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Lab test for OWC at SSSA and CERN secondment prospects

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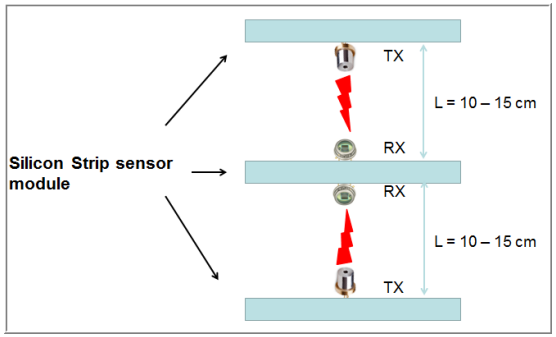
Outline

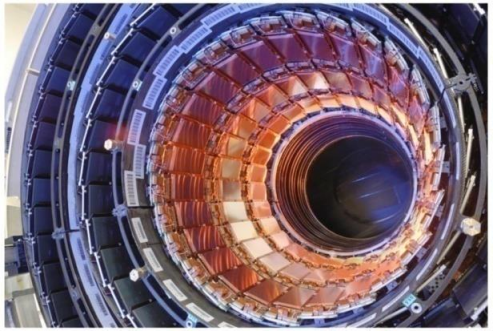
- OWC for Particle Physics Detectors in HEP
- OWC using VCSEL and photodiode with Ball Lens
- Simulations to optimize receiver
- Lab Facilities at SSSA for OWC characterization
- CERN Secondment
- Conclusion

OWC For Particle Physics Detector in HEP

- Goal of the activity:
  - To design high speed (Multi Gb) optical wireless communication (OWC) system for particles detectors (CMS used as a case study).

- Motivation
  - OWC system is required in order to reduce the material budget inside the detector system.
  - OWC system results in radial connection in order to have a faster event selection and lower latency





OWC For Particle Physics Detector in HEP

- System specifications :
  - Data Rate requirement in Gbps (1-10 Gbit/s)
  - Distance (10cm to 15cm Approx)
  - Min requirement of Tolerance to Misalignment (250um)
  - Radiation hard optical devices.

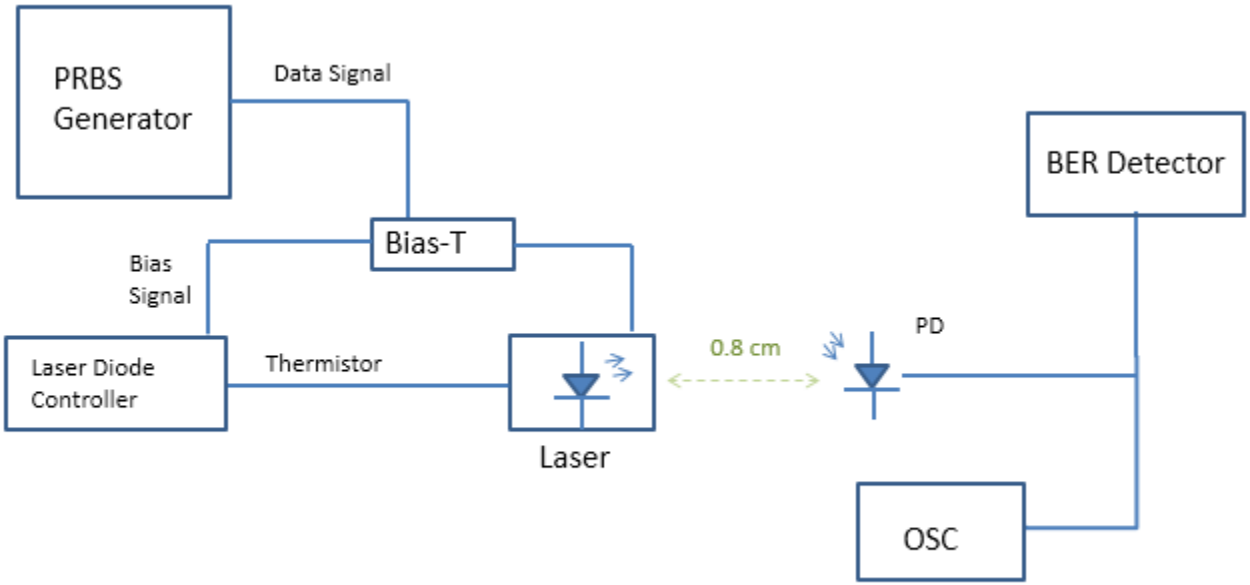
- List of the activities done:
  - Selection of source wavelength
  - Tolerance to misalignment study (2.5Gb/s and 10Gb/s).

