, in the sense that they have readout electronics at the edge and are operated in a row-by-row access mode. Although if time resolution is limited by frame readout rates, those systems are usually less complex and the pixel size is not determined by still quite large bump bond and ro-cell dimensions.

However, for many experiments speed is of course an issue either for occupancy reasons or just to watch fast activities.

We are developing a detector system with 80 kHz frame readout of an array with 512x512 DEPFET pixels with signal compression. The pixels are rectangular shaped and with a size of 60x60µm² notedly smaller than the DSSC pixels. The high speed is achieved by reading out four pixel rows simultaneously with a line readout time of about 100ns. The arrays are 2-side buttable thus a detector system can be composed from 4 modules.

The Quadropix concept, also based on DEPFETs, uses four storage nodes within one pixel, where one node collects charge while the others are insensitive and can be readout. Switching between nodes takes less than 100ns. Independently of the frame readout time four fast samples can be taken.

Despite of their deep transfer depth, pn-CCD pixel can store and transfer a large amount of charge. But a simultaneous operation in low noise and high dynamic range mode is limited by the fix input capacitance of the JFET integrated on-chip as a first amplifier stage. We show that the JFET can be replaced by a linear DEPFET with signal compression to overcome this limitation.

## *The path towards germanium drift detectors*

Andrea Castoldi[1], C.Guazzoni[1], S. Maffessanti[1], T. Krings[2]

[1] Politecnico di Milano and INFN sez. Milano, Italy
[2] Forschungszentrum Jülich, Institut für Kernphysik (IKP), Jülich, Germany

**Abstract**:

The implementation of the drift topology in silicon detectors allowed a clear performance jump in X-ray spectroscopy – in terms of energy resolution and count rate – by breaking the tie between sensitive detection area and anode size.

In order to overcome the energy barrier of 20 keV X-rays, only high-Z materials (e.g. Ge, CZT, CdTe, HgI, GaAs, etc.) can provide sufficient detection efficiency with reasonable material thickness and depletion voltages. Recently novel designs of low-capacitance large-volume HPGe detectors have been introduced to upgrade conventional coaxial detectors, pushed by the demand of higher energy resolution and lower energy thresholds in ultra low-background physics experiments. Given the nowadays established technology in high-quality Ge planar detectors, times are mature to start a challenging R&D program towards the implementation of Ge drift topologies in a fully planar fabrication process. The planar approach will not only produce the expected and significant jump in spectroscopic performance but will also open the way to the powerful integration of drift and pixelated topologies, leading to optimized detection systems for a wide range of applications with hard X- and gamma rays.

The talk will review the state of the art of present low-capacitance detector developments in Ge and compound high-Z materials. The main aim of the talk are is to focus on the technological and design issues tackled by the ongoing R&D project DESIGN aimed at the development of Ge drift detectors in planar technology.

## *Spectroscopic performance of high-Z sensor materials*

Paul Sellin

Department of Physics, University of Surrey UK

**Abstract**:

In this talk I will review the spectroscopic performance of high-Z materials, and summarise their current status as radiation detectors. There are many candidate high-Z materials which have been investigated for use as X-ray and gamma detectors in recent years. Germanium remains a unique high-Z material which has been proven for many years, and it is now finding increasing use as a pixelated detector. In addition a number of wide bandgap high-Z materials (such as CdTe, CZT, and GaAs) are reaching maturity as viable radiation detectors. Whilst "mobility lifetime product" is often used as the primary parameter to assess a material's suitability as a radiation detector, material performance is fundamentally determined by various underlying optical and electrical parameters, such as semiconductor band gap energy, electrical resistivity and conductivity, charge transport properties, and the role of charge traps. In this talk I will review the key topics of device physics which drive detector performance. I will also present a summary of the current status and achievements of these wide band gap high-Z materials, and illustrate their current performance and future potential as X-ray and gamma detectors.

## *Ultimate throughput and energy resolution of analog pulse processing front-ends*

Carlo Fiorini[1,2]

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[2] INFN, Sezione di Milano, Milano, Italy

**Abstract**:

The need of X-ray detectors able to increase the counting rate capabilities, still keeping good energy resolution is of particular interest in view of the ongoing upgrades of actual synchrotron light machines, where a factor between 10 and 100 to beam-on-sample fluxes may be increased with respect to present conditions. Detector solutions, e.g. based on arrays of Silicon Drift Detectors (SDDs), looks promising to cope with such challenges if also the readout electronics, which covers a fundamental role in the noise and throughput performances, can be designed accordingly to fully exploit the ultimate detector performances. The recent availability of CMOS preamplifiers to be directly connected to the detector offer an alternative solution to conventional JFETs, in particular in the direction of high-count rate spectroscopy (e.g. >1Mcounts/s/channel). For what concerns processing electronics, the push towards high-rate spectroscopy measurements further justifies the use of digital pulse processors in the detection system and commercial solutions are available. However, the perspective to build detection systems with few tens, maybe few hundreds, of readout channels, with limited power consumption, can make the use of analog readout ASICs still of interest.

In this work, the fundamental aspects and key design parameters of the analog readout electronics (preamplifiers, pulse processors) for X-ray spectroscopy detectors are first recalled. Then the current state of the art is reviewed. Finally, possible directions for further developments are highlighted to introduce the debate on this topic.

