Radiation Testing of Versatile Transceiver for Versatile Link Project

Results and plans

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Outline

- Introduction
- Results from radiation test
- Conclusions
First radiation test of complete Versatile Transceiver
- 20 MeV neutron beam in Louvain-La-Neuve, total dose of \( \sim 1 \times 10^{15} \) n/cm\(^2\)

### Devices tested

<table>
<thead>
<tr>
<th>DUTs</th>
<th>Tx</th>
<th>ROSA</th>
<th># Tested</th>
</tr>
</thead>
<tbody>
<tr>
<td>SM VTRx</td>
<td>1310 nm EEL</td>
<td>InGaAs</td>
<td>2</td>
</tr>
<tr>
<td>MM VTRx</td>
<td>850 nm VCSEL</td>
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- SM VTRx:
  - 1310 nm EEL InGaAs
  - 2 tested

- MM VTRx:
  - 850 nm VCSEL GaAs
  - 2 tested

Device irradiated in UCL November 2013

VTRx on irradiation PCB
- First radiation test of complete Versatile Transceiver
  - 20 MeV neutron beam in Louvain-La-Neuve, total dose of ~ $1 \times 10^{15}$ n/cm$^2$
- Sensitivity of VTRx to SEUs (on receiver side) measured during the test
- Expected increase in BER during irradiation because of SEUs

<table>
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<tr>
<th>Time Elapsed [hrs]</th>
<th>OMA [dBm]</th>
<th>Pre-Irradiation</th>
<th>Increasing Fluence</th>
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<tr>
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- Error Cross-Section [n/cm²]
Sensitivity of ROSAs to SEUs

- Sensitivity of VTRx to SEUs (on receiver side) measured during the test
  - Expected increase in BER during irradiation because of SEUs

- Error cross-section comparable with other test results
  - same ROSAs tested in PSI proton beam-line
Sensitivity of ROSAs to SEUs

- Sensitivity of VTRx ROSAs to SEUs changes during the irradiation
  - bigger change in SM VTRx compared to MM VTRx

![Graph showing sensitivity of ROSA vs time elapsed]

Gap in Data

caused by change in responsivity?
Sensitivity of ROSAs to SEUs

- Sensitivity of VTRx ROSAs to SEUs changes during the irradiation
  - bigger change in SM VTRx compared to MM VTRx

- RSSI current measurement used to calculate change of responsivity of ROSAs during irradiation

caused by change in responsivity?
Sensitivity of ROSAs to SEUs

- Change in responsivity of devices comparable with pin photodiodes tested

Would still only predict ~ 1dB change in the sensitivity of the devices to SEUs during irradiation
- Change in responsivity of devices comparable with pin photodiodes tested

- Would still only predict ~ 1dB change in the sensitivity of the devices to SEUs during irradiation

- Points to change in leakage current being more important than previously thought?
- LI curves of transmitters collected during irradiation
  - gap in the data due to problems with set-up during test

- Expected change in performance of transmitters: increase in threshold current and decrease in slope efficiency

- Fraction of the damage anneals post-irradiation
Effect of radiation on transmitter, DC

- Are predictions for the expected change in threshold current in VTRx transmitters from irradiations on components measured DC-only of the VTRxs accurate?
  - transmitters from the same manufactures irradiated in the same test
  - comparison between the change in threshold current in both VTRx and transmitter therefore possible
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Effect of radiation on transmitter, DC

- Can radiation tests on MMVCSELs predict how the voltage headroom changes during exposure to radiation?
  - Voltage headroom problem
    - bias current that the GBLD is capable of supplying to the transmitter is limited by the voltage headroom of the chip

![Graph showing bias current setting vs. bias voltage for GBLD v4.1 and v5 at Vdd = 2.5 V, T = 10°C. The graph includes a legend for the fraction of final bias current and bias current settings.]
- Can radiation tests on MM VCSELs predict how the voltage headroom changes during exposure to radiation?

