

Optical Links for the ATLAS SCT and Pixel Detector

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(University Wuppertal)
for the ATLAS
collaboration



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International Workshop on Semiconductor Pixel Detectors
for Particles and X-Rays
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Overview

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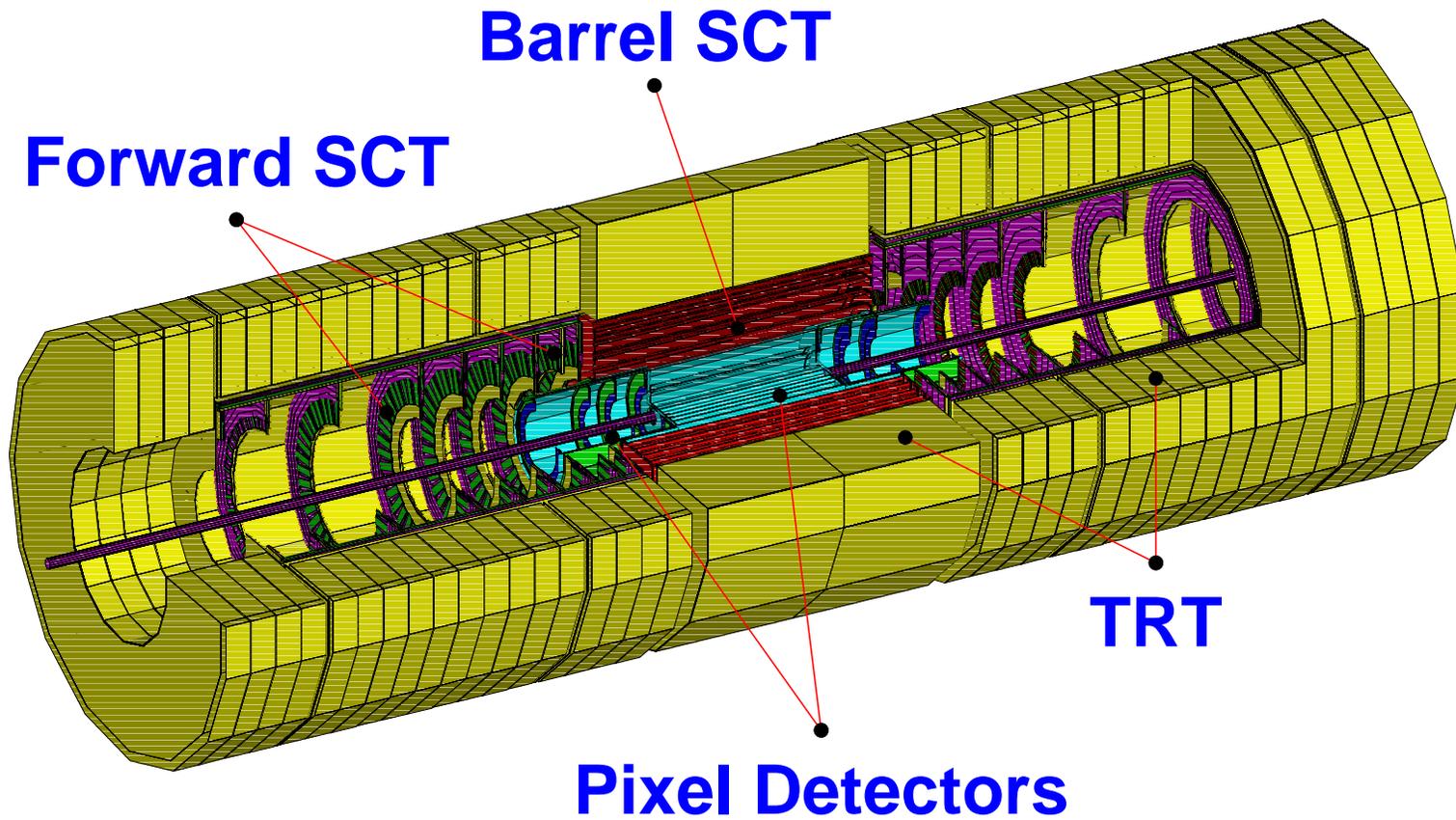
- ATLAS Inner Detector
- Optical Link Architecture
- System Tests
- Conclusion



ATLAS Inner Detector

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Data Transfer

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- Control and clock information must be transferred from acquisition system to the silicon detectors
- Hit data must be transferred from the modules to a remote acquisition system
- use of copper links unfeasible
 - large amount of dead material which would be introduced
 - problems from cross-talk and ground loops
- it is proposed to use custom optical links to transfer data to and from the detector modules (SCT and Pixel Detector)



Special Requirements (1)

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➤ radiation hardness

- ionizing radiation : 100kGy (SCT) to 550kGy (Pixel detector)
- **1 billion lung x-rays**
- neutron radiation :
 - Si-devices: $1 \cdot 10^{15}$ n(1MeV)/cm²
 - GaAs-devices: up to $6.4 \cdot 10^{15}$ n(1MeV)/cm²
- expected over the 10 year lifetime of ATLAS (1st layer)



Special Requirements (2)

