VCSEL Radiation Results with 20 MeV neutrons

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5 year SLHC fluences in 1MeV neutrons

Challenging radiation environment!!

Cyclotron at UCL in Belgium – 20 MeV Neutrons

1st test in collaboration with CMS March 06:
Great success!!

VCSELs irradiated up to $\sim 10^{16}$ n(1MeV/cm$^2$) and annealed for 2 weeks @ 10mA and 1.5 weeks @ 15mA. Devices were monitored during radiation and annealing.
Experimental Setup

Control Room

- Power supply
- Switch unit
- LAPD box
- LED and PIN

Beam Room

- 2m SIMM fibres
- 30m GRIN fibres
- 20m power cable
- 40 VCSELs (Oxide implant)
- Monitoring fibre (no change in GRIN fibre performance)

neutron beam
Experimental setup

Array with 8 VCSELs

5 of these boards

Boards put into carrier box

Box was kept at constant T

Carrier box

Power cables

Rad hard fibres
Experimental Setup LAPD Box (open)

Not shown in picture: Each LAPD was separated by light tight walls from each other.

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Experimental Setup

Circuit of switch unit

Had 2 switch units

- 30 VCSELs were biased in parallel during radiation.
- 10 VCSELs were not biased during radiation.
- After 20min biasing L-I-V of each VCSEL was taken.
- T was monitored and was kept at constant level.
Beam Stability and Temperature

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Absolute T has an offset of ca. 4°C
IV and LI Curves for VCSEL array @ $8 \times 10^{15}$ n/cm$^2$

Annealed for 2 weeks @ 10mA and 1.5 weeks @ 15mA

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IV Curve developments during annealing

Following is observed during annealing for 3 VCSEL arrays:

• Slope resistance increases and decreases.
• Light output is improving with annealing constantly.

![Graph showing IV curve developments during annealing]

- after 2 weeks @10mA
- before irradiation
- 0.5 week @15mA
- 1 week @ 15mA

7x10^{15} \text{n/cm}^2
Results – Slope Efficiency After/Before

2 weeks @ 10mA annealed and 1.5 weeks @ 15mA annealed

Fluence $10^{15} \text{[n(1 MeV)/cm}^2\text{]}$

LHC, annealed @ 20mA, proton implant
Results – Threshold Shift (After-Before)

2 weeks @ 10mA annealed and 1.5 weeks @ 15mA annealed

5 years SLHC @ $10^{35}$ cm$^{-2}$ sec$^{-1}$ with a safety factor of 2

Fluence $10^{15}$ [n(1 MeV)/cm$^2$]

Si

GaAs

LHC, annealed @ 20mA, proton implant

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Summary

• First test in collaboration with CMS  Great success.
• Irradiated 40 VCSELs up to $9 \times 10^{15}$ 1MeV n/cm$^2$ with 20MeV neutrons at UCL in Belgium.
• Monitored VCSEL performance during radiation and annealing.
• Stable environmental conditions.
• VCSELs are all back after annealing at 10mA and 15mA.
• No fatal failures observed.
• Thresholds increases as function of fluence.
• More to analyze and future tests are planned to increase statistics and fluence.
• We will continue to anneal.
Future Tests

• Irradiate more VCSELs at UCL to higher fluences
• Irradiate Si p-i-n arrays at UCL
• Fibre irradiations