## *Power-aware design of highly integrated systems*

Paul O'Connor

Brookhaven National Laboratory, Upton, New York 11973

**Abstract**:

Power budget is frequently given secondary consideration in front-end detector readout design. This can lead to compromises being made at a late stage in the development, either accepting limited speed/noise performance or dealing with difficult cooling problems. This presentation will discuss power-aware design at the transistor, circuit, and system level.

## *Advanced pulse processing techniques for synchrotron and other high rate applications*


Paul Scoullar

Southern Innovation, Melbourne, Australia



**Abstract**:

Southern Innovation, an Australian based technology company, develops solutions for the rapid, accurate detection and measurement of radiation. Our technologies have been integrated into products across a range of industries including: photon detection instrumentation; homeland security; mining; and mineral processing.

This talk presents the fundamentals of model based sensor signal processing and, within the historical context of nuclear electronics, details its application in photon science. Particular challenges of implementing these techniques in modern day digital pulse processors, such as XIA's FalconX, are explored. User applications in Synchrotron science will be discussed in more detail along with some alternate industrial applications.

In conclusion we consider promising areas of future development to further advance the throughput, count-rate and resolution performance of energy dispersive X-ray detection systems.

## ***Status, prospects and challenges of state-of-the-art detector system integration***

Johannes Treis, on behalf of the MPG semiconductor laboratory

MPG Semiconductor Laboratory, Otto-Hahn-Ring 8, 81739 Munich, Germany

**Abstract**:

The evolution of experimental facilities raises the bar for state-of-the-art detector systems. For imaging devices, mainly the ongoing trend towards larger device areas, higher pixel densities and high framerates is driving the development. The challenges are manifold, starting from the sensor, which has to provide the desired response for the given operating conditions, down to the data acquisition system, which has to be capable of processing the target data volume. In addition, a variety of mechanical and thermal requirements have to be tackled, and the design of the power supply system and cable harness has to be tailored to the systems requirements, especially if the target of a compact and mobile instrument is to be met.

The presenter uses two examples from his ongoing research activities, a small-pixel X-ray camera based on pnCCDs and a DEPFET-based direct electron detection camera for TEM applications, to exemplify the impact of the above-mentioned aspects on the system design and the respective approach chosen to keep up with the requirements. Finally, as an outlook, the future implications of recent progress for selected aspects are illustrated.

## *The Maia detector system: a new way to do scanning probe fluorescence imaging*

D. Peter Siddons, for the Maia Collaboration

NSLS-II, Brookhaven National Laboratory, Upton, New York 11973

**Abstract**:

Maia is a new type of x-ray fluorescence detector. It contains a massively parallel detector system with ~400 independent spectroscopic detectors in one instrument. The analog readout electronics for each channel is rather conventional, but it is highly-integrated using custom ASICs to form a compact system [1, 2]. The output from these ASICs is digitized and a powerful FPGA-based system streams the digital information from the detector photon-by-photon, allowing very flexible acquisition methods to be implemented. It was one of the first systems to integrate continuous scanning with data readout. We chose an unusual geometry, using a back-scattering arrangement. This brings two advantages. First, it allows the detector to be very close to the sample, providing a very large solid angle of collection, in spite of the rather small detector elements. Since the sample scan axes are now parallel to the detector face, large-area scans are trivial to implement. Since it is important to have user feedback when performing such experiments, we implemented an on-line analysis system which is implemented within the detector's FPGA fabric using a technique referred to as Dynamic Analysis [3, 4]. This system displays elemental maps as the scan is proceeding, allowing data exploration, sub-region scan selection or early intervention in case of an error. We also store the raw photon data to disk to allow re-interpretation at the User's leisure.

[1] Kirkham *et al.*, AIP Conference series 1234 (2010) 240-243

[2] Siddons *et al*., Journal of Physics: Conference Series 499 (2014) 012001

[3] C.G. Ryan, Int. J. Imaging Systems and Technology 11 (2000) 219-230

[4] Ryan *et al.*, AIP Conference Proc. 1221 (2010) 9-17

## *Multi-element germanium detectors for synchrotron applications*

Abdul K. Rumaiz[1], A.J. Kuczewski[1] , J. Mead[1], E. Vernon[1], D. Pinelli[1], E. Dooryhee[1], S. Ghose[1], T. Caswell[1], D.P. Siddons[1], A. Miceli[2], T. Krings1[3] , J. Baldwin[2], J. Almer[2], J. Okasinski[2], O. Quaranta[2], R. Woods[2] and S. Stock[4]

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[3] Forschungzentrum Julich GmbH, 52425 Julich, Germany.
[4] Northwestern University, Evanston, Illinios 60208, USA.

**Abstract**:

We have developed a series of monolithic multi-element germanium detectors, based on sensor arrays produced by the Forschungzentrum Julich, and on Application-specific integrated circuits (ASICs) developed at Brookhaven. Devices have been made with element counts ranging from 64 to 384. These detectors are being used at NSLS-II and APS for a range of diffraction experiments, both monochromatic and energy-dispersive. Compact and powerful readouts systems have been developed, based on the new generation of FPGA system-on-chip devices, which provide closely coupled multi-core processors embedded in large gate arrays. We will discuss the technical details of the systems, and present some of the results from them.

