

Optoelectronics

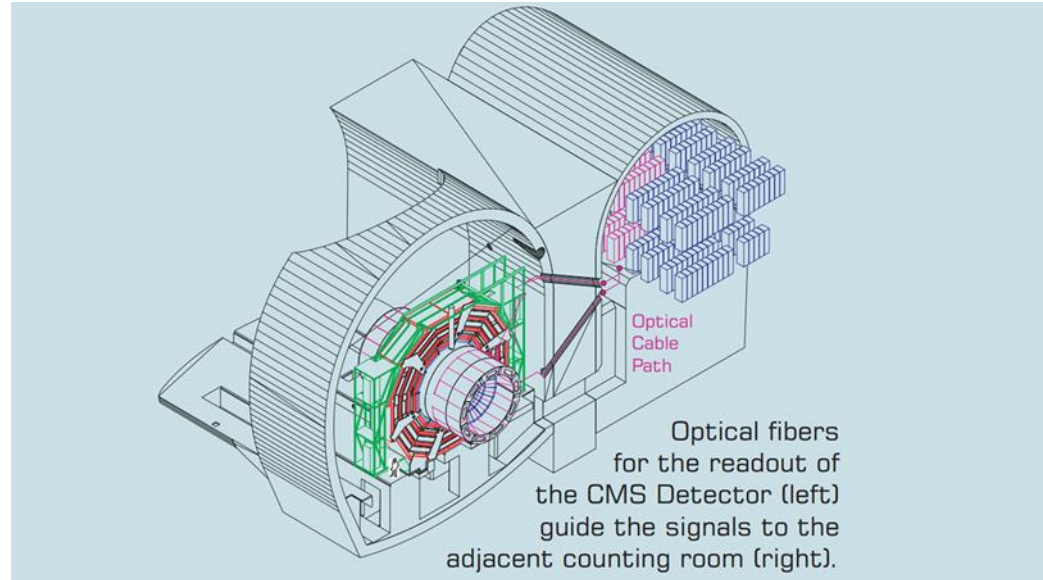


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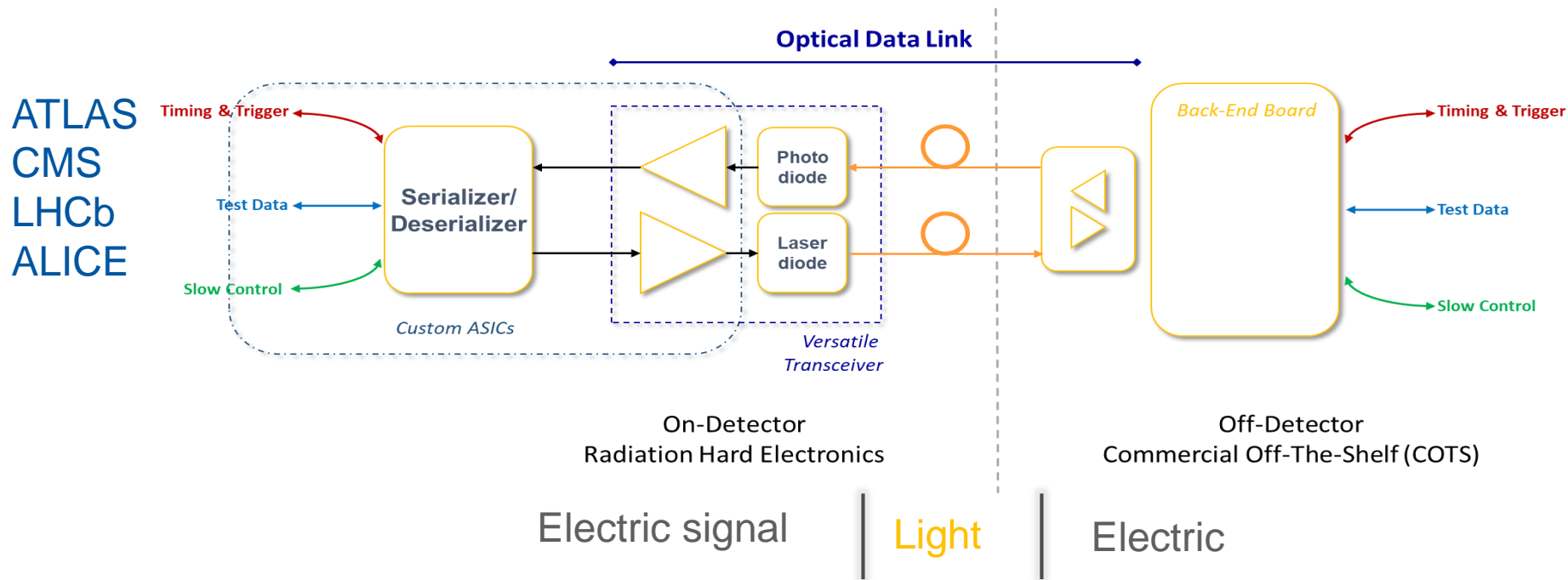
Silja Kinnunen and Antti Asikainen

