Radiation Hard Optical Links for the ATLAS SCT and Pixel Detectors

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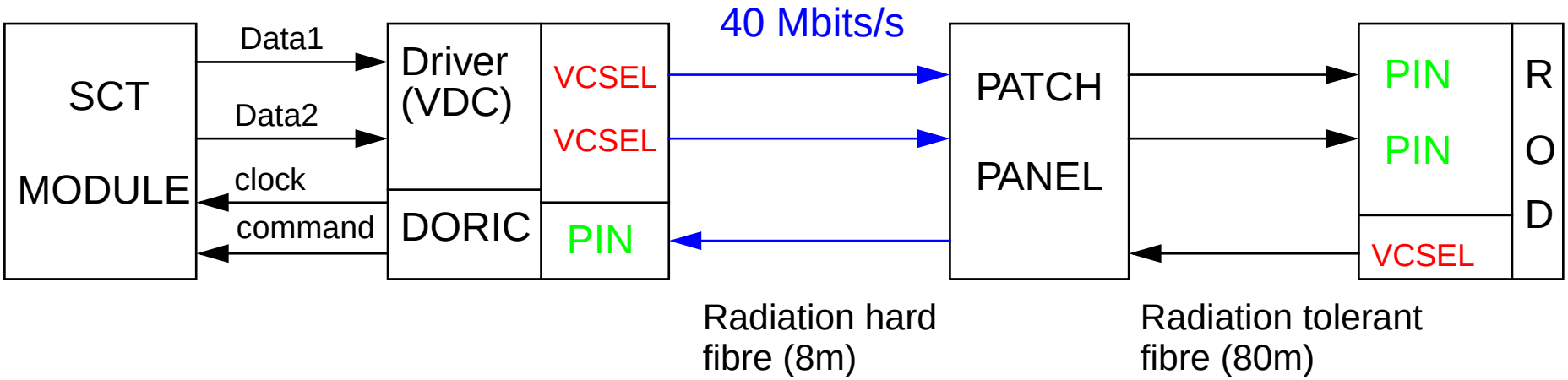
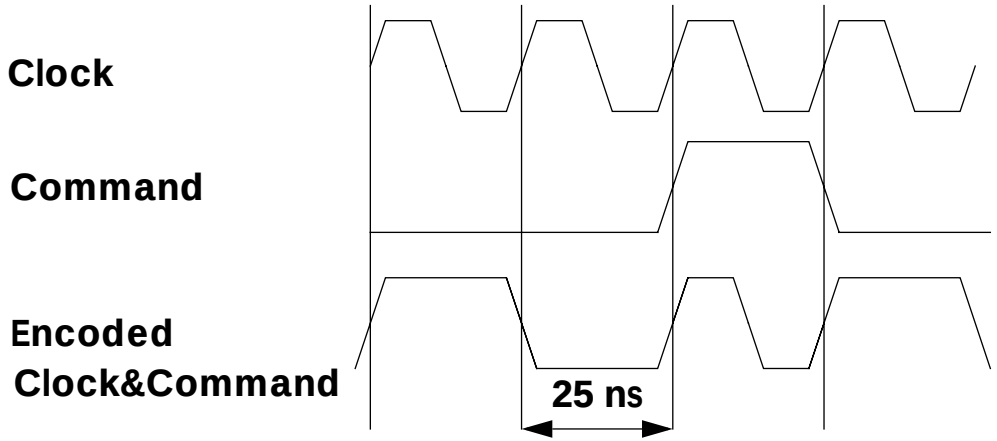
Plan

- SCT Readout Scheme
- Optical Packages
- Radiation hardness of
  - DORIC/VDC chips
  - Optical emitters (VCSELs)
  - Optical Receivers (Epitaxial Si PIN photodiodes)
- Environmental tests
- Single Event Upset studies
- Conclusion