## ***Digital pulse processing for monolithic multi-element spectroscopy detectors***

Graham Dennis[1], W. Helsby[2], D. Omar[1], I. Horswell[1], S. Chatterji[1], N. Tartoni[1]

[1] Diamond Light Source, Didcot, Oxfordshire, UK
[2] Science & Technology Facilities Council (STFC), Daresbury Laboratory, Warrington, Cheshire, UK

**Abstract**:

Digital Pulse Processors (DPP) have been used for many years to produce spectra from spectroscopy grade detectors such as HPGe detectors. The synchrotron radiation facilities in the UK have pioneered the use of digital pulse processors to produce spectra from multi-element monolithic spectroscopy grade detectors with the Xspress pulse processing algorithm at the SRS at Daresbury laboratory. The availability of increasingly powerful digital processing hardware leads to pulse processors with more and improved functionality, which in turn allows investigation of detector and system issues that have so far been neglected. This is exemplified in Xspress2 (used at Diamond Light Source (DLS) for 11 years [1]) and more recently Quantum Detectors Xspress3 (used at DLS and X-ray facilities worldwide).

DLS has recently developed the fourth generation pulse processor in the Xspress family – Xspress4. It harnesses the power and size of the latest generation of FPGAs matched with a new cross-coupled hardware architecture to produce a multi-channel DPP where individual channels can pass information between each other. The first application of this architecture is used to correct crosstalk between channels observed in some HPGe detectors. Xspress4 implements a real time pixel-to-pixel crosstalk correction algorithm that results in typically a factor 3 increase in detector system count rate for the same key performance indicators (FWHM resolution, peak to background ratio) compared with existing systems. Xspress4 was recently installed on beamline I20 at DLS to read-out a Canberra Monolithic 64-pixel Segmented HPGe detector. The presentation will describe the complete detector system and will show comparative results from recent commissioning experiments on I20.

Further, the Xspress4 architecture could be used in the future to implement functionalities such as anti-coincidence acquisition that could reject charge shared events. Charge shared events become more and more important as the size of the individual pixels of detectors shrink [2] and such detectors could in principle be operated without a collimator.

[1] S. Chatterji, G.J. Dennis, W.I. Helsby, A. Dent, S. Diaz-Moreno, G. Cibin and N. Tartoni, "Overview of multi-element monolithic germanium detectors for XAFS experiments at diamond light source", AIP Conference Proceedings 1741, 040030 (2016).

[2] N. Tartoni, R. Crook, T. Krings, D. Protic, C. Ross, L. Bombelli, R. Alberti, T. Frizzi and V. Astromskas, "Monolithic Muti-Element HPGe Detector Equipped With CMOS Preamplifiers: Construction and Characterization of a Demonstrator", IEEE Transactions On Nuclear Science (Volume 62 Issue 1 Feb 2015 Pages 387-394)

## *High energy X-ray imaging technology (HEXITEC): development of a spectroscopic X-ray imaging camera*

Matthew C. Veale, P. Seller and M. Wilson

STFC Rutherford Appleton Laboratory, Didcot, Oxfordshire, OX11 0QX, UK.

**Abstract**:

The High Energy X-Ray Imaging Technology (HEXITEC) UK-based collaboration was established in 2008 [1]. The aim of this collaboration was to develop spectroscopic imaging technology with excellent energy resolution at hard X-ray energies (>10 keV) for use in materials science applications at large science facilities like synchrotron light sources.

As part of the collaboration the STFC's Rutherford Appleton Laboratory developed the HEXITEC ASIC to readout compound semiconductor materials like CdTe, CdZnTe and GaAs:Cr [2]. The ASIC consists of 80 × 80 pixels on a 250 µm pitch with each pixel containing a pre-amplifier, shaping amplifier and peak-track-and-hold circuit; the voltage measured in each pixel is directly proportional to the energy measured by that pixel. The detector is operated using a rolling shutter readout at a rate of 10 kHz giving a minimum frame time of 100 µs. Due to charge sharing effects, in practice, the detector is operated at a maximum occupancy of ~ 10 % per frame giving a maximum rate of $10^6$ photons $s^{-1}$ $cm^{-2}$. When bonded to 1 mm thick Al-anode Schottky Acrorad CdTe ~ 30 % of events demonstrate charge sharing, after removal of these events the energy resolution per channel is 0.8 +/- 0.2 keV at room temperature (300 K) [3]. Detectors are three-side-buttable and have been produced as single modules [4] as well as larger tiled systems with an active area of 100 $cm^2$ [5].

Now 10 years old, the HEXITEC technology is in use across a broad range of academic and commercial application areas, from synchrotron science to security scanners. At the STFC we are now planning the next generation of this imaging technology with users pushing for operation at higher fluxes and higher energies. This talk will give an overview of the HEXITEC technology, how it is being used today and our plans for a new generation of detectors that aims to meet our user's demands.