The purpose of optoelectronics

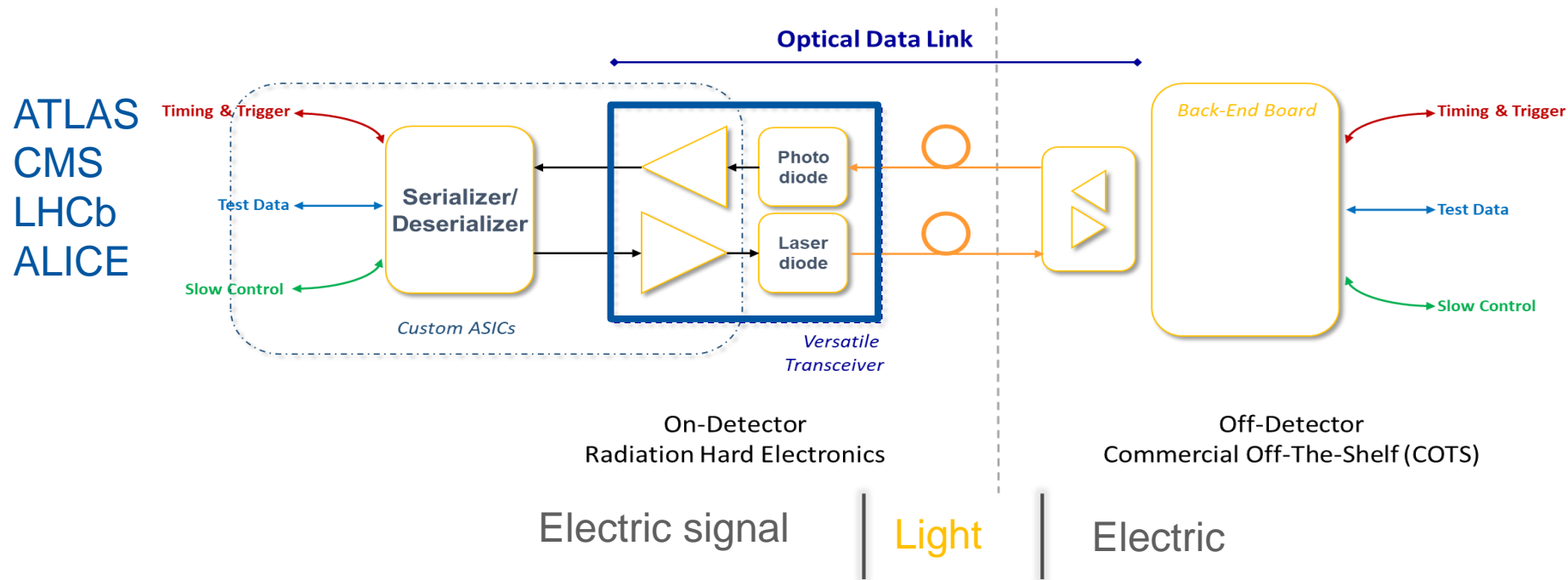
- Lots of information needs to be transferred from a detector to its counting room.
- Due to the distance and required speed, optical fibers are the only feasible option



Signal path of an optical link

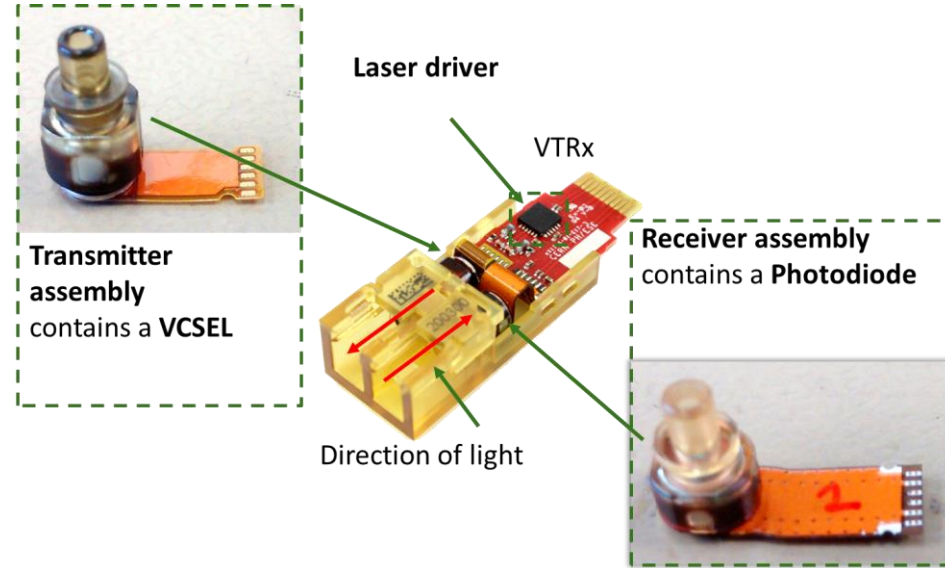


Signal path of an optical link



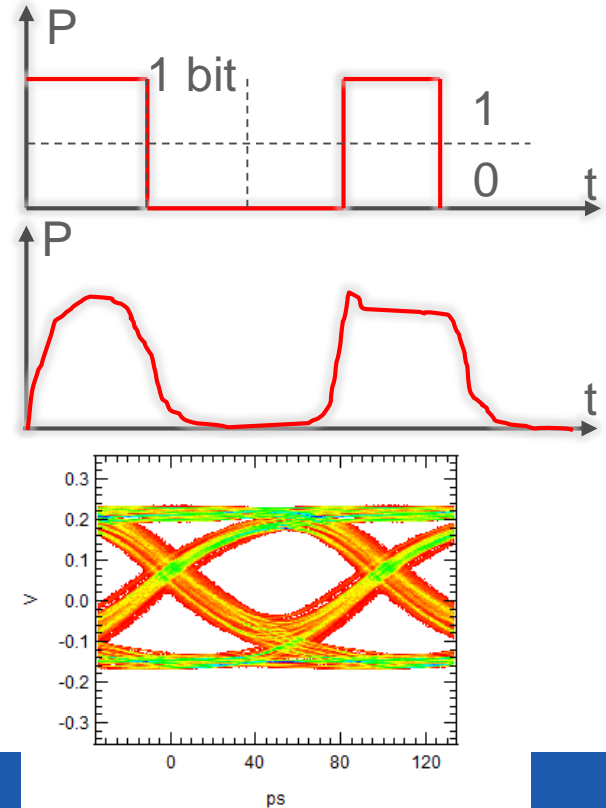
Versatile transceiver

- Transforms the electric signal from the serializer into light.
 - This is done with a laser diode
- Transforms optical signals into electricity.
 - Done with a photo diode
- One of the possible points for the signal to be corrupted
 - Requires careful design and **characterization**

