The LAMBDA detector and High-Z developments

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Overview

LAMBDA (Large Area Medipix3-Based Detector Array)

- System
- High-Z detector developments

Applications at synchrotrons
Medipix3 readout chip

> Collaboration of ~20 groups led by CERN

> Flexible pixel design
  - 2 counters and thresholds per 55µm pixel, plus interpixel communication

> Applications:
  - Fast, deadtime-free frame readout
    - 2000 fps @ 12 bit depth
  - Energy binning with charge summing
  - Pump / probe…
Module design

- 12 readout chips bonded to large Si sensor

256 x 256 chip

1536 x 512 module (750k)

1.5k x 1.5 k multimodule
High-speed readout electronics

- Based on common DESY high-speed readout card
  - Virtex-5 FPGA plus on-board RAM
  - Up to four 10 Gigabit Ethernet links for high-speed readout to PC

Thanks to: Igor Sheviakov, Qingqing Xia, Manfred Zimmer – DESY FEA
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X-ray tube tests with silicon detector
High-Z pixel detectors

- **Aim:** Increase QE at 50 keV by factor of 10
  - replace silicon sensor in LAMBDA with high-Z semiconductor
  - Combine high QE with hard X-rays, high frame rate, high signal-to-noise

- Investigating different materials in collaboration with other institutes and industry
  - Cadmium telluride
  - Gallium arsenide
  - Germanium

*Photoelectric absorption of X-rays*
Cadmium Telluride

- Collaboration with Uni Freiburg
  - 1 mm-thick CdTe from Acrorad
  - Hexa layout (768 x 512 pixel, 55um pixel size)

Flat field (300V)

USB stick, FF corrected
Gallium Arsenide

> Collaboration with Uni Freiburg & RID Ltd (Tomsk)

- 500μm-thick Cr-compensated GaAs
- Hexa layout (768 x 512 pixel, 55μm pixel size)

Flat field (300V)
Ge hybrid pixel detector production

- 2 high purity Ge wafers produced by Canberra France
  - 16 sensors / wafer
  - 55µm pixel size, 256 x 256 pixels
  - ~700µm thick
  - Electron readout (n contact)

- Indium bump bonding at Fraunhofer IZM (Berlin)
  - Low-temperature process necessary to avoid damage to Ge
  - Ductility of indium prevents cracking of bonds during cooling
Test results from prototype sensors

- Tested around -100°C to -110°C in vacuum chamber (-100V bias)
- High pixel yield, generally uniform response
  - Edge pixels nonfunctional due to high leakage current

Flat illumination from 50kV Ag

USB stick (uncorrected)
Further work on Germanium

- Hexa-sized Ge sensors produced at Canberra
  - Still to be bump-bonded at IZM
- Portable cooling and vacuum system in development
Experiments with LAMBDA at PETRA-III + Others

- P02 (GaAs sensor) – Time-resolved extreme conditions experiments
- P03 – Time resolved GISAXS
- P05 – High-speed tomography with HZG
- P06 – Ptychography
- P08 – GISAXS
- P10 – Rheology and XPCS (3 blocks of beamtime, each with 3 groups); Waveguide imaging; Ptychography
- P11 – Ptychography, measurements of multilayer optics
- February 2014: ESRF/DUBBLE (Rheology)
- June 2014: ESRF/ID15 (High E) + DIAMOND (Rheology)
Extreme conditions experiments (PETRA P02.2)

- Extreme pressure in diamond anvil cell (100GPa), extreme temperature from laser heating (3000 °C) – equivalent to > 1000 km depth
  - Hard X-rays needed (42 keV here)

Detector measures scattering pattern
How quickly can we measure structure?

- GaAs detector tested at P02.2
  - 42 keV energy
- Useful data obtained from test standards in 1ms
  - Powder samples – produce distinct diffraction rings
- Plan to use larger systems to measure rapid changes in samples
Rheology

- Investigates structure changes and particle dynamics in fluids under shear forces
- Requires high frame rate, high SNR, small pixel size
Large amplitude oscillatory shear on nematic colloidal platelets

Result:
Time- and spatial-resolved structure information

Lettinga, Struth et al, PRL 109, 246001 (2012)

f=0.04 Hz, strain=6.4

Thanks to Pavlik Lettinga, Peter Holmqvist - Jülich
Summary

➢ LAMBDA systems working with a variety of materials
  ▪ Development continuing on larger-area systems
  ▪ Germanium sensors show high quality and good bump yield

➢ Useful for a range of experiments requiring high speed, small pixels and high sensitivity

Thank you