OWC Using VCSEL and Photodiode with Ball Lens

- We realized 2.5 Gb/s setup but at distance of 0.8cm approx.
- We used VCSEL with out any optics and it emits light with higher divergence angle. This results in short communication distance
- Although we used photodiode with focusing ball lens (1.5mm diameter), yet we observed that sensitive area of ball lens is not at right focal length of ball lens.

Experimental Setup:

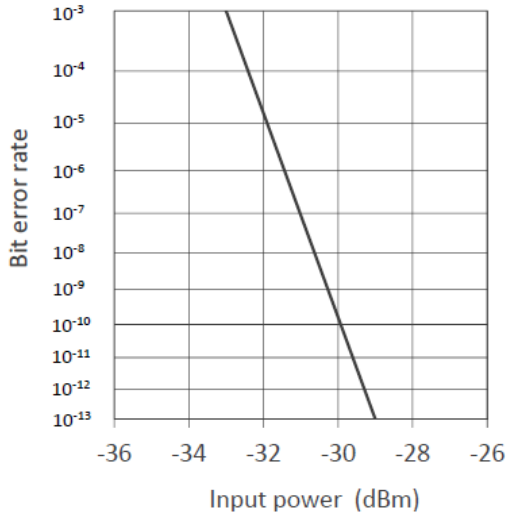
- Figure presents simple setup of OWC using VCSEL, which is directly modulated by providing data signal from pattern generator and bias signal from laser diode controller. Received signal on photodiode is analyzed using BER detector and oscilloscope (OSC)



VCSEL Specifications	
Threshold Current_Max(mA)	4 mA
Output Power (mW)	1
Divergence (Full Angle)	16
Beam Waist (um)	10

Simulation to optimize receiver

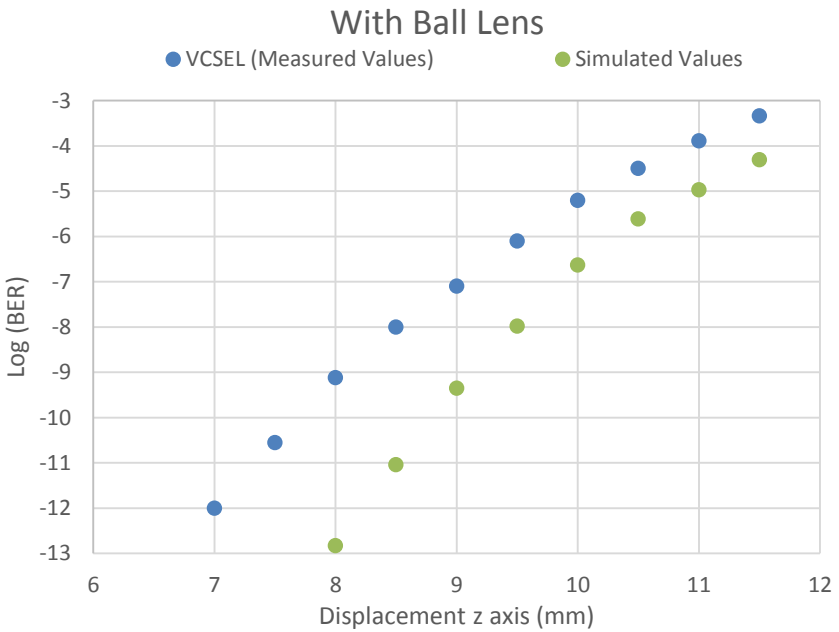
- Because it is hard to find VCSEL with high power providing Gb/s data rate at 1550nm, we planned to optimize receiver.
- We performed simulation using Ray tracing software (Tracepro) and compared results with experimental values.
- We can only calculate received power with ray tracing software therefore, we calculated approx. BER, using BER vs power curve of photodiode specification.



Comparison of Simulated and Measured Values

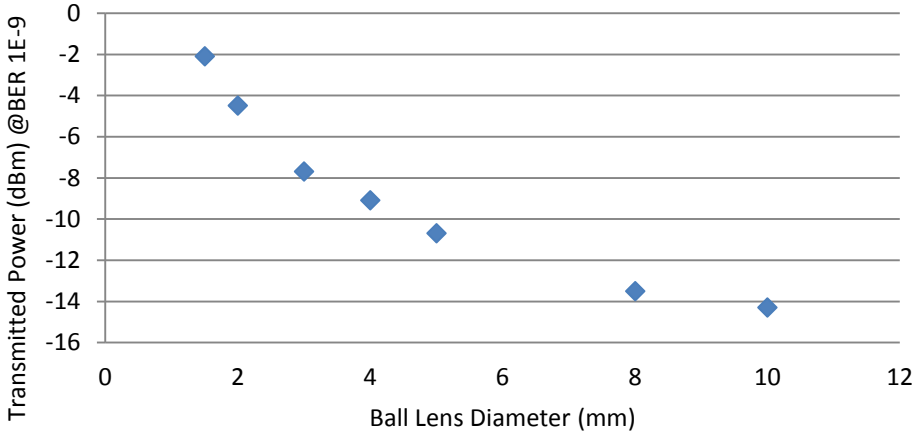
- BER vs. horizontal displacement are compared for simulated and measured values in order to calculate power penalty at 2.5 Gb/s data rate.