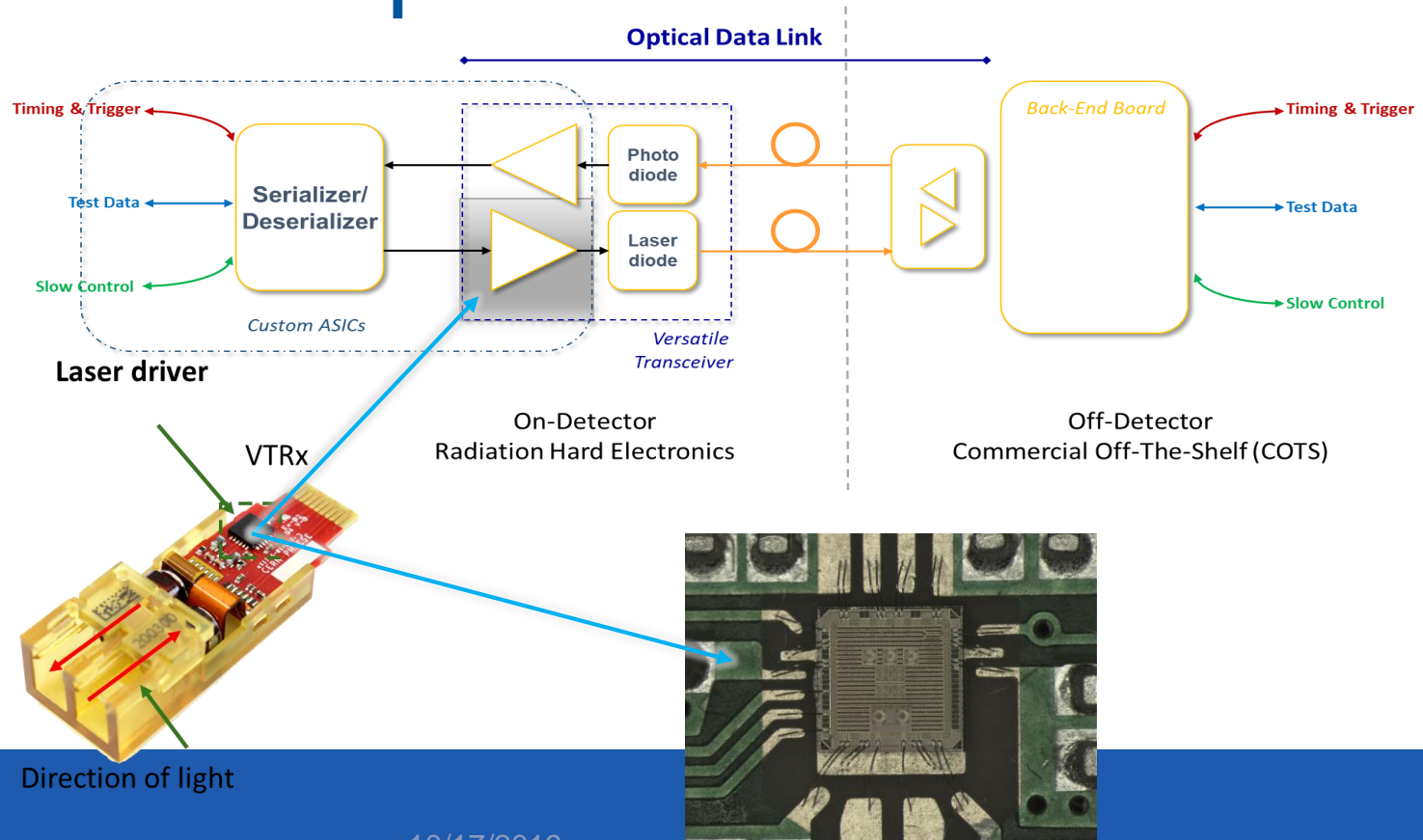


Signal strength and eye diagrams

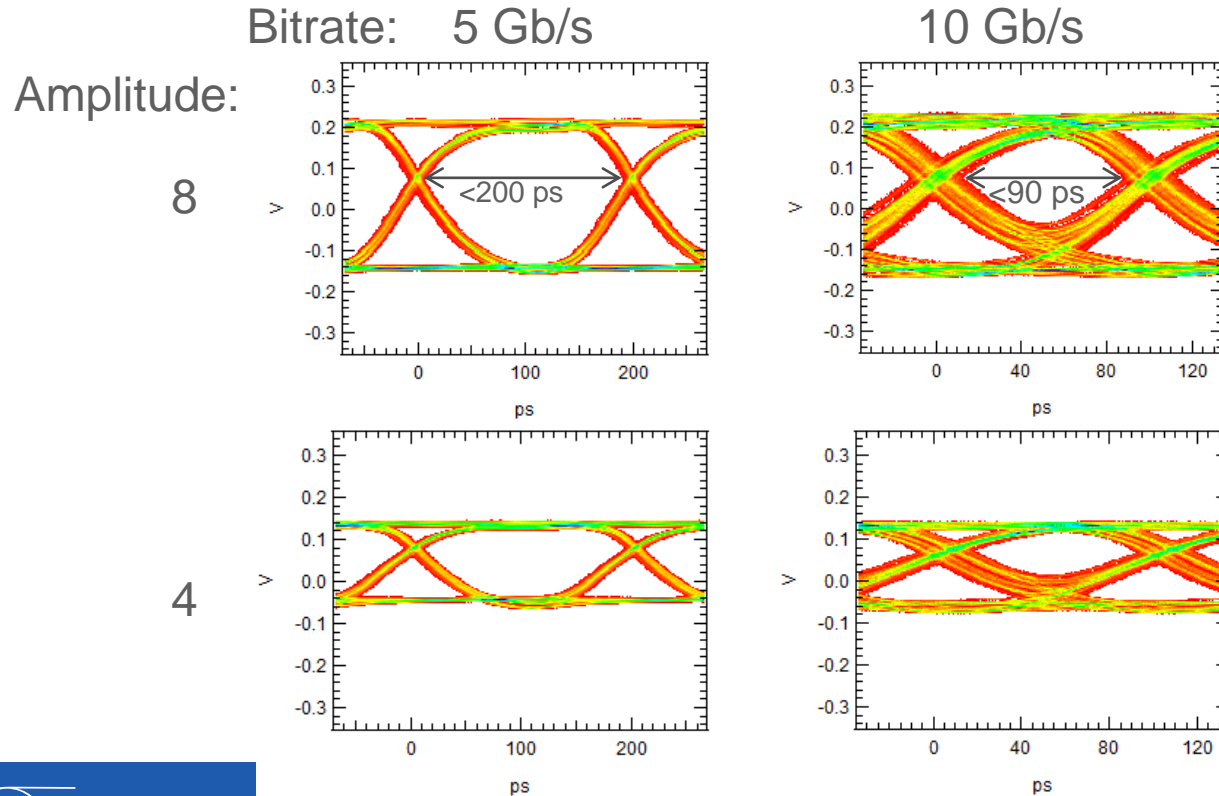
- Above: Ideal binary signal
- Below: More realistic binary signal
- Physical limitations of the components cause several sources of inaccuracy:
 - E.g. noise, risetime, falltime, overshoots
- Signal is read at the center of a bit
- Quality of data stream is often presented with eye diagrams
- An eye diagram is a combination of every possible path the signal can take across one bit
- The area enclosed by the diagram describes how reliably the signal can be read