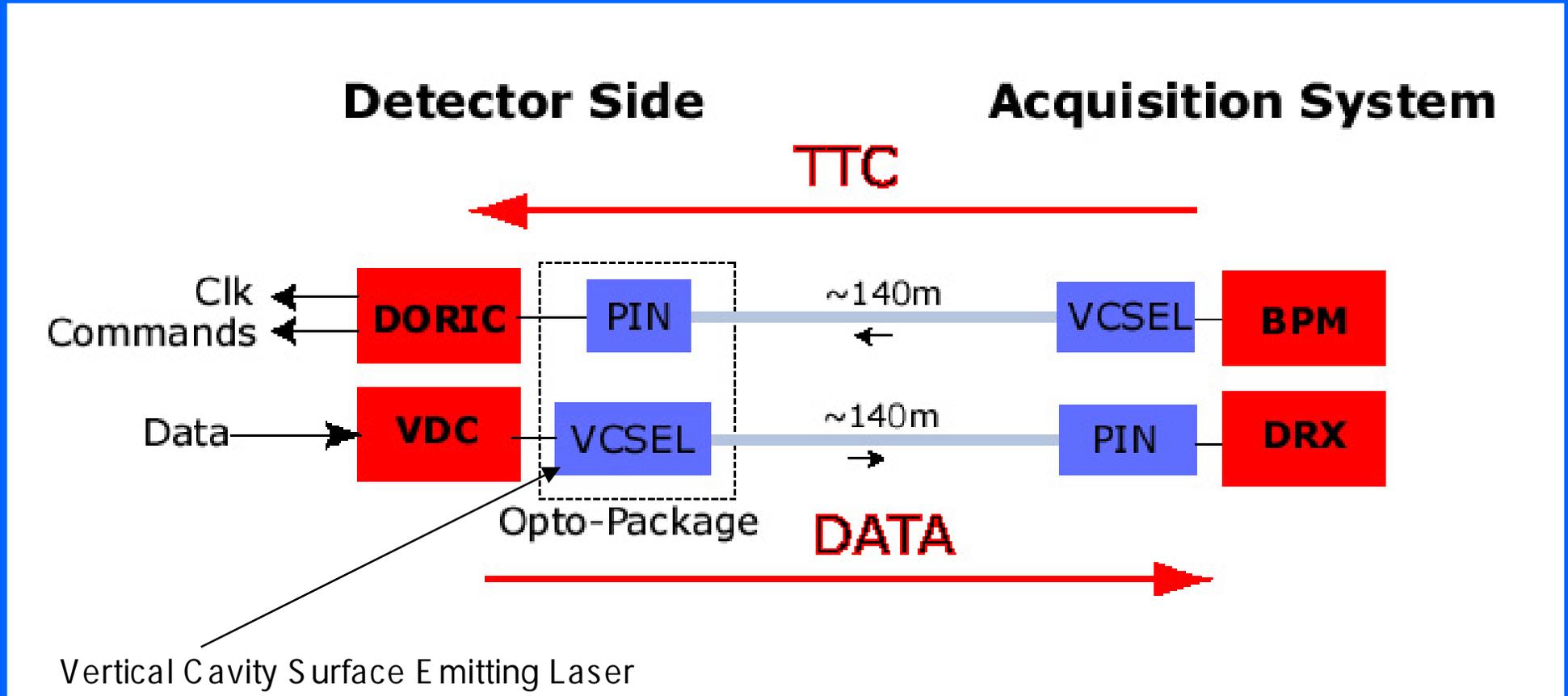
- non-magnetic to avoid perturbing the inner detector magnetic field
- low mass
 - additional interactions in non-instrumented regions of the detector would compromise the quality of momentum measurements
 - particle conversion
- reasonably low cost



Read-Out Link Architecture

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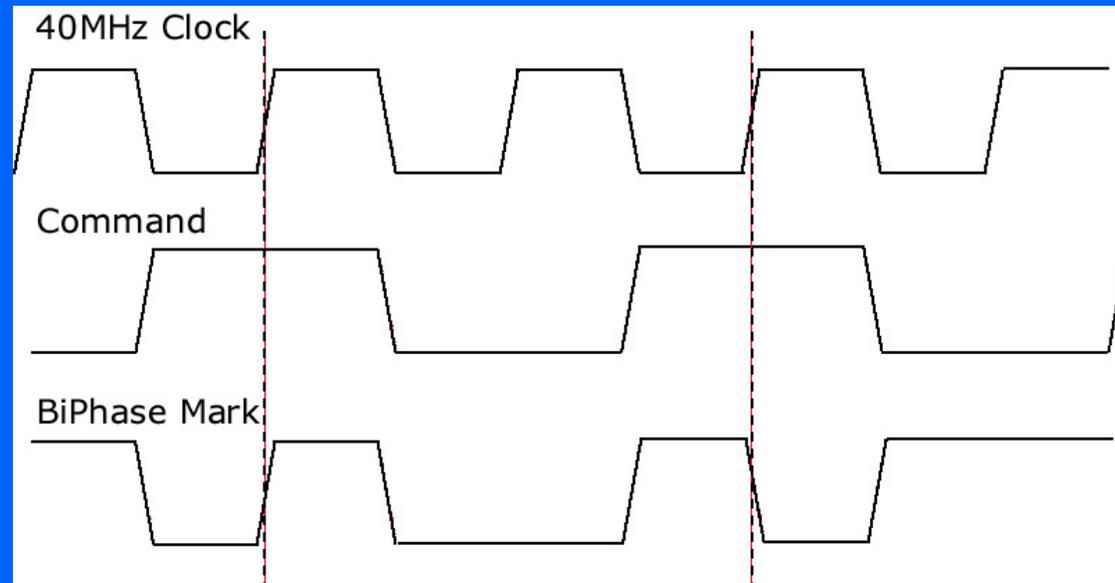


Timing Triggering and Control (TTC link)

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BPM



- VCSEL Driver BiPhase Mark Encoder
- driver chip for VCSEL on acquisition side (12 way)
- 40MHz-Clock and Commands on one link



TTC Link

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DORIC

- Digital Optical Receiver IC
- decodes the signals received by the PIN
- recovers commands and 40MHz-clock
- LVDS output

- 2 versions: bipolar (SCT) and CMOS (Pixel)
- SCT redundancy system: TTC data can be taken from redundancy link from a neighbouring data