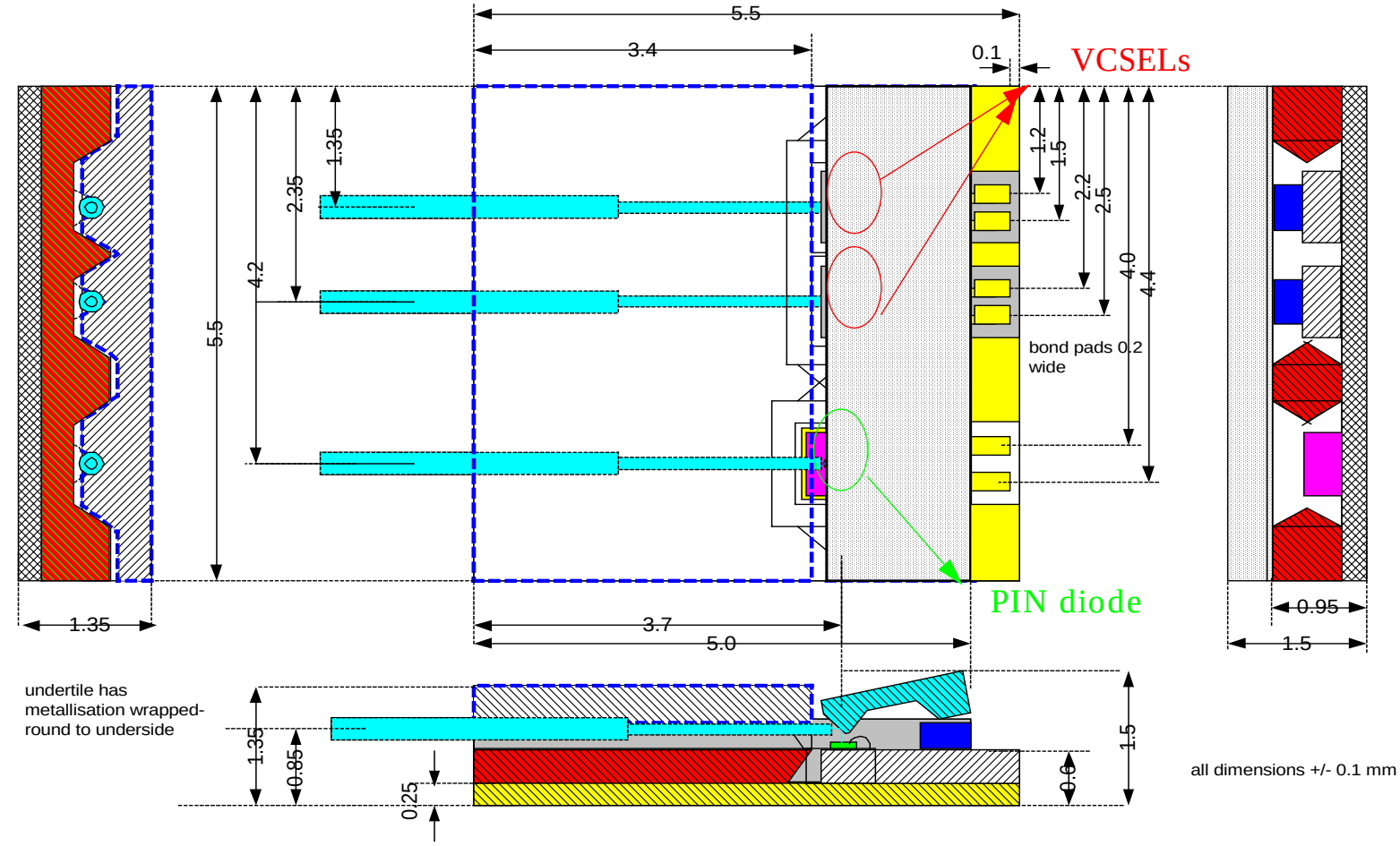
The Optical Readout Chain of the SCT



- Bi-Phase Mark encoding is used to encode Control Data on top of the 40 MHz bunch crossing clock.