[1] P. Seller et al, "Pixellated Cd(Zn)Te high-energy X-ray instrument," JINST 6, 2011, C12009. http://iopscience.iop.org/article/10.1088/1748-0221/6/12/C12009

[2] L. Jones et al, "HEXITEC ASIC – a pixelated readout chip for CZT detectors," NIMA 604, 2009, 34-37. https://doi.org/10.1016/j.nima.2009.01.046

[3] M. C. Veale et al, "Measurements of charge sharing in small pixel CdTe detectors," NIMA 767, 2014, 218-226. https://doi.org/10.1016/j.nima.2014.08.036

[4] http://quantumdetectors.com/hexitec/

[5] M. D. Wilson et al, "A 10 cm × 10 cm CdTe Spectroscopic Imaging Detector based on the HEXITEC ASIC," JINST 10, 2015, P10011. https://doi.org/10.1088/1748-0221/10/10/P10011

## *Current and future capabilities of transition-edge sensor microcalorimeters for x-ray beamline science*

Douglas A. Bennett

National Institute of Standards and Technology, Boulder, CO, USA

**Abstract**:

Transition-edge sensor (TES) x-ray microcalorimeters offer a unique combination of large collecting area and good energy resolution. These unique qualities are enabling new measurements capabilities at x-ray beamlines [1,2]. TES arrays are also finding applications in laboratory x-ray science, for example enabling tabletop ultrafast time-resolved x-ray emission spectroscopy [3]. Recent innovations in the TES readout technology are enabling larger arrays of much faster sensors. The first part of this presentation will describe the current capabilities of TES spectrometers and give an overview of systems that have been deployed to beamlines [4], including systems at the National Synchrotron Light Source, the Stanford Synchrotron Light Source, and the Advanced Photon Source. The second part of talk will describe near term capabilities and instruments that will be deployed at Linear Coherent Light Source II and the Advanced Photon Source. Finally, I will describe our understanding of the practical limits of TES microcalorimeters and our vision for what is possible for future TES instruments at x-ray beamlines.

[1] J. Uhlig, Jens, et al. "High-resolution X-ray emission spectroscopy with transition-edge sensors: present performance and future potential." *Journal of synchrotron radiation* **22** 776 (2015).

[2] Titus, Charles J., et al. "L-edge spectroscopy of dilute, radiation-sensitive systems using a transition-edge-sensor array." *The Journal of chemical physics* **147** 214201 (2017).

[3] Miaja-Avila, Luis, et al. "Ultrafast time-resolved hard X-ray emission spectroscopy on a tabletop." *Physical Review X* **6** 03104 (2016).

[4] Doriese, William B., et al. "A practical superconducting-microcalorimeter X-ray spectrometer for beamline and laboratory science." *Review of Scientific Instruments* **88** 053108 (2017).

## *Superconductor Tunnel Junction (STJ) soft-X-ray detectors for synchrotron radiation facilities*

Masataka Ohkubo[1,2,3], S. Shiki[1], G. Fujii[1], and M. Ukibe[1]

1 National Institute of Advanced Industrial Science and Technology (AIST)
2 University of Tsukuba, Faculty of Pure and Applied Sciences
3 High Energy Accelerator Research Organization (KEK)

**Abstract**:

Superconductor Tunnel Junction (STJ) type detectors have the same thin film layer structure of Josephson junctions: superconductor/insulator(~1nm)/superconductor. Josephson effect is killed by applying a weak magnetic field to be operated so-called Giaever mode. X-ray photon absorption results in Cooper-pair breaking, which creates quasielectrons. Within the recombination lifetime into Cooper-pairs, those quasi electrons tunnel through the insulation barrier and creates X-ray photon pulses. Integration of each current pulse is proportional to the X-ray photon energy. The advantage of STJ is that superconducting energy gap (~ meV) is about 1000 times smaller than that of semiconductors (~ eV), which leads to 30 times higher energy resolution than that of semiconductor-based EDS in principle, providing the Poisson statistics. The theoretical limit is ~2 eV at 6 keV and 0.5 eV at 392 eV (N-K) for an absorber of Nb ($\varepsilon = 1.7\Delta = 2.6$ meV).

In reality, because of imperfect charge collection, multiple tunneling statistical noise, spatial inhomogeneity, etc, our best energy resolution values were 4.1 eV (measured) and 3.6 eV (intrinsic) for 400 eV SR beam. These values are significantly smaller than natural line widths of light element K-lines such as B, C, N, O in compounds or matrices, and thus they are enough for partial fluorescence-yield XAFS measurement for trace light elements. Currently, an STJ spectrometer with 100 pixels of 100 µm square and an automated cryostat is in routine use at KEK PF,1 and has a total measured energy resolution of 7 eV, a maximum counting rate of 200 kcps, and a slid angle of 10-3 that is 1000 times higher than conventional WDS. These data were obtained by FPGA-based real-time signal acquisition system. Users can adjust parameters for XAFS measurement, seeing PHA spectra as they do it with conventional instrument. The STJ system has advantages in the high resolution and high counting rate over conventional system in a range less than 2 keV. A 512-pixel system is under development for PIXE.

[1] M. Ohkubo et al., Sci. Rep. 2, 831 (2012): doi:10.1038/srep00831.

## *Magnetic micro-calorimeters for atomic and particle physics*

Andreas Fleischmann

Kirchhoff-Institute for Physics, Heidelberg University, Im Neuenheimer Feld 227, 69120 Heidelberg, Germany

**Abstract**:

Metallic magnetic calorimeters (MMC) are calorimetric particle detectors, operated at temperatures below 50mK, that make use of a paramagnetic temperature sensor to transform the temperature rise upon the absorption of a particle in the detector into a magnetic flux change in a SQUID. During the last years a growing number of groups started to develop MMC for a wide variety of applications, ranging from alpha-, beta- and gamma-spectrometry over kilo-pixels molecule cameras to arrays of high resolution x-ray detectors. For soft x-rays an energy resolution of 1.6 eV (FWHM) has been demonstrated and we expect that this can be pushed below 1eV with the next generation of devices. We give an introduction to the physics of MMCs and summarize the presently used readout schemes for single channel read-out and multiplexing. We discuss design considerations, the micro-fabrication of MMCs and the performance of micro-fabricated devices in the fields of atomic, molecular and particle physics.