Data Link

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VDC

- VCSEL Driver Chip
- LVDS input
- 40Mbit/s (SCT), 80Mbit/s (Pixel 1st and 2nd layer) or 160Mbit/s (B-layer)
- NRZ (20MHz = 40Mbit/s)
- 2 versions: bipolar (SCT) and CMOS (Pixel)
- SCT: in the event of failure, the data can be rerouted through the second link
- Pixel: one link for outer layers, two for B-layer (160MBit/sec)



Opto-Package Specs

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- Custom package made of material with low Z, non-magnetic, with 2 VCSELs and 1 PIN
- Fibres attached without standard connector
- not larger than 5.5 mm x 5.5 mm x 1.6 mm
- package and including devices have to stand radiation levels
- operation temperature during testing: -25°C to 40°C
- operation temperature during ATLAS: -25°C to 15°C

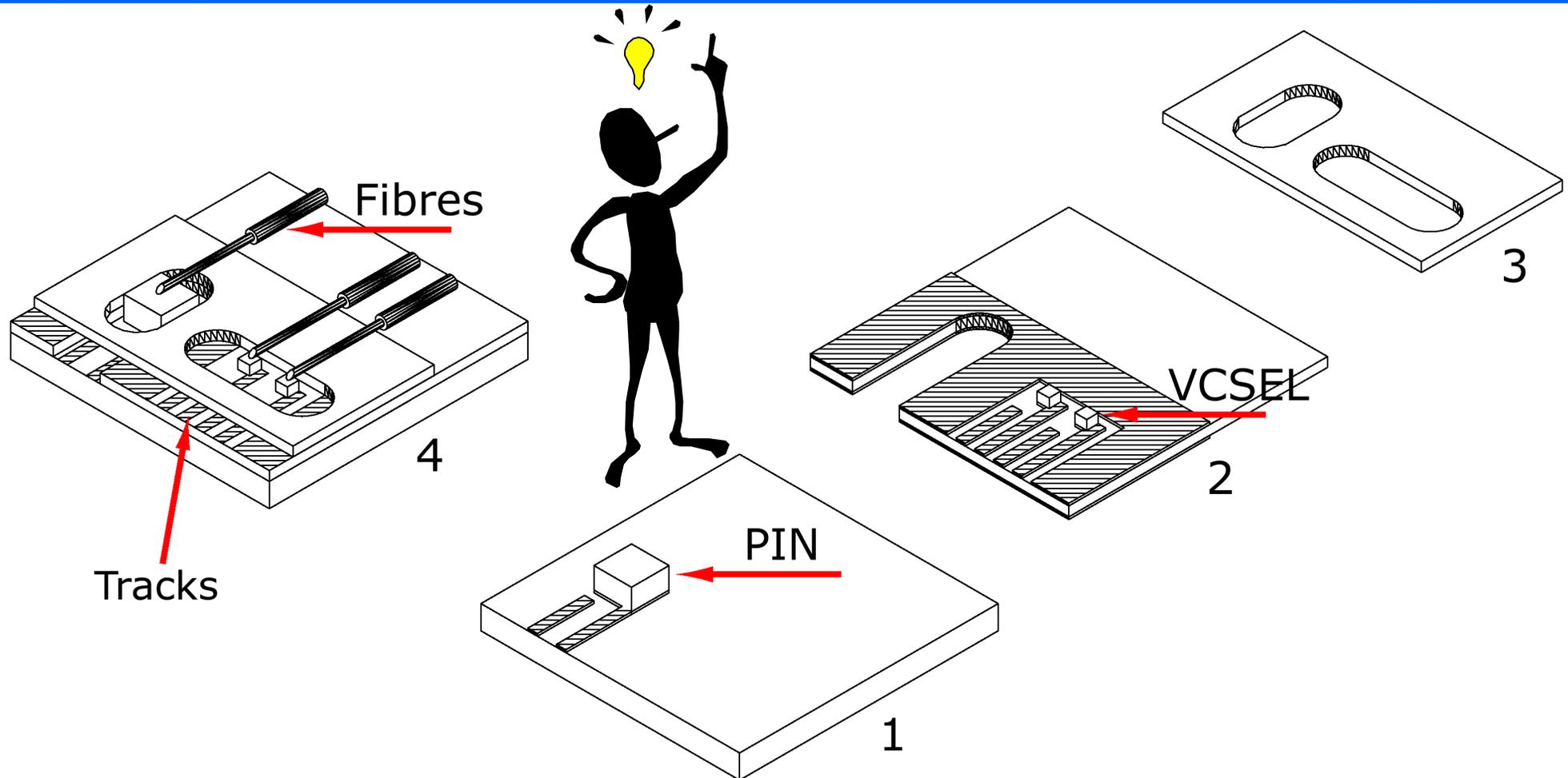
- three different designs under survey



Taiwan Opto-Package

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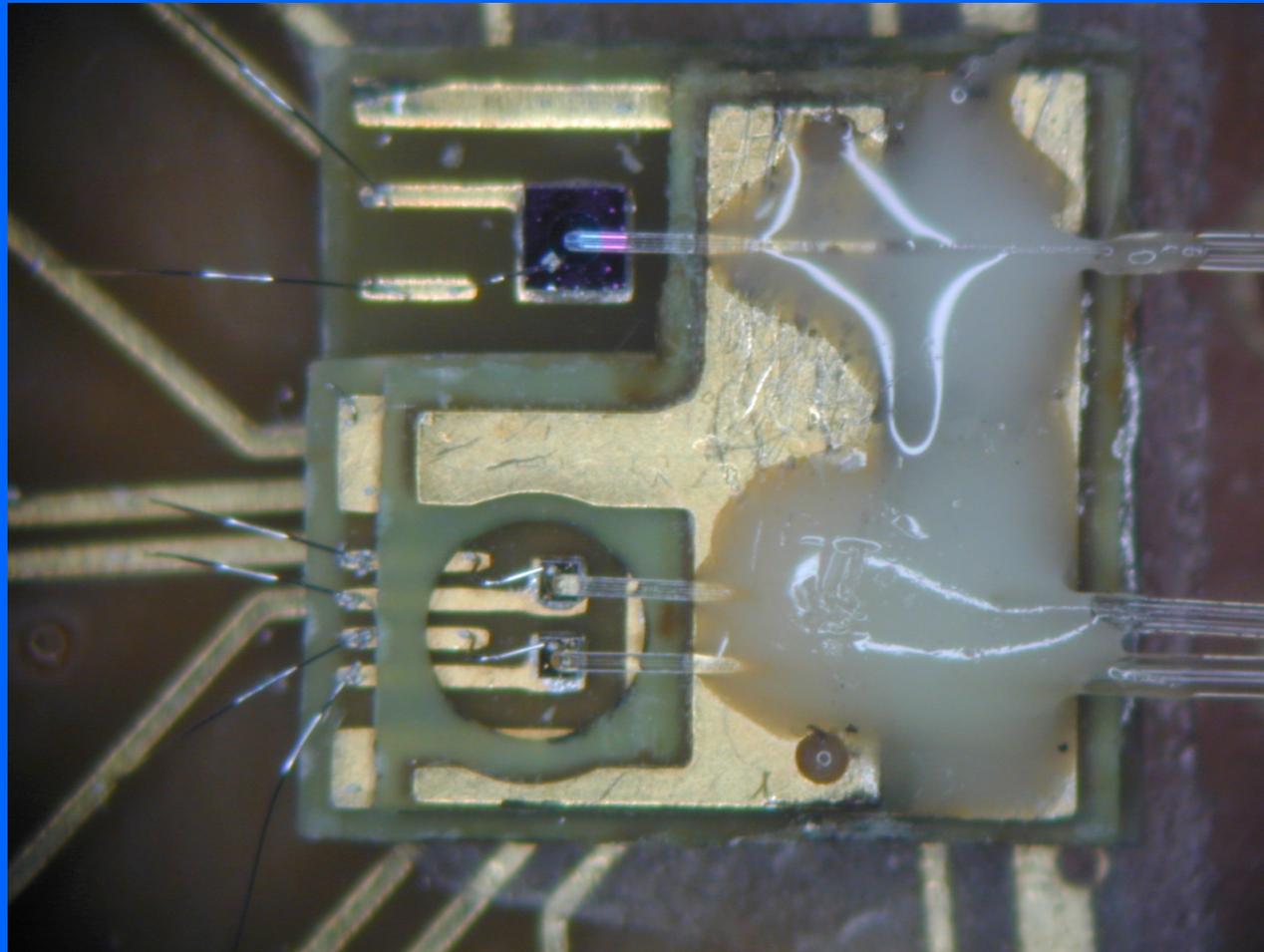