Measured part

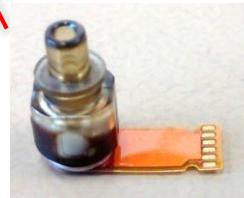
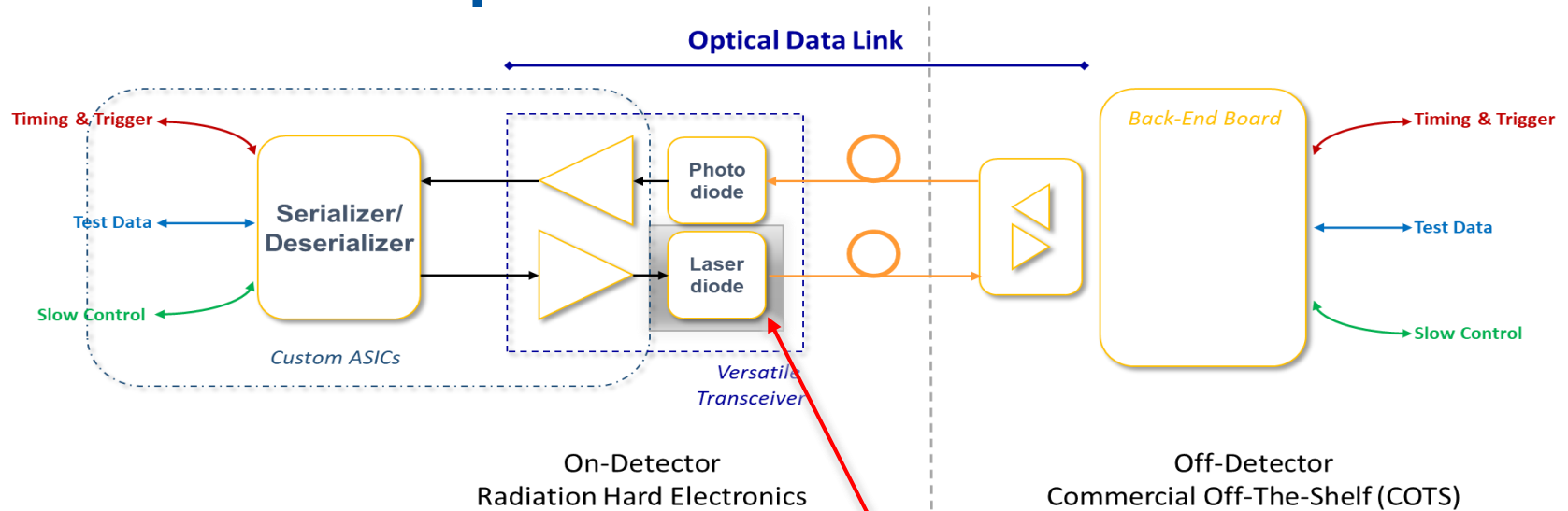


Examples of electrical laser driver eye diagrams

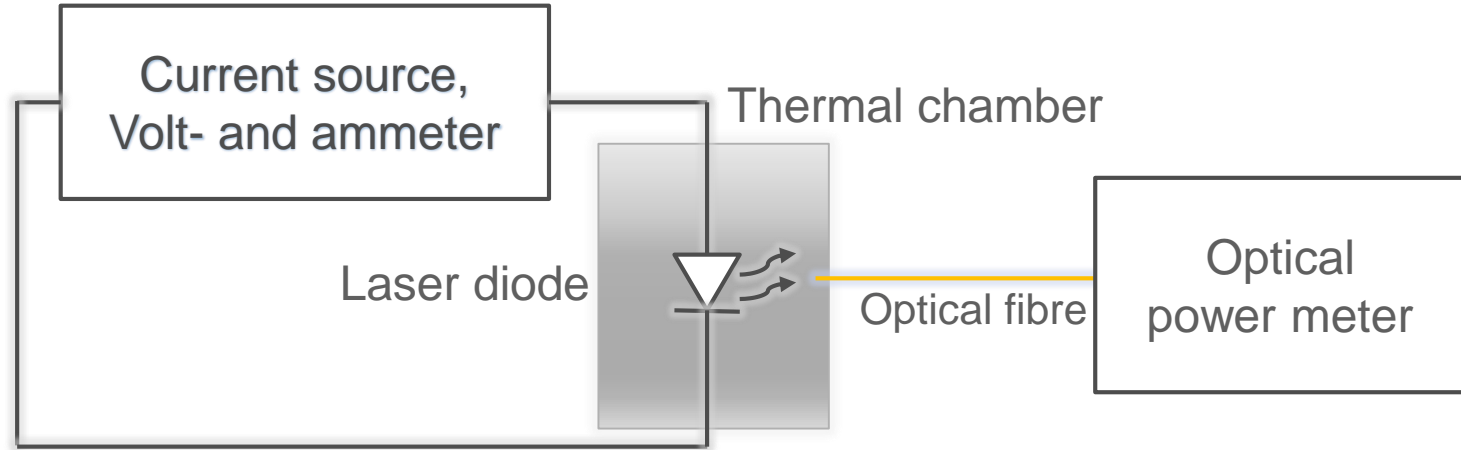


- Raising the bitrate decreases both the width and the height of the diagram
- Raising the amplitude increases the height

Measured part

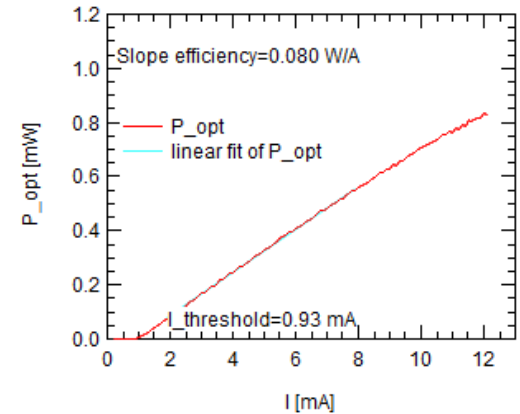
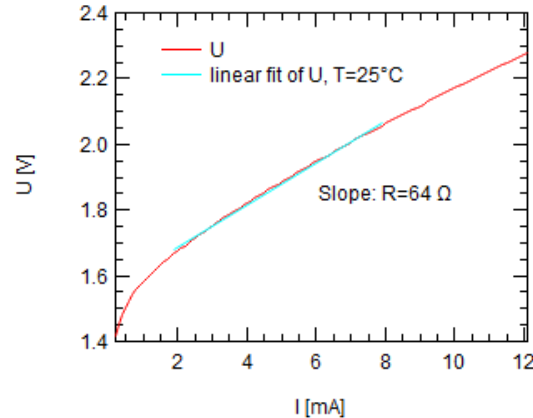


