Results on Opto-Link R&D

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Outline

- Radiation hardness of PIN arrays
- Radiation hardness of VCSEL arrays
- Study of opto-chips
- Summary
Opto-Link at SLHC

● ATLAS is a detector studying pp collisions of 14 TeV at CERN
  ✷ silicon detectors use opto-links for data transmission
  ✷ pixel detector is innermost tracker
  ✷ new barrel layer with smaller radius planned in 2013
  ✷ detectors upgrade planned for Super-LHC in 2016

⇒ study radiation-hardness of VCSEL and PIN arrays and opto-chips for the opto-link upgrades
Radiation-Hardness of Silicon PIN

- irradiate PIN with 24 GeV protons at CERN
  - SLHC dosage: $2.6 \times 10^{15}$ p/cm$^2$ ($1.5 \times 10^{15}$ 1-MeV n$_{eq}$/cm$^2$)
  - 2007 irradiation with 60% higher dosage:
    - Taiwan array responsivity (A/W): decrease by a factor of 3
  - 2008 irradiation with SLHC dosage:
    - Taiwan array responsivity: decrease by a factor of 2
    - Hamamatsu device responsivity: decrease somewhat less
Radiation-Hardness of GaAs PIN

- Irradiate PIN with 24 GeV protons at CERN
  - SLHC dosage: $2.6 \times 10^{15} \text{ p/cm}^2 (8.2 \times 10^{15} 1\text{-MeV n}_{eq}/\text{cm}^2)$
  - 2007 irradiation with 60% higher dosage:
    - Responsivity: decrease by a factor of 10
  - 2008 irradiation with SLHC dosage:
    - Responsivity: decrease by a factor of 2-4
Radiation-Hardness of GaAs PIN

Preliminary

- 2007 irradiation with 60% higher dosage:
  - Optowell responsivity: decrease by a factor of 10
- 2008 irradiation with SLHC dosage:
  - Optowell responsivity: decrease by a factor of ~2
  - Hamamatsu responsivity: decrease by a factor of ~1.6
### Radiation-Hardness of PIN

<table>
<thead>
<tr>
<th>Material</th>
<th>Gb/s</th>
<th>Responsivity (A/W)</th>
<th>Pre</th>
<th>Post</th>
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<tr>
<td>GaAs</td>
<td>4.25</td>
<td>0.50</td>
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<td>ULM</td>
<td>2.5</td>
<td>0.60</td>
<td>0.19</td>
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<td>AOC</td>
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<td>0.25</td>
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<td>Optowell</td>
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<td>0.32</td>
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<td>Hamamatsu G8921</td>
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<td>0.33</td>
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<td>Si</td>
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<td>Taiwan</td>
<td>1.5/2.0</td>
<td>0.25</td>
<td>0.21</td>
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</table>
VCSEL Power vs Dosage

- 2007 irradiation with 60% higher dosage:
  - close to zero power on some channels
- 2008 irradiation with SLHC dosage:
  - AOC(5 & 10 G) have good power
Opto-Chips

0.13 µm

640 Mb/s VCSEL Driver

3.2 Gb/s VCSEL Driver

640 MHz clock multipliers
(4 x 160 and 16 x 40 MHz)

PIN receiver/decoder
(40, 160, 320 MHz)
VCSEL Driver Chip

- Slow VDC 640 Mb/s
- Fast VDC 1 Gb/s
- Fast VDC 3.2 Gb/s

- both chips are working in preliminary study
- LVDS receiver working at high speed
- need detailed study without package

K.K. Gan
Siena08
VDC Irradiation

- Drive current decreases with radiation for constant ISET
- Need detailed study after cool down

K.K. Gan

Siena08
Receiver/Decoder Chip

- Properly decode 40, 80, and 160 Mb/s signals but not 320 Mb/s
  - LVDS-like output has proper amplitude and baseline
  - small clock jitter (e.g. < 50 ps @ 160 MHz)
  - no significant degradation after irradiation

Threshold for 1 bit error/s
Clock Multiplier

- Both 4 x and 16 x clock multipliers work
  - clock jitter < 8 ps (0.5%)
  - two of the four chips lost lock during irradiation
    - need power cycling to resume operation at 640 MHz
  - no change in current consumption
Summary

- Good PIN candidates identified for SLHC opto-link
- Good VCSEL candidates identified for SLHC opto-link
- First 0.13 μm submission mostly successful
  - full characterization of pre/post irradiation in progress
  - aim for next iteration in winter 2009