  - Voltage headroom problem
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    - observed as saturation in the LI curve of the VTRx

![Graph showing the effect of radiation on transmitter, DC voltage headroom.](image)
Effect of radiation on transmitter, DC

- Can radiation tests on MM VCSELs predict how the voltage headroom changes during exposure to radiation?
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  ![Graph of LI curve showing saturation point](image)

  - Expect to see a change in the saturation point of the MM VTRx during irradiation
    - can we use the information from the VI curves of irradiated transmitters to predict how the saturation point changes?
Effect of radiation on transmitter, DC

- Voltage at which the GBLD head-room is no longer sufficient extracted from the pre-irradiation data ($V_{max}$)
- Voltage at which the GBLD head-room is no longer sufficient extracted from the pre-irradiation data ($V_{max}$)

- Compare bias current at ($V_{max}$) from VI curves of transmitters to saturation point from LI curves of MM VCSELs during irradiation
  - trends are the same for both devices
  - can use VI data of MM VCSELs to predict change in saturation point of MM VTRxs
- Assumption has always been that the spec for the slope efficiency of the transmitter is such that no additional radiation penalty is required:
  - transmitters threshold current and slope efficiency change during irradiation
  - OMA depends on both
  - can we maintain the minimum OMA during irradiation?
  - if not, can we adjust the settings of the VTRx to compensate?

\[
\text{OMA} = P_1 - P_0 = I_{\text{mod}}\eta \Rightarrow \eta = \frac{OMA}{I_{\text{mod}}}
\]

\[
\frac{OMA}{I_{\text{mod}}} \geq \eta_{\text{min}}
\]
Effect of radiation on transmitter, AC

- Assumption has always been that the spec for the slope efficiency of the transmitter is such that no additional radiation penalty is required:
  - transmitters threshold current and slope efficiency change during irradiation
  - OMA depends on both
  - can we maintain the minimum OMA during irradiation?
  - if not, can we adjust the settings of the VTRx to compensate?

- Tried to change the transmitter settings (I_{mod}, I_{bias}) during the test with information obtained from the LI curves to maintain a “good” eye
  - if we do nothing (i.e. default settings)
  - worst in SM case than MM case

\[
OMA = P_1 - P_0 = I_{mod} \eta \Rightarrow \eta = \frac{OMA}{I_{mod}}
\]

\[
\left. \frac{OMA}{I_{mod}} \right|_{irrad} \geq \eta_{\text{min}}
\]
- Tried to change the transmitter settings (Imod, Ibias) during the test with information obtain from the LI curves

**Default Settings**

- SM_VTRx_A: Ibias = 24.08 mA, Imod = 20.000 mA
  - Fluence = 1.2e+15 n/cm²

- MM_VTRx_B: Ibias = 6.96 mA, Imod = 6.000 mA
  - Fluence = 1.6e+15 n/cm²

**Optimized Settings**

- SM_VTRx_A: Ibias = 40.08 mA, Imod = 20.000 mA
  - Fluence = 1.18e+15 n/cm²

- MM_VTRx_B: Ibias = 6.96 mA, Imod = 6.000 mA
  - Fluence = 1.55e+15 n/cm²
Effect of radiation on GBLD v4

- Checked for SEUs in the GBLD during irradiation
  - GBLD registers read at regular intervals during the test and compared against “default” values

![Graph showing data for different GBLD registers during pre-irradiation, during-irradiation, and post-irradiation.](image)
Effect of radiation on GBLD v4

- Checked for SEUs in the GBLD during irradiation
  - GBLD registers read at regular intervals during the test and compared against “default” values

- Clearly see errors in the GBLD during irradiation
  - error cross section: $1.2 \times 10^{-14}$ errors/n/cm$^2$
  - other devices behaved in a similar manner

Further away from the beam
Effect of radiation on GBLD v4

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  - GBLD registers read at regular intervals during the test and compared against “default” values
  - Clearly see errors in the GBLD during irradiation
  - error cross section: $1.2 \times 10^{-14}$ errors/n/cm$^2$
  - other devices behaved in a similar manner

- Checked whether these errors were “detectable” by any of the on-line measurements we were doing

Further away from the beam
Conclusions

- First radiation test on full VTRx object
  - SM and MM variants with GBLD v4.1 and GBTIA v2 tested
  - transmitters degrade in the same manner predicted by radiation tests carried out on the passive components
  - change of saturation point of MM VTRxs can be predicted from the change in the VI curves of the transmitters during irradiation
  - leakage current of the photodiodes has a higher than expected impact on the sensitivity of the ROSAs to SEUs
  - SEUs observed in the GBLD

- Future Plans
  - Qualification of lasers and photodiodes for production of VTRxs
Back-Up Slides