Measurement of a laser diode

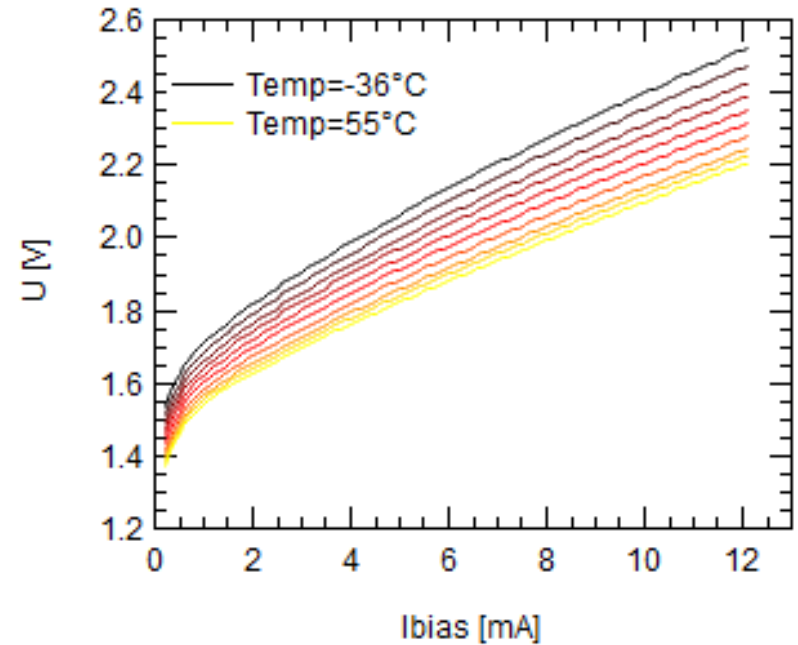
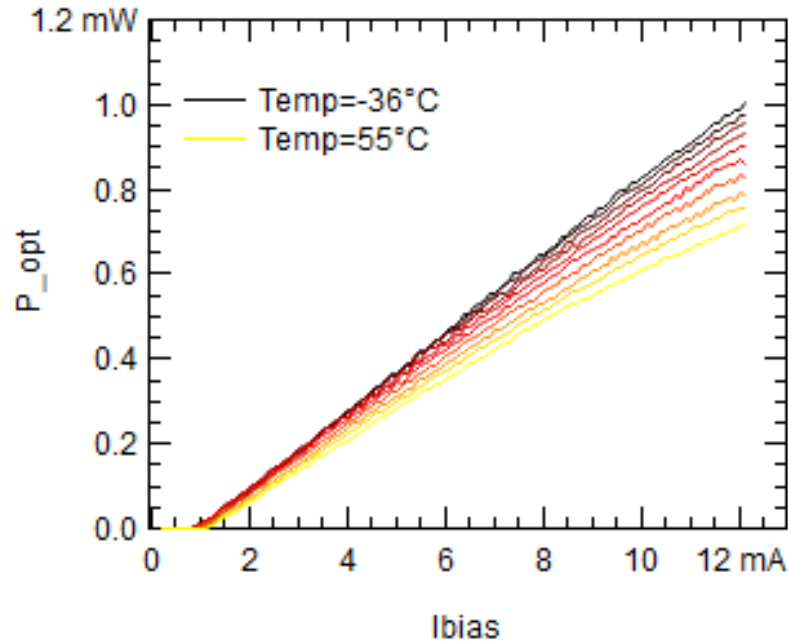


Results

- We measured the voltage over the diode and the emitted optical power as a function of the bias current.
- Images show the method of acquiring resistance, slope efficiency and threshold currents using linear fits.



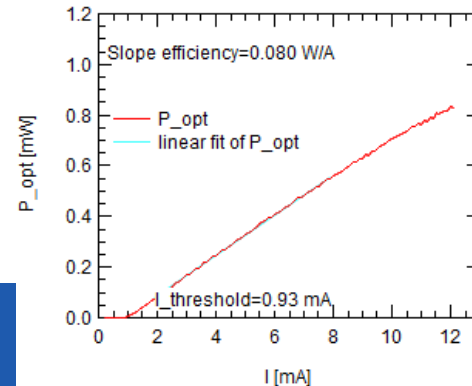
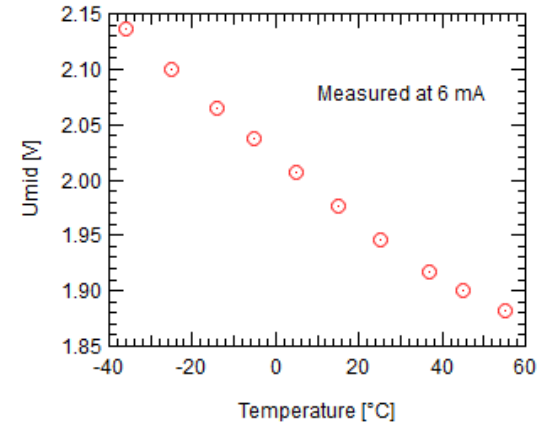
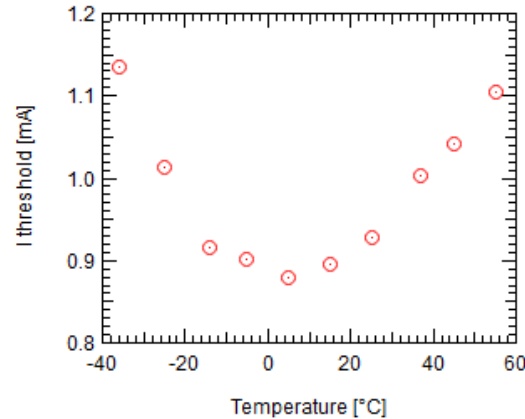
Effects of temperature