## *Wavelenght dispersive spectrometers*

Simo Huotari

Department of Physics, University of Helsinki, Finland

**Abstract**:

Wavelength dispersive detectors or spectrometers are based on crystal optics and can be used in applications that require even higher resolving power than obtainable with energy dispersive detectors today. Besides giving information on elemental absorption and emission lines, reaching 1 eV resolution in the x-ray range enables one to obtain chemical information, and spectrometers operating at or below 1 meV energy resolution give access to low-energy excited states of matter such as phonons and magnetic waves in crystals, or vibrational modes in molecules. Fast development is currently taking place in the soft x-ray range, for which several spectrometers with ~10 meV energy resolution are being planned, constructed or recently inaugurated at many synchrotron light facilities. But also wavelength dispersive optics requires a detector, and in many cases the detector development has brought many advances to the field of high resolution spectroscopy. An added challenge for the detection technology is the advent of x-ray free electron lasers, especially European XFEL in Hamburg, which delivers ultra-fast and extremely bright x-ray pulses. This contribution will describe the main principles and recent developments in this field, concentrating on the hard x-ray range where up to now highest energy resolving power can be demonstrated.

## *The first two years of transition-edge sensor (TES) spectrometer at SSRL*

Sang Jun Lee[1], M. L. Baker[2], H.-M. Cho[1], W. B. Doriese[3], J. W. Fowler[3], K. Gaffney[1], J. D. Gard[3], G. C. Hilton[3], K. D. Irwin[1,2], Y. Joe[3], J. Knight[1], J.-S. Lee[1], D. Li[1], R. Marks[1], K. M. Morgan[3], D. Nordlund[1], G. C. O'Neil[3], C. D. Reintsema[3], D. R. Schmidt[3], D. Sokaras[1], D. S. Swetz[3], C. J. Titus[2], J. N. Ullom[3], T.-C. Wenig[1], C. Williams[1], B. A. Young[2]

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**Abstract**:

Transition-edge sensor (TES) technology presents a rare opportunity to build novel detectors with greatly increased sensitivity in the soft X-ray regime. We have developed an X-ray spectrometer based on an array of 240-pixel TESs with a scientific motivation to probe local electronic structure of ultra-low concentration sites in biology, surface chemistry, and materials science. Since its commissioning in the spring of 2016 at SSRL beam line 10-1 at SLAC, the TES spectrometer has demonstrated soft X-ray RIXS, XAS and XES with much higher efficiency and much lower beam damage than traditional spectrometers in a broad range of science. In this talk, I will present recent results including measurements on frozen solutions of sub-mM aqueous iron model compounds [1]. I will also describe our on-going efforts for seamless integration of the TES spectrometer with routine synchrotron-based X-ray spectroscopy, and its aspect as a R&D testbed for forthcoming TES spectrometers at SSRL beam line 13-3 and LCLS-II SXR beam line at SLAC.

[1] C. J. Titus et al., "L-edge spectroscopy of dilute, radiation-sensitive systems using a transition-edge-sensor array", The Journal of Chemical Physics 147, 214201 (2017).

# *The Large Pixel Detector for the European XFEL: overview of the system and experience of operation at the FXE beam line*

Matthew Hart[1], Marcus French[1], Matt Veale[1], Philipp Lang[2], Dmitry Khakhulin[2]

[1] The Science and Technology Facilities Council, Rutherford Appleton Lab, UK
[2] The European XFEL, Hamburg, Germany

**Abstract**:

The Large Pixel Detector 1 Megapixel System was specially designed and built for use at the European XFEL. In line with the XFEL machine it operates with a 4.5MHz burst mode, capturing up to 512 high speed images before reading out and preparing to capture again a $10^{th}$ of a second later. The pixels are 500µm, giving a detection area around half a meter across. Delivered to Hamburg in early 2017, the system has been under test and commissioning at XFEL for almost 1 year. It is installed on the FXE beam line where it is run under ambient conditions, typically in laser pump probe type experiments. First user operations started in September and in recent weeks beam time was available for further detector characterization. The presentation will cover an overview of the system, experience of integration at XFEL.eu, feedback from the first user experiments, some results from commissioning beam time and also a brief look at work on the future options for LPD.