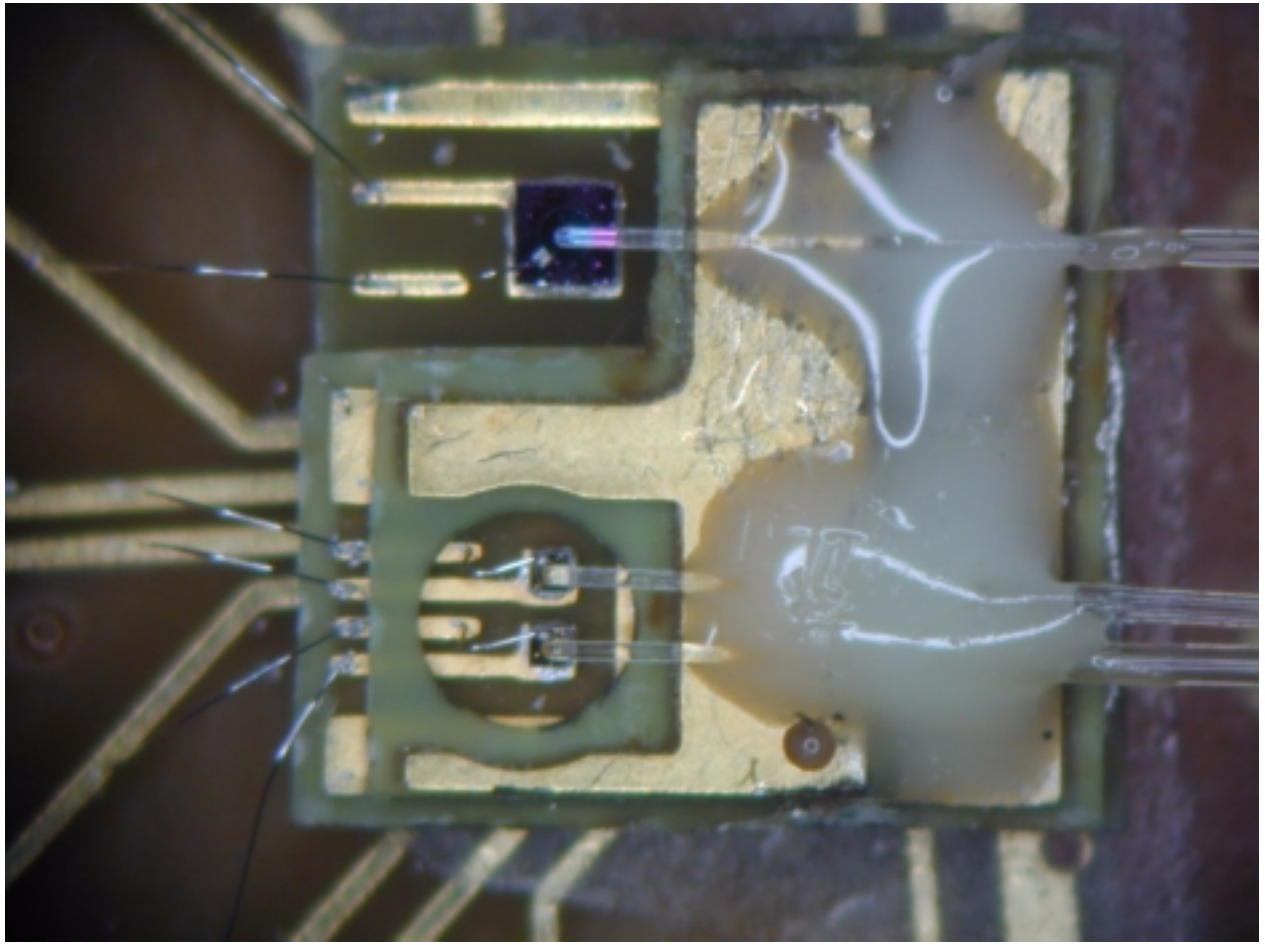
Details of the Optical Package (Marconi, UK)

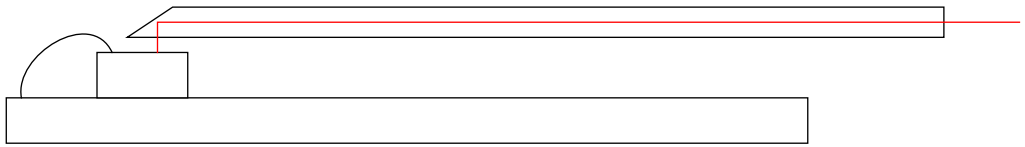


Silicon packaged VCSEL-PIN unit - schematic showing proposed key dimensions - prepared by J. Hall 25.3.99 - Marconi Materials Technology, Caswell

- Radiation hard, low mass and non-magnetic.

Alternative Opto-Package (Taiwan)





Radiation hardness of DORIC4/ VDC

- AMS 0.8 μm BiCMOS technology. Radiation hard design made by:
  - using only bipolar npn transistors
  - using large current so that the DC current gain β is large and less sensitive to radiation damage;
  - using design in which the circuit is very insensitive to changes in β.
- 20 DORIC4 and 9 VDC chips have been irradiated up to $3x10^{14}$n cm^{-2} at Ljubljana and 100 kGy with a Co^{60} gamma source. They were powered during the gamma irradiation. No performance degradation has been observed.
- A further 9 DORIC4 chips have been irradiated to $3x10^{14}$n cm^{-2} and 500 kGy with no reduction in performance.
- Lifetime(ageing test): < 0.3% failure (90 % C.L.) expected over 10 ATLAS-years, reduced even further by a redundancy scheme.

Radiation hardness of opto-components

- VCSELs (GaAs)

  Coupling: ~1mW at 10mA before irradiation, threshold ~4mA

  Radiation hard: shift of 2mA in the L-I characteristics at $3x10^{15}$ n cm^{-2}.