Taiwan Opto-Package

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5.5 mm

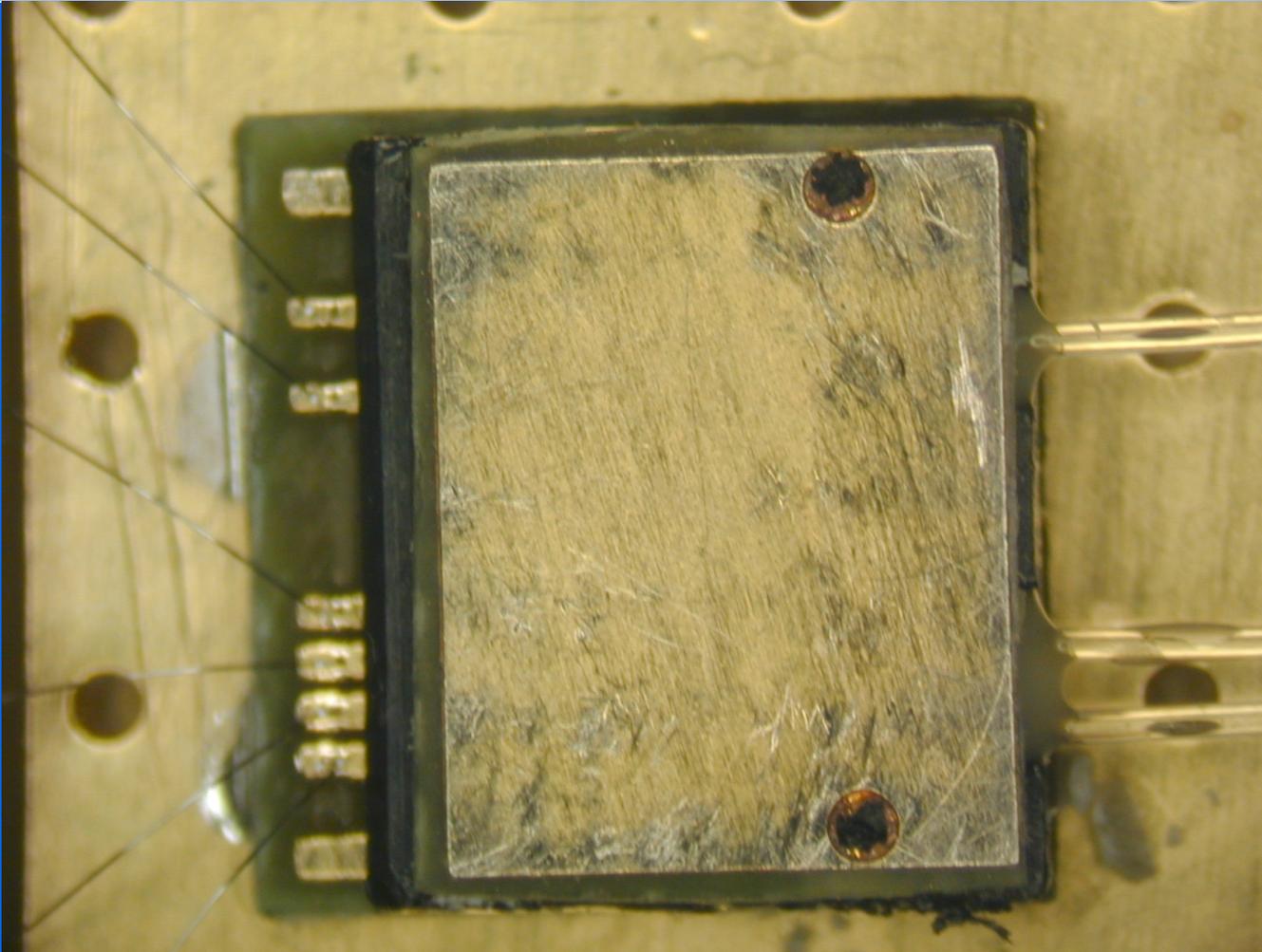




Taiwan Opto-Package

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Pixel2000 Genova, Italy

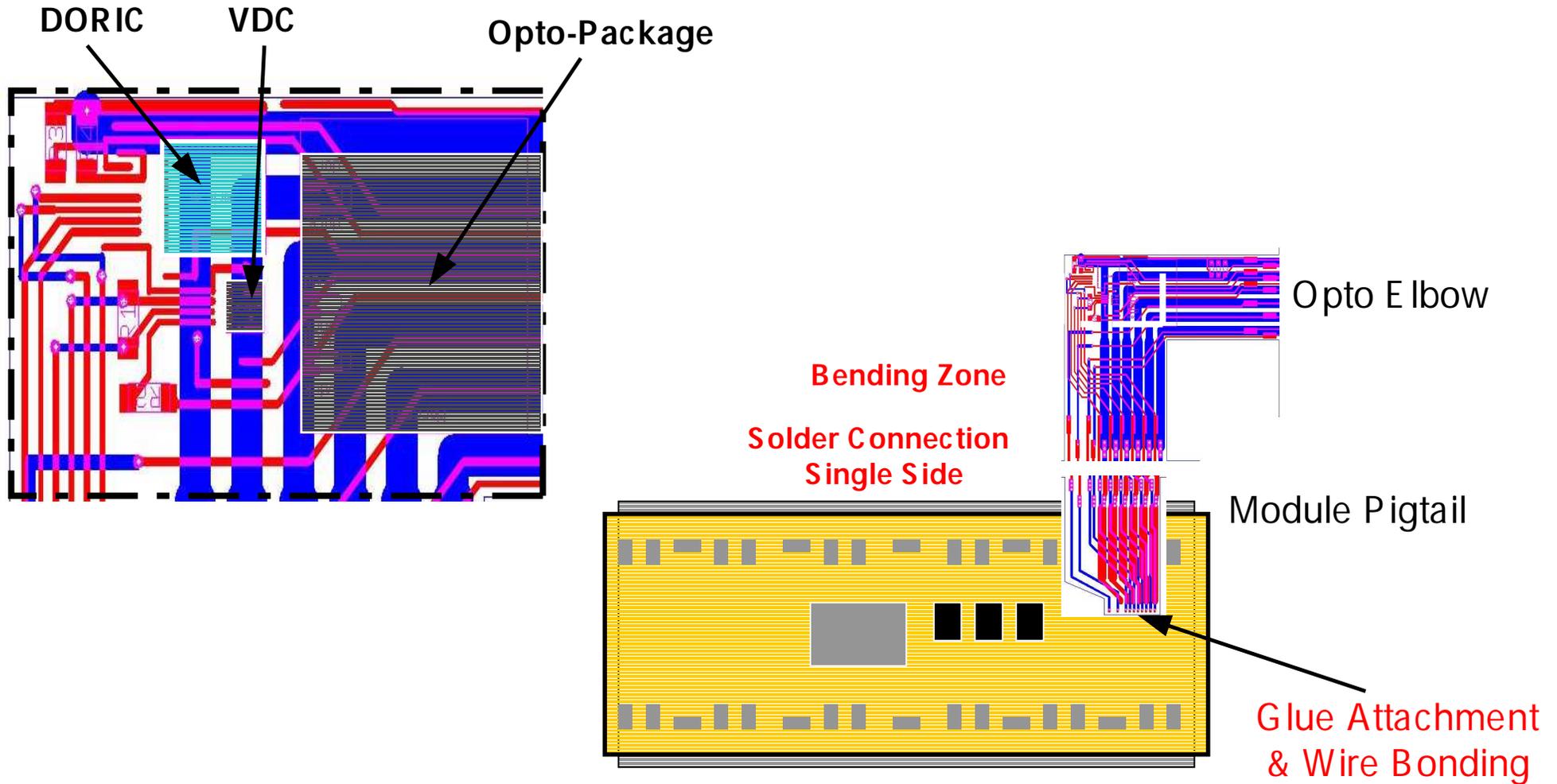
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Opto-E Ibow (Pixel)