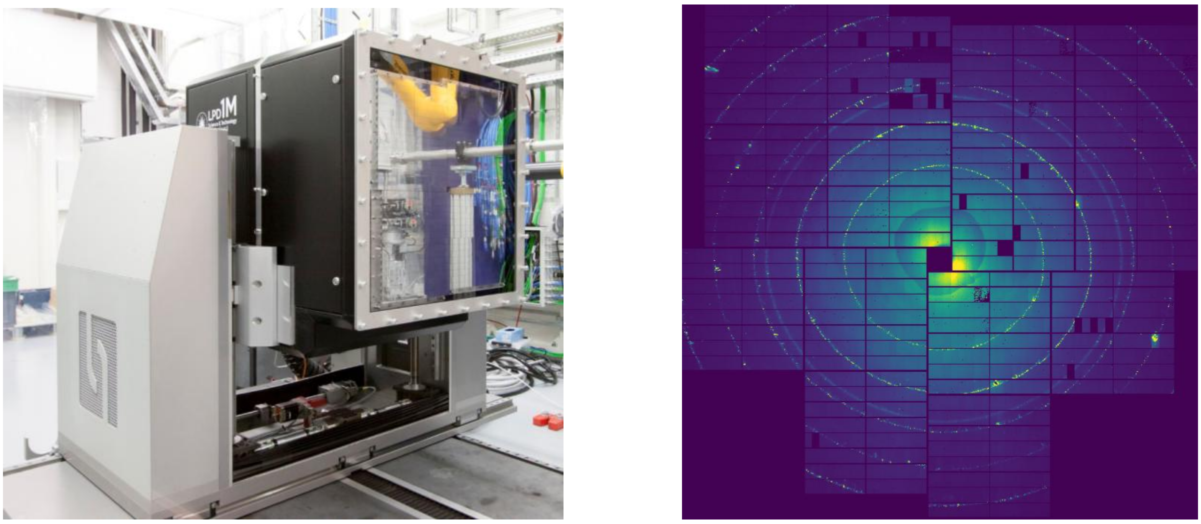

Figure 1: Left LPD installed at the FXE Beam line, Right: Example diffraction pattern

## *1 Mpix adaptive gain integrating pixel detector (AGIPD) for European XFEL: installation, commissioning and first user operation at SPB/SFX instrument*

Jolanta Sztuk-Dambietz, for the European XFEL Detector Group[1], SPB/SFX Instrument Group[1], IT and Data Management Group[1], Advanced Electronics Group[1] and the AGIPD Consortium[2]

[1] European XFEL GmbH, Holzkoppel 4, 22869 Schenefeld, Germany
[2] Deutsches Elektronen-Synchrotron, Paul Scherrer Institut, University of Hamburg, University of Bonn

**Abstract**:

The European X-ray Free Electron Laser (XFEL.EU) is the world's most brilliant X-ray free-electron laser delivering of up to 27000 ultrashort (< 100 fs) spatially coherent X-ray pulses in the energy range between 0.25 and 20 keV, organized in 10 equidistant X-ray pulse trains per second [1]. The large variety of scientific applications at the XFEL.EU require different instrumentation, in particular different 2D imaging detectors which can cope with high repetition rate of 4.5 MHz. The facility went into its operation phase on July 1, 2017. The first two instruments, which were open for user experiments in September 2017, are the Femtosecond X-ray Experiments (FXE) instrument [2] focused on ultra-fast X-ray spectroscopy and X-ray scattering and the Single Particles, Clusters, and Biomolecules & Serial Femtosecond Crystallography (SPB/SFX) instrument [3] aiming for three dimensional structural determination of submicron scale, at atomic or near-atomic resolution using primarily serial crystallography or single particle imaging techniques.

The 1 Megapixel AGIPD detector [4] developed by the AGIPD Consortium is the primary detector used at the SPB/SFX instrument. The detector consists of a hybrid pixel array with readout ASICs bump-bonded to a silicon sensor with a pixel size of 200 μm × 200 μm. The ASIC is designed in 130 nm CMOS technology and implements a gain switching technology providing a dynamic range of $10^4$ photons at E = 12 keV. The ASIC internal analogue memory can store at the maximum 352 pulse resolved images. The images are subsequently read out and digitized during the 99.4 ms break between the XFEL X-ray pulse trains. I will report about the experience gained with the AGIPD detector during integration, commissioning and the first six months of user operation at the SPB/SFX instrument, including first calibration and characterization results.

[1] M. Altarelli et al., “European X-ray Free Electron Laser”, Technical Design Report, ISBN 978-3-935702-17-1 (2006).

[2] C. Bressler et al., “Technical Design Report: Scientific Instrument FXE,” European XFEL GmbH, Technical Report 2012-008 (2012).

[3] A. P. Mancuso et al., “Technical Design Report: Scientific Instrument SPB”, European XFEL GmbH, Technical Report 2013-004 (2013)

[4] B. Henrich et al.,” The adaptive gain integrating pixel detector AGIPD a detector for the European XFEL”, Nucl. Instr. and Meth. A, DOI: 10.1016/j.nima.2010.06.107.

## *Status of the JUNGFRAU project: detector design and result from the SwissFEL pilot experiment phase*

Aldo Mozzanica, M. Andrä, R. Barten, A. Bergamaschi, M.Brückner, R.Dinapoli, E.Fröjdh, D. Greiffenberg, C. Lopez-Cuenca, D. Mezza, M. Ramilli, S. Redford, M. Ruat, Ch. Ruder, B. Schmitt, X. Shi, D. Thattil, G. Tinti, S. Vetter, J. Zhang

Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

**Abstract**:

JUNGFRAU is a novel, two-dimensional pixel detector for high performance photon science applications at free electron lasers (FEL) and synchrotron light sources. It is developed primarily for the SWISSFEL machine [1], which is now starting operation at PSI.

JUNGFRAU is a charge integrating detector, featuring a three-stage, gain-switching preamplifier in each pixel, which automatically adjusts its gain to the amount of charge deposited on the pixel [2]. The automatic gain switching capability guarantees single photon sensitivity while covering a dynamic range of four orders of magnitude. In particular, photons with energies as low as 2keV can be detected with single photon resolution. The geometry of the JUNGFRAU module is similar to the one of the EIGER systems, with modules of 1024 × 512 pixels of 75 µm × 75 µm each, for a total of about 500 kpixels per module.

