Pseudo-3D pixel detectors for powder diffraction

Martijn Fransen
Agenda

- Solid state position-sensitive detectors @PANalytical
- Spatial resolution … in three dimensions
- The importance of dynamic range
- Dealing with polychromatic radiation
- The challenges of non-Cu radiation
- Conclusions
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Around 1985 Philips started with position-sensitive detectors

2001: X’Celerator: the world’s first solid state strip detector reducing measurement time for powder diffraction data from hours to minutes

2007: PIXcel1D: a solid state strip detector with more and narrower channels and a highly improved dynamic range, based on Medipix2 technology

2010: PIXcel3D: the first solid-state hybrid pixel detector allowing 0D-1D-2D-3D experiments

2012: PIXcel3D 2x2: enlarged angular coverage

2014: Introduction of Medipix3 technology; enhanced wavelength coverage

2015: Introduction of GaliPIX: a new large solid-state 2D detector, optimized for hard radiation experiments
The origin of Medipix technology

From the huge Atlas detector…

… to the PIXcel detector family that fits a lab diffractometer
The latest addition: GaliPIX\textsuperscript{3D}

- Developed by Pixirad, an INFN spin-off
- High-quality sensor material
  - Large stopping power of Cd and Te
  - 100% absorption efficiency @ 25 keV
- High resolution
  - Pixel size 60 μm
- Large field of view
  - Active area 31 x 25 mm\textsuperscript{2}

Absorption comparison

Galileo Galilei
(1564 – 1642)
Basic working principles

X-ray source

X-rays

object to image

flip-chip bump bonding connections

CMOS pixel read-out chip

semiconductor sensor chip

single pixel read-out cell

Bias Voltage

N-diffusion

Detector substrate (Si)

P-electronics

Counter Particle count

Pixel electronics

P-electronics

P-electronics
### Key specifications

<table>
<thead>
<tr>
<th></th>
<th>PIXcel(^{3D})</th>
<th>PIXcel(^{3D}) 2x2</th>
<th>GaliPIX(^{3D})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detector size (pixels)</td>
<td>256 x 256 pixels</td>
<td>516 x 516 pixels</td>
<td>512 * 476 pixels</td>
</tr>
<tr>
<td>Detector size (mm)</td>
<td>14.1 mm * 14.1 mm</td>
<td>28.4 mm * 28.4 mm</td>
<td>30.1 mm * 24.2 mm</td>
</tr>
<tr>
<td>Pixel size</td>
<td>55 µm * 55 µm</td>
<td>60 µm * 51 µm</td>
<td></td>
</tr>
<tr>
<td>Point spread function</td>
<td>1 pixel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>99 % linearity range</td>
<td>0 - 6.5 x 10(^9) cps - Overall</td>
<td>0 - 5.2 x 10(^9) cps - Overall</td>
<td>0 - 3.9 x 10(^9) cps - Overall</td>
</tr>
<tr>
<td></td>
<td>0 - 25 x 10(^6) cps - Column</td>
<td>0 - 1 x 10(^7) cps - Column</td>
<td>0 - 7.8 x 10(^6) cps - Column</td>
</tr>
<tr>
<td>Background noise (whole detector)</td>
<td>&lt; 0.5 counts / s</td>
<td>&lt; 2 counts / s</td>
<td>&lt; 6 counts / s</td>
</tr>
<tr>
<td>Dynamic range</td>
<td></td>
<td>&gt; 10(^9)</td>
<td></td>
</tr>
<tr>
<td>Energy discrimination</td>
<td></td>
<td>Two level discriminator (user adjustable)</td>
<td></td>
</tr>
<tr>
<td>Calibration by user</td>
<td></td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Exchange of detection medium</td>
<td></td>
<td>None (solid state technology)</td>
<td></td>
</tr>
</tbody>
</table>
Hybrid pixel detectors: four modes of operation

0D

The signal from all pixels is added up to lead one value as a function of detector position

1D

The signal from each column is added up, creating a static or scanning 1D detector

2D

The signal from each pixel is stored individually, the detector is used static or scanning. In scanning mode, a ‘strip file’ is created which resembles a Debye-Scherrer film

3D

The signal from each pixel is stored individually, the sample is rotated in order to get multiple radiographs for 3D reconstruction
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The point spread function (PDF) describes the spread of one event (an incoming photon) over its neighbors.

With hybrid pixel technology, this effect is virtually absent: the PSF has a width of 1 pixel.
Want to see the full presentation?

Send me an e-mail with your name and address details and I’ll send you the full version

martijn.fransen@panalytical.com
Summary

- Hybrid pixel detectors are the state-of-the-art in X-ray detection
- Key detector parameters for the powder lab:
  - **Spatial resolution** in x, y and z, angular coverage
  - **Dynamic range** and low noise
  - 2-level **energy discrimination** to deal with the tube-sample spectrum
  - Ability to deal also with **non-Cu radiation**
The PANalytical Award

- The PANalytical award recognizes and praises groundbreaking research that required the use of a laboratory X-ray diffraction, X-ray fluorescence or X-ray scattering instrument as the primary analytical technique.

- As such, recipients will not be limited to any brand of instrument, but rather to research that utilised an X-ray source to reach their conclusions.

- The annual award consists of a €5 000 cash prize, a trophy and a certificate.

- http://www.panalytical.com/Events-overview/The-PANalytical-Award.htm

- Submissions for the PANalytical Award will be accepted until and including 1 December 2016. The full application form is to be completed by the first author of the journal article. Questions may be directed to award@panalytical.com