Fabrication and performance test of the silicon photo-strip detector coupled with a crystal scintillator

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We develop a silicon photodetector coupled with a crystal scintillator. The silicon photo-strip detector consists of a single crystal and two silicon photo-strip sensors. The photo-strip sensor is designed and fabricated based on concept of a AC-coupled single-sided silicon strip sensor but the incident layer of the strip sensor is modified to detect scintillation light. The two photo-strip sensors sandwiching opposite face of one crystal scintillator are oriented orthogonal to each other. When a particle enters a crystal, the scintillation light is emitted and converted into electronic signals in the silicon photo-strip sensors. This detector configuration provides the two-dimensional position information and a depth of interaction by measuring signal ratios between the first and second photo-strip sensors. This detector concept can be applied in radiation, medical applications and nuclear medical cameras.

- One crystal scintillator + two photo-strip sensors
- Two sensors sandwiching opposite faces of a scintillator are oriented orthogonal to each other
- The detector provides position information in x, y, z coordinate
- A depth of interaction by measuring signal ratios between the first and second photo-strip sensors
- The device may be applied in radiation application, medical application, and nuclear medical cameras

**Electrical characteristics**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current (nA)</td>
<td>50 ± 10</td>
</tr>
<tr>
<td>Threshold voltage (V)</td>
<td>1 V</td>
</tr>
<tr>
<td>Dynamic range (V)</td>
<td>10 V</td>
</tr>
<tr>
<td>Capacitance (pF)</td>
<td>50 ± 10</td>
</tr>
<tr>
<td>Gain</td>
<td>200</td>
</tr>
</tbody>
</table>

**Spectral response of the PIN photodiode**

- Silicon PIN photodiode (1.0 mm x 1.0 mm)
- Quantum efficiency (%)
  - 400 nm: 45%
  - 500 nm: 55%
  - 600 nm: 65%

**Photometry**

- LED - 850 nm: 65 nm > 95% QE
- LED - 950 nm: 60% QE

**Performance test results of the photo-strip sensor with readout electronics**

- The photo-strip detector provides 2 dimensional position information
- From 2D position results, we can also obtain the interaction point of LED by position height distribution of two photo sensors
- Plan for imaging test with a (CaTl) crystal

**Schematics of the electronics and Picture of the home-made DAQ board**

**Conception of detector**

**Conceptual drawing of the detector**

**Pictures of the Ca(Tl) coupled fabricated sensor on the hybrid board**

**Pulse height distributions with various radioactive sources**

**Reconstruction of 2D position information by using the LED source**

**Position reconstruction of the LED source**

**Silicon photo-strip sensors are developed**

- Deep bulk 100/300 μm thickness
- PIN photodiode
- Fabricated sensors show good electrical characteristics
- Depletion voltage ~ 65V
- Leakage current ~ 24A/strip
- Sensors show good photosensitivity

**Fabrication and performance test of the silicon photo-strip detector**

**Fabricated sensors show good electrical characteristics**

- Energy resolution: 13.8% (611 keV, gamma-ray)
- The readout electronics is tested with the photo-strip sensor
- Energy resolution: 13.8% (611 keV, gamma-ray)
- The photo-strip detector provides 2 dimensional position information

**Depletion voltage ~ 65V**

**Hybrid board**

- Hybrid board
- Photo-strip sensor
- PIN photodiode
- Preamp
- FADC
- 4-channel trigger system
- Xilinx Virtex 4PX-200 FPGA
- Ethernet board

**Readout electronics and DAQ system**

**Ethernet board**

- ASDA: Analog signal detector
- Sense amplifier: 4-channel, gain: 1000
- ADC: 12-bit, 4-channel
- Ethernet board

**PC**

- Windows
- Xilinx ISE (10.1)
- Ethernet board
- Xilinx Virtex 4PX-200 FPGA
- Xilinx ISE (10.1)

**Performance test with a Ca(Tl) crystal**

- LED - 850 nm: 65 nm > 95% QE
- LED - 950 nm: 60% QE

**Spectro-photometry test at Korea Research Institute of Standards and Science**

- LED - 850 nm: 65 nm > 95% QE
- LED - 950 nm: 60% QE

**Spectra-photometry**

- LED - 850 nm: 65 nm > 95% QE
- LED - 950 nm: 60% QE

**Performance test results with a Ca(Tl) crystal**

- LED - 850 nm: 65 nm > 95% QE
- LED - 950 nm: 60% QE