For the pilot experiment phase at SwissFEL 2 JUNGFRAU cameras have been installed at two end-stations: a 1.5M camera in air at the Bernina end-station, and a 4.5M in vacuum detector for X-ray emission spectroscopy at Alvra.

The talk will give a general overview of the detector and its performances, and will present the results of the JUNGFRAU commissioning and successful user operation during the SwissFEL pilot experiment phase. Results from PX measurements at synchrotron sources, with both monochromatic and pink beams, will also be reported.

[1] C. Milne et al., Appl. Sci. 2017, 7(7), 720, "SwissFEL: The Swiss X-ray Free Electron Laser" (2017)

[2] A. Mozzanica et al. J. Instr. 11, "Prototype characterization of the JUNGFRAU pixel detector for SwissFEL" C02047 (2016)

## *Detector calibration and data acquisition environment at the European XFEL*

Markus Kuster, S. Hauf, K. Wrona and S. Brockhauser for the European XFEL Detector, IT and Data Management (ITDM) and Control and Analysis (CAS) groups

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**Abstract**:

The European X-ray Free Electron Laser (XFEL.EU) is a high brilliance X-ray light source in Hamburg/Schenefeld, Germany, which commenced user operation at its first photon beam line in September 2018. In its final configuration, the facility will provide spatially coherent ultra short X-ray pulses (< 100 fs) in the energy range between 0.25 keV and 25 keV. The up to 27.000 X-ray pulses per second are delivered by the machine in a unique time structure consisting of up to 2700 X-ray pulses at the repetition rate of 4.5 MHz, organized in 10 equidistant pulse trains 10 times per second.

The large variety of scientific applications at the European XFEL require different instrumentation, in particular large area 2D imaging detectors which can cope with high pulse repetition rate of 4.5 MHz. Direct consequence of these high frame rates are the resulting raw data volumes of the order of 13 GByte per second and detector, data rates previously unprecedented in photon science. Additionally, the imaging detectors' on-sensor memory-cell and multi-gain-stage architectures pose unique challenges in detector-specific data corrections and subsequent calibration of scientific data. As a result, the European XFEL implemented a data processing and calibration concept quite novel to photon science, which moves these data preparatory steps away from facility users and instead provides them with a fully corrected and calibrated dataset as the primary data product.

I will present on overview on the data handling, data management and data processing concepts implemented at the European XFEL and the experience gained during first six months of user operation.

[1] M. Kuster, D. Boukhelef, M. Donato, J. S. Dambietz, S. Hauf, L. Maia, N. Raab, J. Szuba, M. Turcato, K. Wrona, and C. Youngman, "Detectors and Calibration Concept for the European XFEL," *Synchrotron Radiation News*, vol. 27, no. 4, pp. 35–38, Jul. 2014.

## *Building a data system for LCLS-II*

Jana Thayer

LCLS, SLAC National Accelerator Laboratory, San Francisco Bay Area 108

**Abstract**:

The volume of data generated by the upcoming LCLS-II upgrade will present a considerable challenge for data acquisition, data processing, and data management. According to current estimates, one instrument could generate instantaneous data rates of hundreds of GB/s. In this high-throughput regime, it will be necessary to reduce the data on-the-fly prior to writing it to persistent storage. Even with data compression, it is expected that operating all four new instruments will produce an estimated 100 PB of data in the first year alone.

We present a description of the envisioned LCLS-II Data System, which provides a scalable data acquisition system to acquire shot-by-shot data at repetition rates up to 1 MHz, an inline data reduction pipeline that provides a configurable set of tools including feature extraction, data compression, and event veto to reduce the amount of data written to disk, an analysis software framework for the timely processing of this data set, and an expanded data management system for accessing experiment data and meta-data.

## *DAQ system at SACLA and future plan for SPring-8-II*

Takaki Hatsui[1,2], T. Abe[1,2], T. Kameshima[1,2], K. Nakajima[1,2], T. Sugimoto[1,2], M. Yamaga[1,2], and Y. Joti[1,2]

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**Abstract**:

The X-ray free-electron laser facility SACLA has started the public beamtime since March 2011. Since then, we have improved the data acquisition, calculation and storage capacity. Currently, we operate a computing infrastructure with in total 125 TFLOPS and 11 PB, which is directly or indirectly connected to the beamline instruments such as X-ray imaging detectors. The SACLA DAQ and analysis systems can be described as *Center-Heavy computing infrastructure*, where all the instruments are cooperatively working together to enable data intensive XFEL experiments. We are proposing upgrade the synchrotron facility to DLSR (SPring-8-II). Toward the upgrade, we are developing a new fast framing integration type detector CITIUS. The detector data rate is reaching 140 Gbps per sensor tile (0.3 Mpixel), and demands intensive computation for the precise calibration. The foreseen computation power for the calibration reaches 80 TFLOPS for single sensor tile. Due to the computation hungry detector, we plan to have *Edge-heavy and Center-heavy computing infrastructure* with cloud computing resource for off-loading of the peak computing power. We present some idea on the planned upgrade, and results on the recent feasibility study.