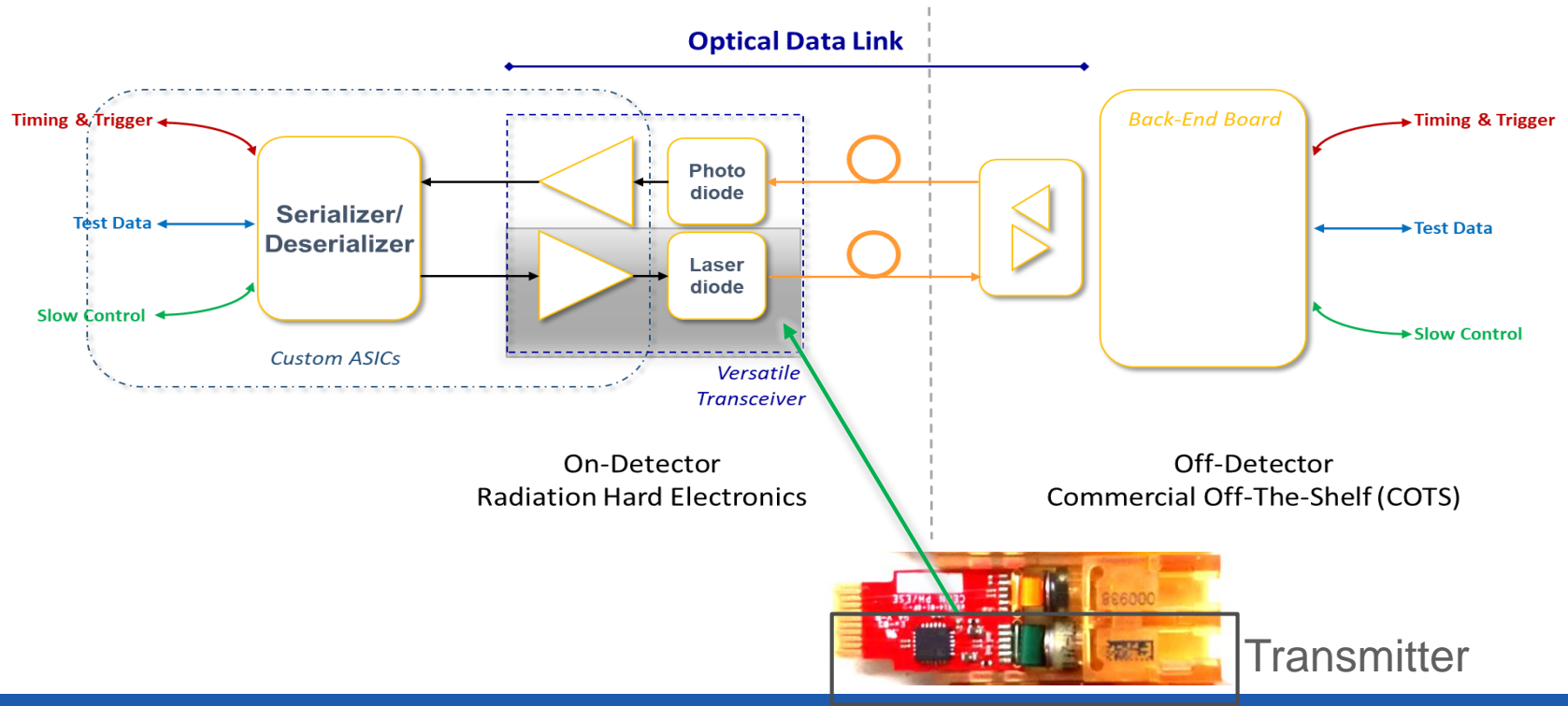
Analysis of the results

- The required operating voltage of the diode increased when lowering the temperature.
- When getting lower than $\sim 5^{\circ}\text{C}$, the threshold current increased as temperature decreased.

→ Both of these will limit the amplitude the diode is able to transmit.

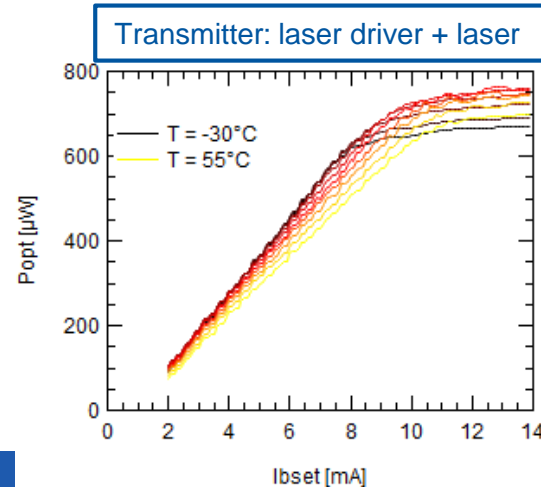
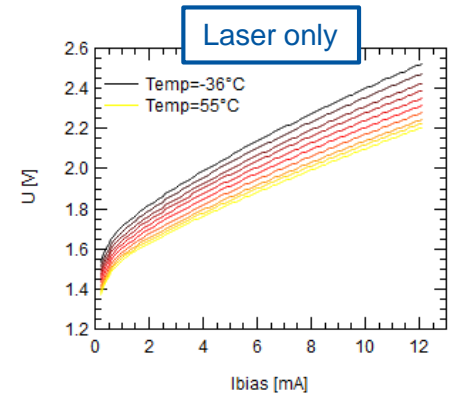
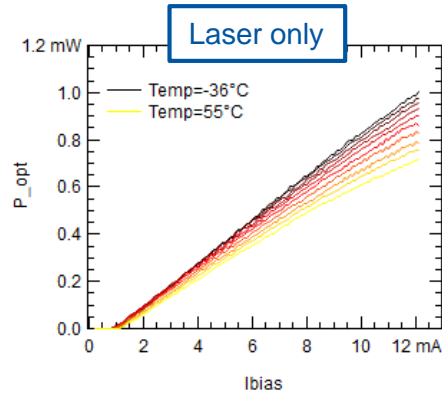