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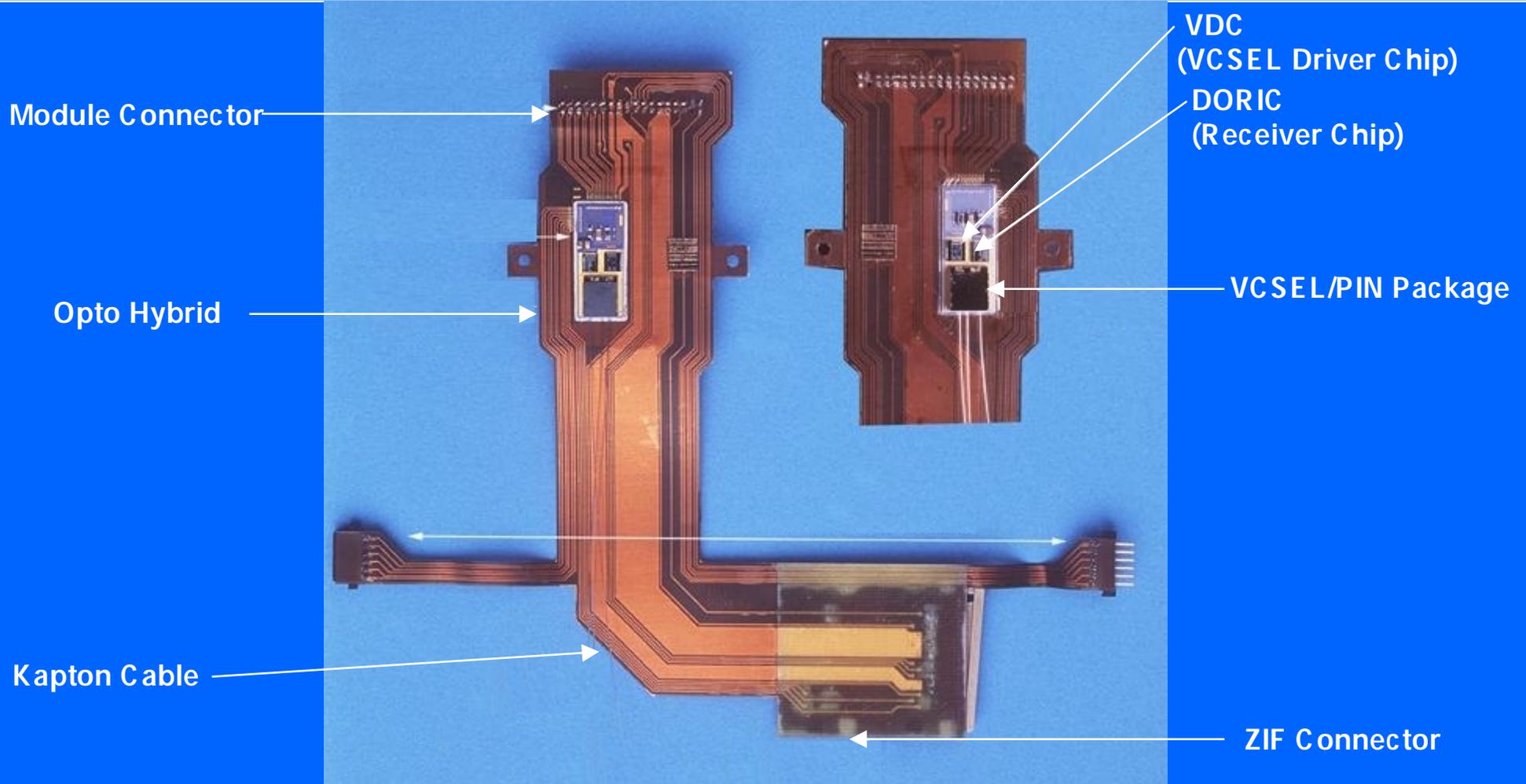




Opto Package Support (SCT)

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System Tests

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- Characteristics of opto-link for this system under test:
 - Radiation and Annealing studies
 - Lifetime studies
 - Bit Error Rate
 - Single Event Upsets