## ***Current and planned technical solutions at ESRF for high throughput data acquisition and management***

Pablo Fajardo, A. Götz, L. Claustre, A. Homs, A. Solé, C. Nemoz, F. Calvelo and W. Mansour

ESRF – The European Synchrotron, 71 avenue des Martyrs, 38043 Grenoble, France

**Abstract**:

At present, the requirements and needs as well as the technical choices and solutions implemented at ESRF for data acquisition and management are not completely homogeneous across beamlines. However, the enormous challenges presented by the experiments requiring the highest throughput data flows are unavoidably enforcing a progressively higher and higher level of standardisation both in the data acquisition infrastructure and in the associated hardware and software tools. This presentation will give a very general overview of the current status and the foreseen evolution of the architectures and technical solutions chosen at ESRF to deal with data acquisition including aspects related to metadata management, as well as data analysis, data archiving and export.

The talk will also briefly present ongoing plans and R&D activities aimed at boosting data acquisition and on-line data processing close to the detectors. In particular, the development of a general configurable framework to implement RDMA based data transfer from the detectors to the first processing computing layers (RASHPA) and a new generation or the widely used LIMA library (LIMA3) that will allow distributed data acquisition and processing.

## ***High bandwidth data transfer in and off-chip for HEP: modeling, design and verification***

Tomasz Hemperek, H. Krüger

University of Bonn

**Abstract**:

Readout chips for silicon pixel detectors are one of the most complex parts of particle detectors for High Energy Physics (HEP) experiments. Their development experienced a fast increase in complexity and innovative features, driven by the progress in the semiconductor industry in recent decades. Main design challenges are large area, high granularity, very high data rate, long buffering time (trigger latency), an extremely hostile radiation environment, and high constraints on power consumption. This presentation shows the recent developments of mixed-signal pixel readout chips designed for HEP experiments like ATLAS, CMS, LHCb and Belle II in 130 and 65nm technologies. The primary focus is on modeling of data processing, buffering and encoding, modern verification methodologies, and digital-on-top design flow including multi-gigabit transmission interfaces between the chip and data acquisition systems.

## *The Mu3e data acquisition system – handling Terabits per second*

Sebastian Dittmeier for the Mu3e collaboration

Physikalisches Institut, Heidelberg University

**Abstract**:

The Mu3e experiment at PSI searches for the charged lepton flavour violating decay $\mu^+ \rightarrow e^+e^-e^+$ with a target sensitivity of one in $10^{16}$ decays. A continuous beam of $10^8 - 10^9$ muons per second is stopped on a target and the decays are studied using an ultra-thin silicon pixel tracking detector, scintillating fibres and scintillating tiles.

The Mu3e detector consists of several thousand sensors that send their zero-suppressed data continuously without a hardware trigger to the data acquisition system (DAQ). Using three stages, the DAQ collects the data on FPGAs at the front-end, merges the data streams of all sub-detectors and performs online event reconstruction and selection on GPUs. In this scheme, the raw data rate of several terabits per second is reduced to 50 - 100 MB/s that can be stored to disk.

In this talk, the current developments of the Mu3e DAQ will be presented. Challenges and technological advances will be discussed.

## *Modern DAQ architectures for HEP experiments: intelligent detectors and smart data reduction in the era of Big Data*

Emilio Meschi

CERN – CH1211 Geneva 23, Switzerland

**Abstract**:

Future HEP experiments, including the HL-LHC upgrades, will feature massive high-precision trackers, extreme granularity calorimeters, some based on silicon sensors, and improved muon systems capable of high-efficiency identification. The use of fast optical links enables unprecedented data rates, in the tens of Tb/s range, necessary to fully exploit these detectors. A clear trend over the last two decades has also been to progressively reduce the role of custom hardware triggers in favor of faster readout, and software triggers. In many instances, however, power/cooling infrastructure and the subsequent material budget, still make a two-stage data acquisition a necessary choice. The brute-force readout of the upgraded LHC detectors at the full machine clock speed, for example, is still technically challenging.

In my presentation, I will discuss the different approaches to exploit these powerful detectors while performing data reduction at early stages, along with potential alternatives, including alternative readout schemes. I will review how "intelligent" detectors - along with their corresponding fast hardware feature-extraction engines – can partially overcome the inherent efficiency limitations of a two-level trigger system and optimize the use of available bandwidth. I will focus on common practices for online data reduction and selection and how they can be streamlined and standardized using techniques nowadays ubiquitous in other fields of data science. I will conclude by outlining possible architectures that can process the massive amount of data and preemptively extract and index the interesting features.

# Full list of participants

| | | |
|---|---|---|
| Douglas | BENNETT | National Institute of Standards & Technology |
| Paolo | BUSCA | ESRF |
| Gabriella | CARINI | SLAC National Accelerator Laboratory |
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| Heinz | GRAAFSMA | DESY |
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| Jean Marie | POLLI | Brazilian Synchroton Light National Lab-LNLS |
| Matteo | PORRO | European XFEL GmbH |
| Thomas | REGIER | Canadian Light Source |
| Rainer | RICHTER | MPI-HLL |
| Abdul | RUMAIZ | Brookhaven National Laboratory |
| Bernd | SCHMITT | Paul Scherrer Institute |
| Paul | SCOULLAR | Southern Innovation |
| Paul | SELLIN | University of Surrey |
| David Peter | SIDDONS | Brookhaven National Laboratory |
| Fei | SONG | Shanghai Institute of Applied Physics - CAS |
| Jolanta | SZTUK-DAMBIETZ | European XFEL |
| Nicola | TARTONI | Diamond Light Source |
| Jana | THAYER | SLAC National Accelerator Laboratory |
| Johannes | TREIS | MPI-HLL |
| Matthew | VEALE | STFC Rutherford Appleton Laboratory |