Measured part



Transmitter results

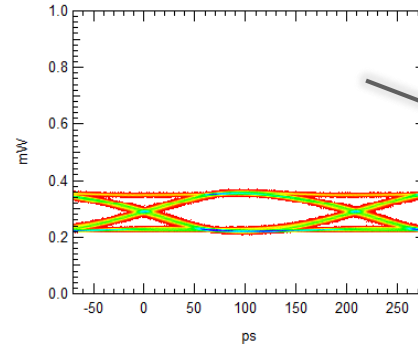
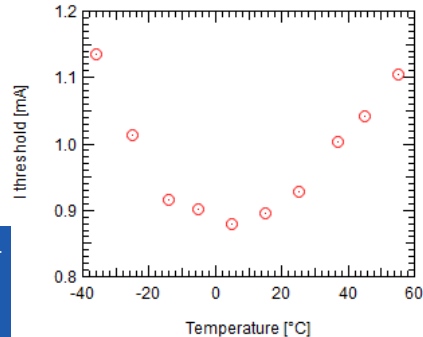
- Due to the manufacturing process, the limit of the operating voltage for the laser driver is 2.5V.
 - Setting the bias current higher won't increase optical power emitted after a certain point.
 - This effect is more noticeable at lower temperatures because of the characteristics of the laser diode.
- Voltage across the laser diode limits the maximum output power



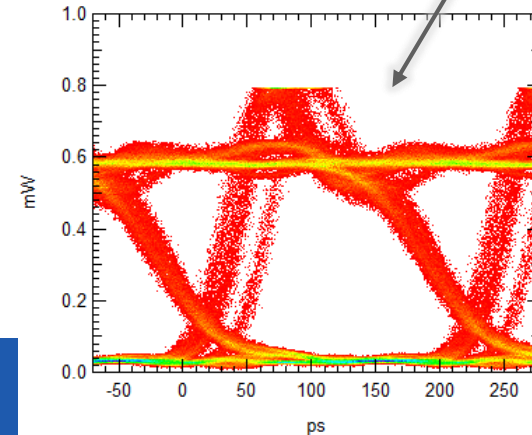
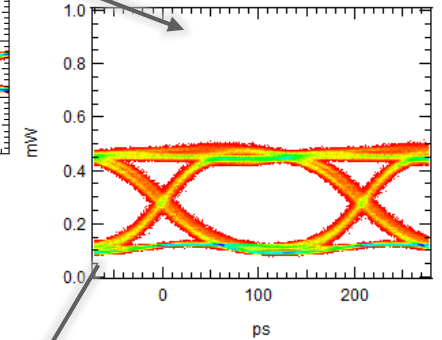
Transmitter results

- Although raising modulation current increases optical amplitude, pushing the diode to the threshold current (on right) will limit the performance

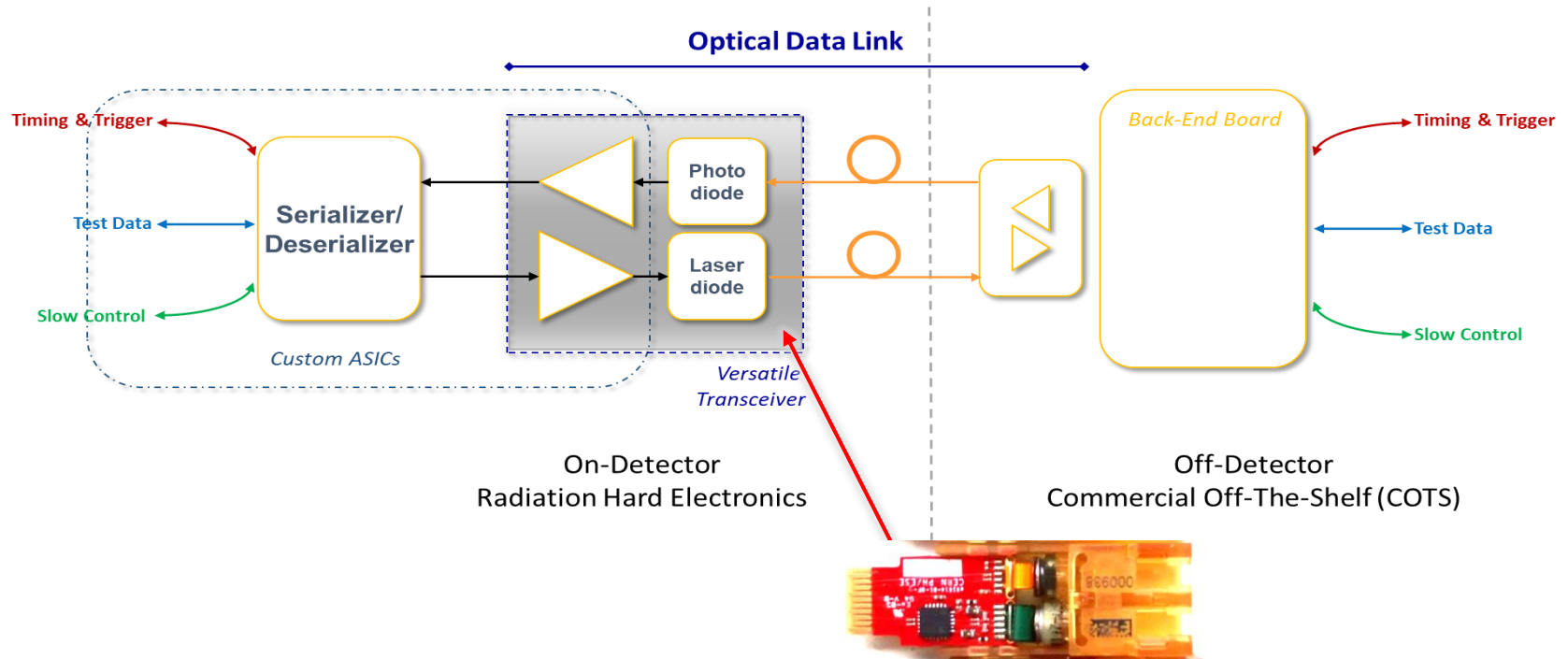
→ The increasing threshold current reduces the available modulation