  Lifetime: <0.2 % failures over the ATLAS running period (90% C.L.)

- PIN photodiodes (Epitaxial Si)

  Radiation hard: drop of 30% in responsivity (from 0.5 A/W) at 10^{15} n cm^{-2}

  Rise/fall times < 1ns for 5V reverse-bias

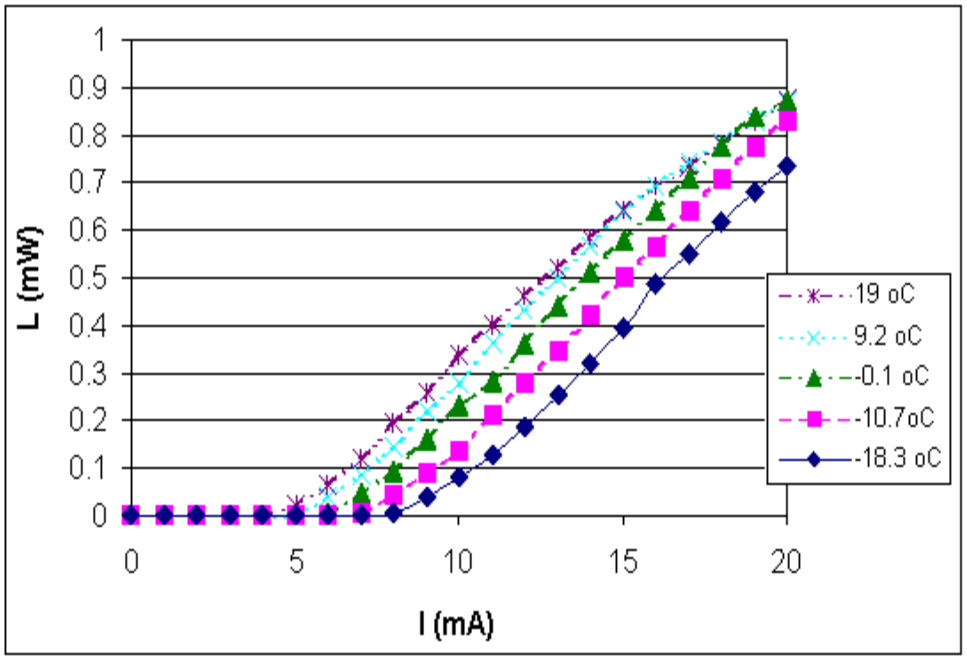
  Lifetime: <0.2% failures expected over 10 ATLAS-years (90% C.L.)

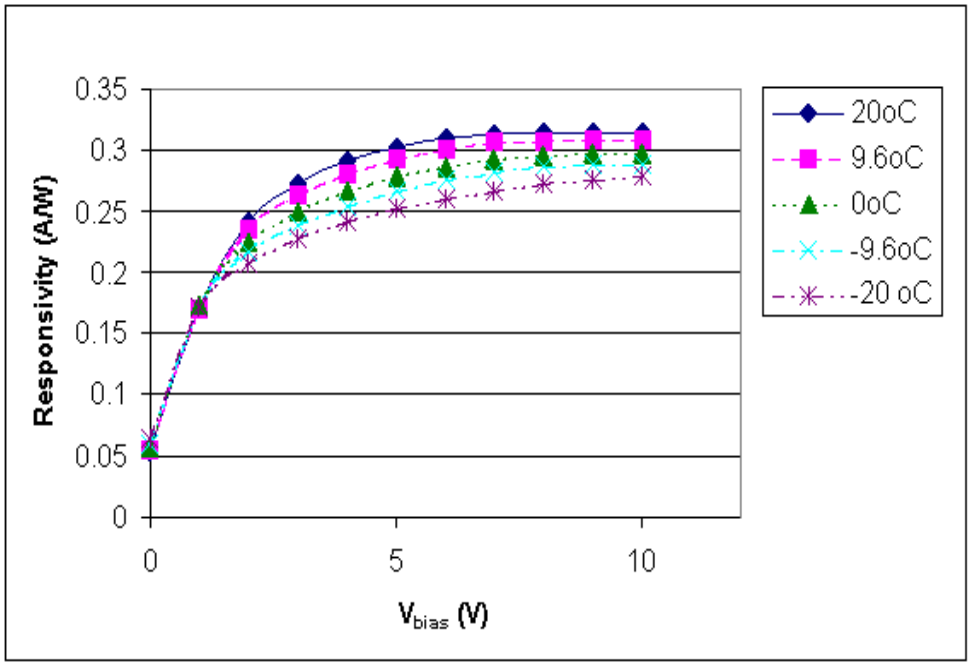
- Optical fibre

  Pure silica SIMM 50/60/125/250 fibre from Fujikura shows a total loss < 0.05 db/m after irradiation (330 kGy).