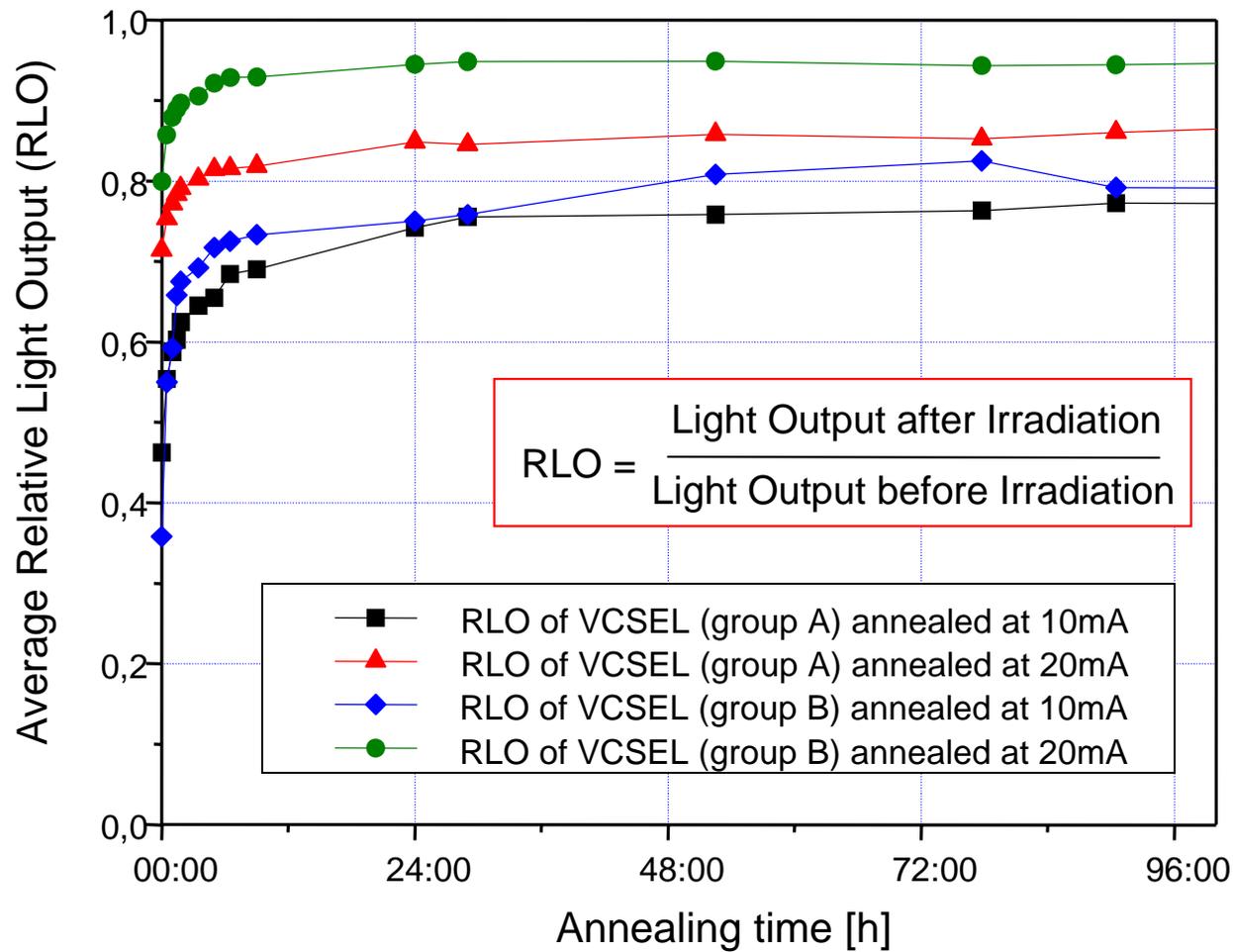




Annealing Studies of VCSEL

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Radiation levels:

$$A = 8 * 10^{14} \frac{n}{cm^2}$$

$$B = 5 * 10^{14} \frac{n}{cm^2}$$



VCSEL tests

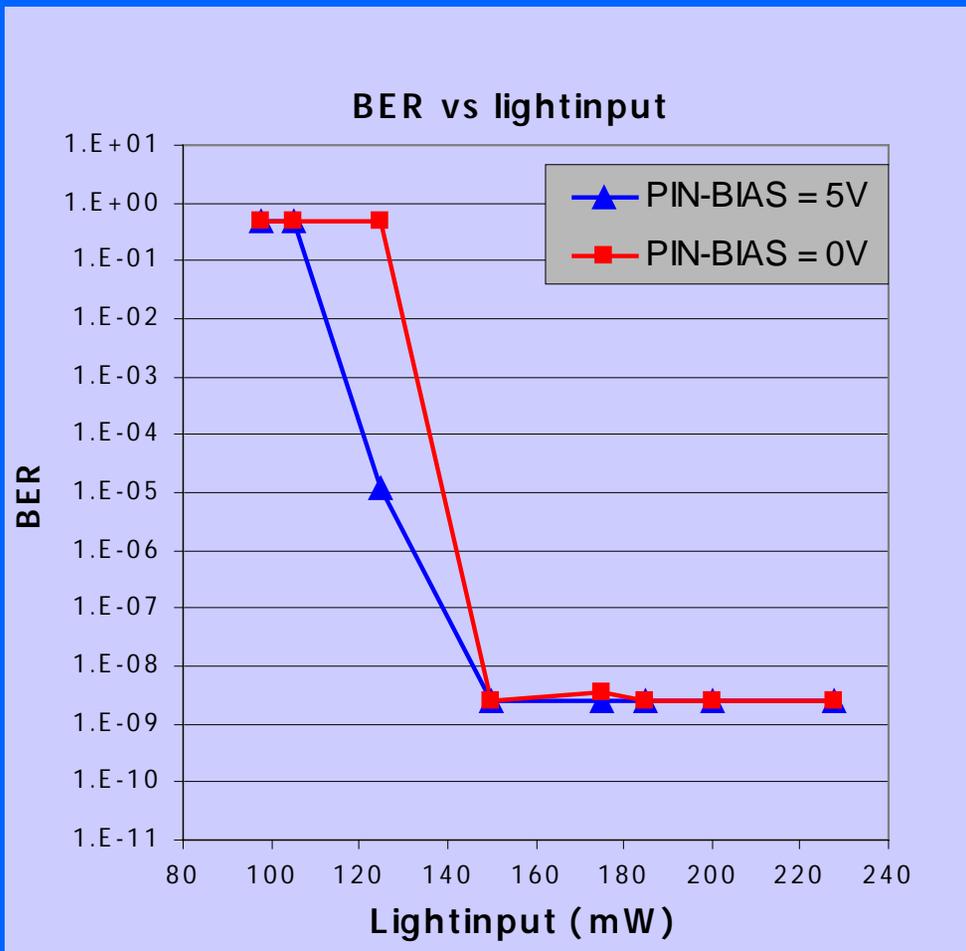
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- VCSELs were not powered during irradiation
- radiation induced damages can be annealed up to 90% over a period of days/weeks
- results suggest brief 20 mA current annealing sessions
- following aging tests showed an expected lifetime of a **few hundred** years (irradiated)
- further irradiation and lifetime tests are under way (up to Pixel level of $6.4 \cdot 10^{15}$ n(1MeV)/cm²)