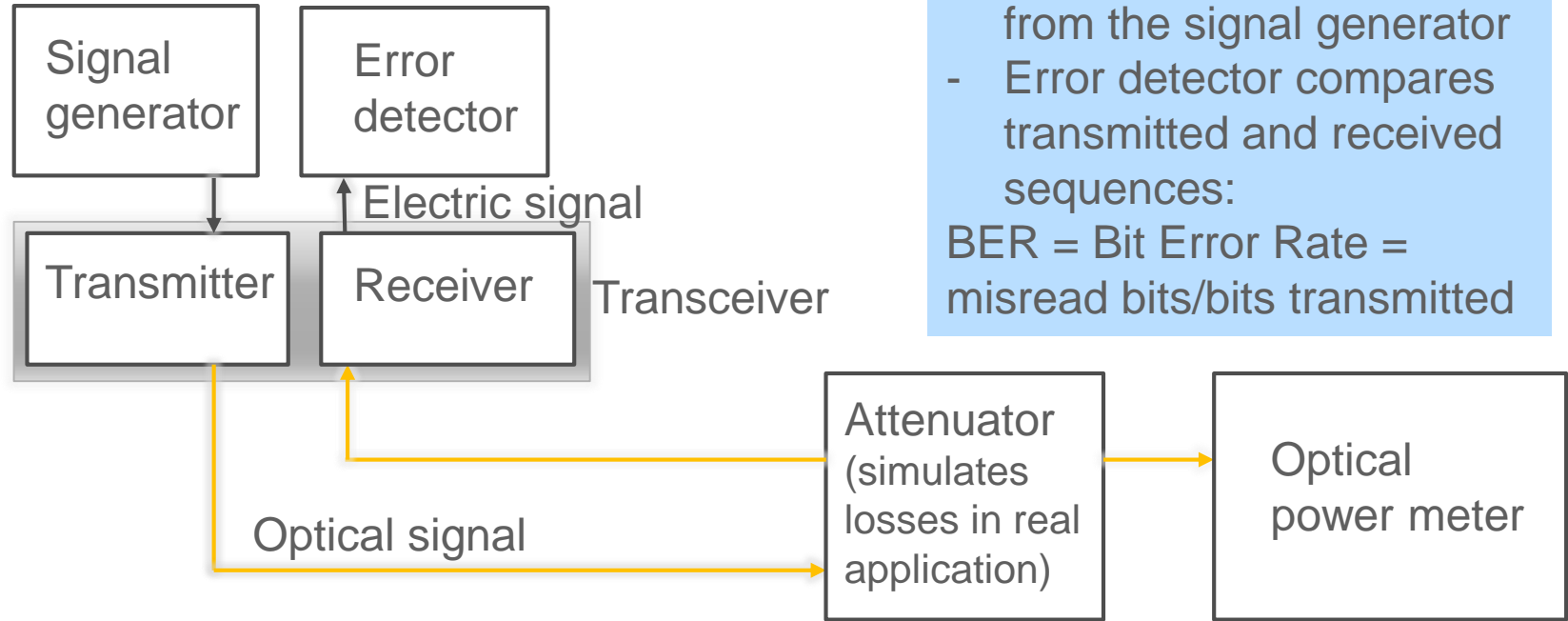
More modulation current



Measured part



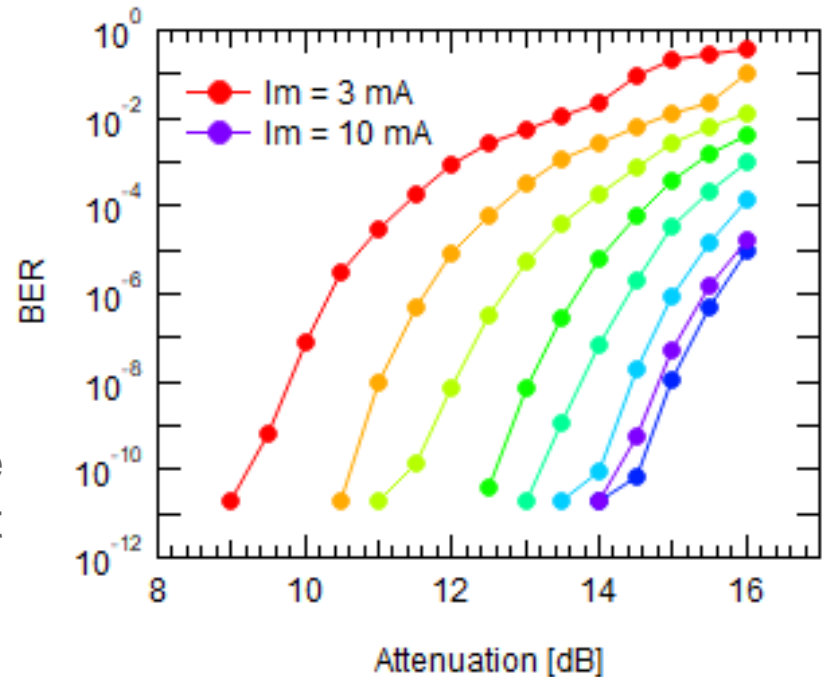
Testing the BER of the transceiver



- Pre-defined bit sequence from the signal generator
- Error detector compares transmitted and received sequences:
$$\text{BER} = \text{Bit Error Rate} = \frac{\text{misread bits}}{\text{bits transmitted}}$$

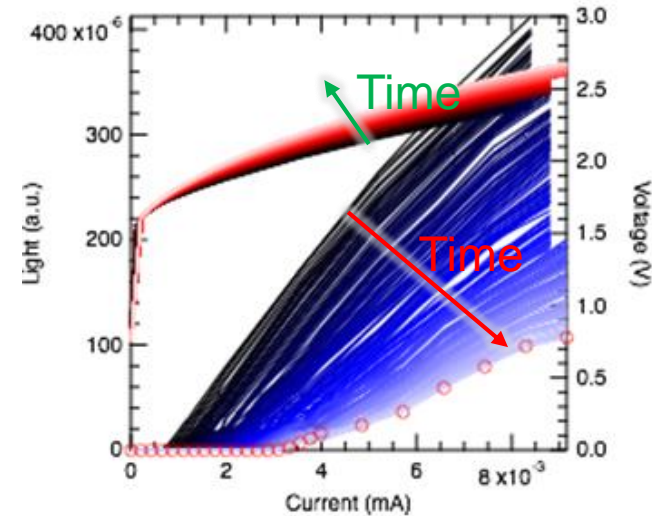
Results of the measurement

- BER is here plotted as a function of attenuation, i.e. how much the optical signal is dimmed
- Raising the modulation amplitude decreased the BER, which means that fewer errors are detected in the receiver
- However, after a certain point ($\sim 9\text{mA}$) the signal didn't improve because the current hit the threshold current at lowest points



Radiation

- Additional to the factors we were able to test, radiation affects the signal strength negatively.
- Radiation damage affects the characteristics of the components in a way similar to cold temperatures.
- Radiation damage builds up over time and the components within a detector aren't easily replaceable.



Summary

- Detector chamber's unusual environment causes several different problems for optical data links.
- However, optical fibre is currently the only data transferring method capable of meeting the requirements of the experiments.
- With careful characterization and design, CERN has been able to overcome these problems.