Upgrade of the detector for imaging of explosions

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Detector for Imaging of Explosions (DIMEX) is successfully used at beam line 0 at VEPP3 and at beam line 8 at VEPP-4M for more than 15 years.

VEPP-4M, beam line 8

VEPP-3, beam line 0
Main DIMEX parameters:

Spatial resolution \(\sim 200 \mu m\) FWHM (electron diffusion in gas)
Max. frame rate 2 MHz (front-end ASIC)
Channel pitch – 100 \(\mu m\), number of channels 512
Number of frames – 32 (front-end ASIC)
Maximum signal \(\sim 5000\) photons/chan*bunch (space charge in gas, front-end ASIC)
Noise \(\sim 2000e\) (\(\sim 7\) photons, 20 keV)

DIMEX-G
Gaseous detector with new front-end ASIC
Max frame rate - 10 MHz
Number of frames – 100
Maximum signal – \(2 \times 10^6\) e (\(\sim 7000\) photons, 20 keV)
Noise - \(< \sim 4000\) e

DIMEX-Si
Si micro-strip detector with new front-end ASIC
Max frame rate – 50 MHz
Spatial resolution – 50 \(\mu m\) FWHM
Channel pitch – 50 \(\mu m\), number of channels – 1024
Maximum signal – \(10^6\) photons/chan*bunch (20 keV), noise - \(< \sim 100\) photons (5*10^5 e)
Development of new ASIC based on 180 nm technology
2013-2014 2 iterations of prototypes
Block-diagram of the final ASIC

ENC vs capacitance for DMXG12B
DIMEX-G
DMXG64A
64 channels
100 analogue cells in each channel
Size ~ 6x6 mm
Input pads pitch ~60 µm
Noise ~ 3000 e
Max. signal ~2x10^6 e
Max. frame rate 10 MHz
DIMEX-G

Signal from DMXG64A vs input charge

Signal from DMXG64A vs delay between detector clock and bunch passing moment
DIMEX-Si

SR spectra from 7-pole wiggler in comparison with VEPP-3 beam line 0

<table>
<thead>
<tr>
<th>Conditions</th>
<th>no detector</th>
<th>0.3 mm Si</th>
<th>10 mm Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>VEPP-3, total flux (ph/bunch*chan)</td>
<td>1.7x10⁴</td>
<td>8.9x10³</td>
<td>1.7x10⁴</td>
</tr>
<tr>
<td>VEPP-3, average energy (keV)</td>
<td>16.6</td>
<td>13.4</td>
<td>16.5</td>
</tr>
<tr>
<td>VEPP-4M, 4GeV, total flux (ph/bunch*chan)</td>
<td>3.7x10⁵</td>
<td>1.0x10⁵</td>
<td>3.5x10⁵</td>
</tr>
<tr>
<td>VEPP-4M, 4GeV, average energy (keV)</td>
<td>25.8</td>
<td>17.4</td>
<td>24.2</td>
</tr>
<tr>
<td>VEPP-4M, 5GeV, total flux (ph/bunch*chan)</td>
<td>9.3x10⁵</td>
<td>1.9x10⁵</td>
<td>8.1x10⁵</td>
</tr>
<tr>
<td>VEPP-4M, 5GeV, average energy (keV)</td>
<td>33.0</td>
<td>19.3</td>
<td>30.0</td>
</tr>
</tbody>
</table>
Si microstrip sensors produced by Hamamatsu Photonics p-on-n technology
DC coupled metal strips
polysilicon resistors between each strip and guard ring
wide guard ring
30 mm long strips
50 µm strip pitch
320 µm sensor thickness

Sensor position in the final detector
Resistance of the polysilicon resistor as a function of current

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum total photon flux per bunch per channel</td>
<td>$8.1 \times 10^5$</td>
</tr>
<tr>
<td>Average photon energy, keV</td>
<td>30.0</td>
</tr>
<tr>
<td>Maximum released charge per bunch per channel</td>
<td>$6.75 \times 10^9$ e $\approx 1.1 \times 10^{-9}$ C</td>
</tr>
<tr>
<td>Peak current per bunch per channel (current pulse duration 1 ns)</td>
<td>1.1 A</td>
</tr>
<tr>
<td>Average current per channel with open fast shutter (300 ns between bunches)</td>
<td>3.7 mA</td>
</tr>
</tbody>
</table>
DIMEX-Si

Voltage pulse at 50 Ohm load from one strip, induced by SR flash from one bunch (sensor at 90°, 43 m from source, 10 mA)

Charge from one strip induced by one SR flash, 33 m from the source, 7 mA
Charge from one strip induced by one SR flash, 33 m from source, 7 mA

Charge from one strip per mA vs Si effective thickness. Measurement and simulation.
Prototypes of new ASIC for Si detector were produced in autumn 2015. At present the detector prototype with Si microstrip sensor and 10 new ASICs (120 channels) is under construction.
Conclusions

New ASIC DMXG64A has been developed for the DIMEX-G, It allows to perform experiments with max. frame rate 10 MHz, noise at 3000 e and max. signal up to $2 \times 10^6$ e.

Full-size detector with the new chips was assembled and is being tested now.

Si microstrip sensors from Hamamatsu were tested at high intensity SR beam at beam line 8 at VEPP-4M, the sensors demonstrate stable operation with $\sim 10$ times higher photon rate than at VEPP-3 beam line 0.

Polysilicon resistors have non-linear behavior and have to be substituted by different technology.

Two kinds of slow components of the signal was found during measurements ($\sim 20$ ns and $\sim 50$ ns) that will make difficult precise measurement of the induced charge within 20 ns, however it is possible within 50 ns.