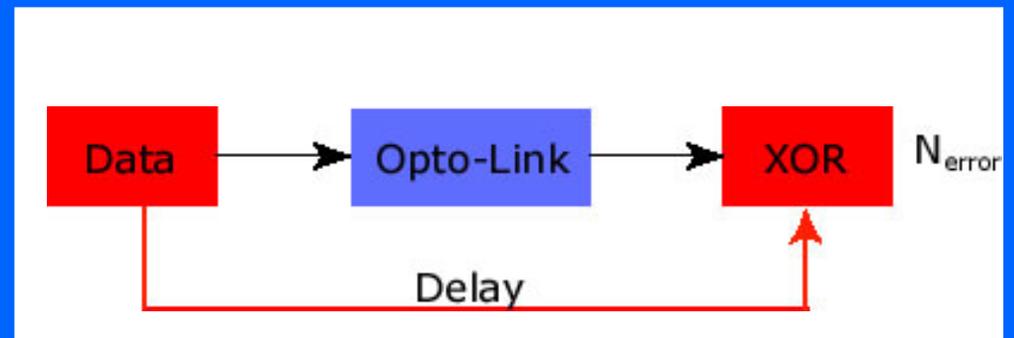


Bit Error Rate (BER)



- BER: good parameter to evaluate the performance of the optolink

$$BER = \frac{N_{error}}{N_{bits}} < 10^{-9}$$



- Good results with S C T link
- Pixel test under way



Single Event Upsets

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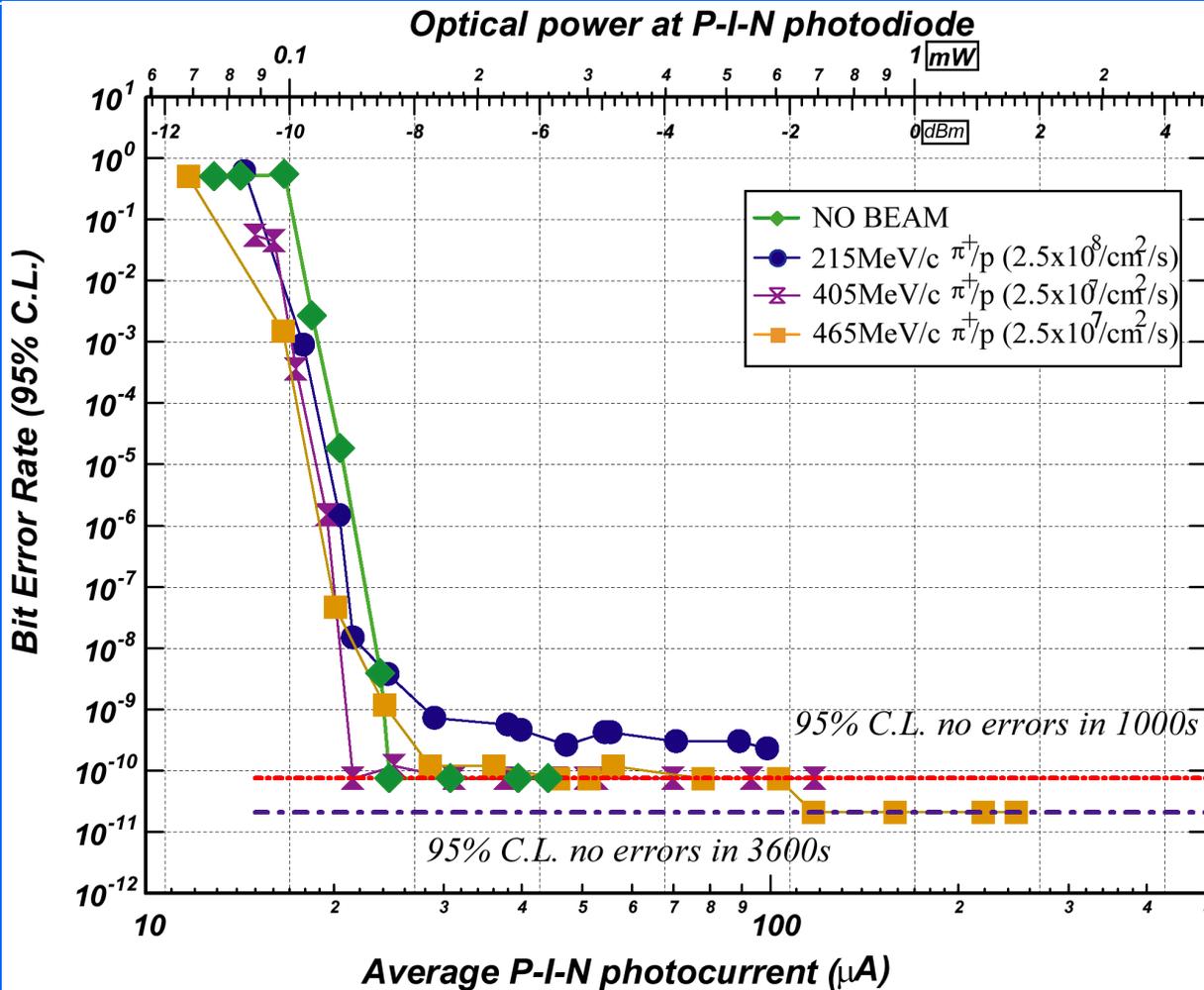
- Single Event Upsets caused by a very high energy deposition in a small volume of electronics chips
- most sensitive region: reverse-biased p/n junction where high electric field is very effective in collecting the charge by drift
- PIN = reverse biased p/n junction
- $100\mu\text{m} \times 50\mu\text{m} \times 50\mu\text{m}$!
- First SEU appearance : NPL neutron beam
- test with pions at PSI



SEU at PSI

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- Sensitive power around $100 \mu\text{W}$
- for $P > 350 \mu\text{W}$, BER $< 10^{-10} \text{s}^{-1}$
- discrepancy between counter and Al foil
- repeat next week



Conclusion

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- data transfer using optical links
- custom packaging developments for the 40 Mb/s optical link show good physical results
- design of complete Pixel opto-link under way
- radiation induced damages can be annealed up to 90% over a period of days
- results suggest brief 20 mA current annealing sessions
- SEU problems can be fixed by sending more light



Conclusion

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➤ http://www.atlas.uni-wuppertal.de/Optolink/Pix_Optolink.html