Environmental tests

- Irradiated VCSELs show an increase of 4 mA in the laser threshold from room temperature to -18.3^{o}C.
- The PIN diode responsivity drops at a rate of 0.25%/^{o}C with decreasing temperature.



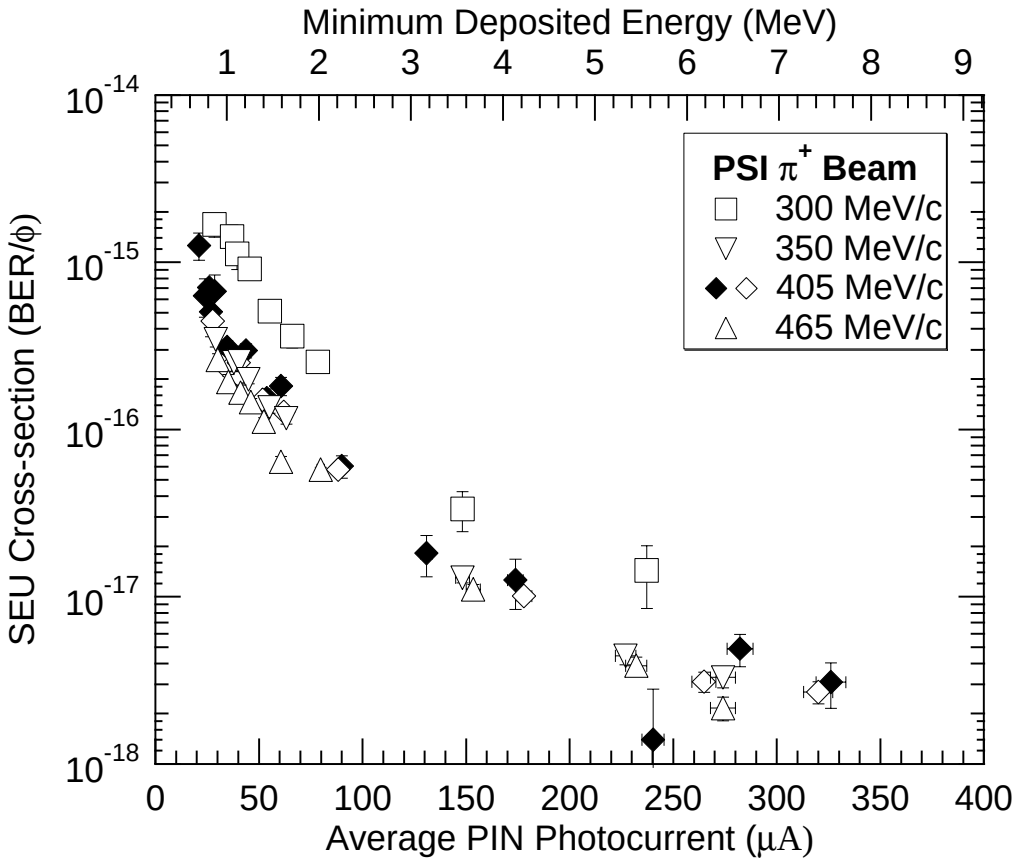


Single Event Upset

- PSI π beam used to test SEU in the Marconi package.
- SEU cross section is defined as:

$$\sigma = \frac{BER}{Flux}$$

- SEU occurs in the large active PIN volume, 15μm x 549μm^2
- Φ_{pixel}=3x10^{7}cm^{-2} s^{-1}, BER<10^{-9} for I_{pin} > 150 μA ($P_{delivered}$>1 mW)



Conclusion

- We have developed a rad hard opto-package (and an alternative version) suitable for the binary readout of the ATLAS SCT and Pixel detectors;
- All optical components, including fibres, have been rigorously tested at the radiation levels expected in the Pixel detector (~10^{15} n cm^{-2}, ~300 kGy);
- Single event upsets have been measured for a complete SCT readout package and have an acceptable rate (i.e. Bit Error Rate < 10^{-9});
- Sample opto-packages (60 of each type) are available for systems tests in realistic setups;
- Detailed information can be found at:

  http://atlas.web.cern.ch/Atlas/GROUPS/INNER_DETECTOR/Electronics/links/