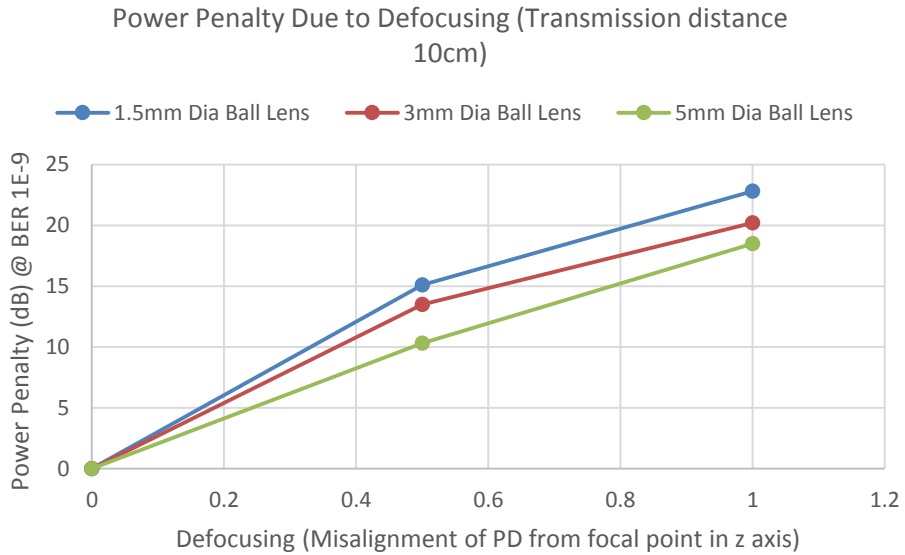
	Ball Lens (10.5mm)	Ball Lens (12mm)
Simulation Received Power	-29.58	-31.14
Measure Received Power	-30.6	-31.79
Difference	1.02	0.65

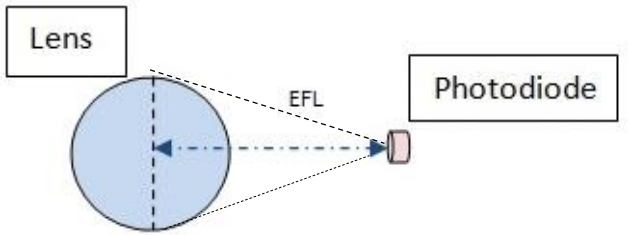


Receiver Optimization performing Simulations

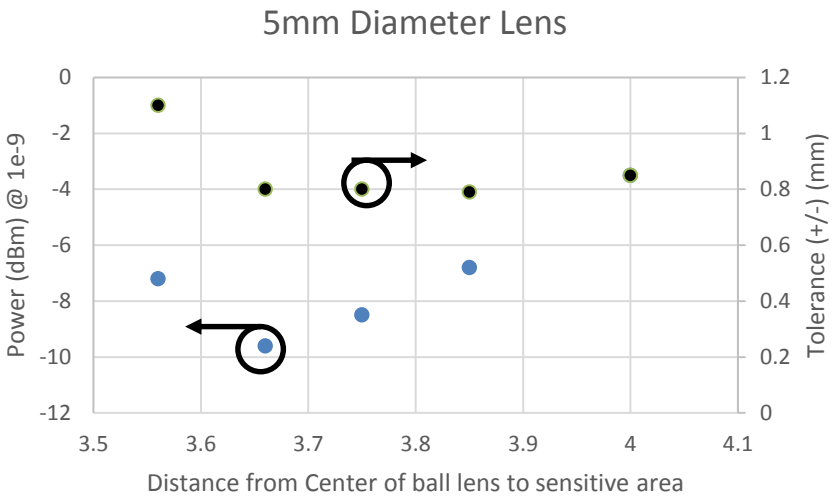
- Simulation were performed to optimize receiver by increasing the ball lens radius and placing the sensitive area of the ball lens at right focal length of lens.

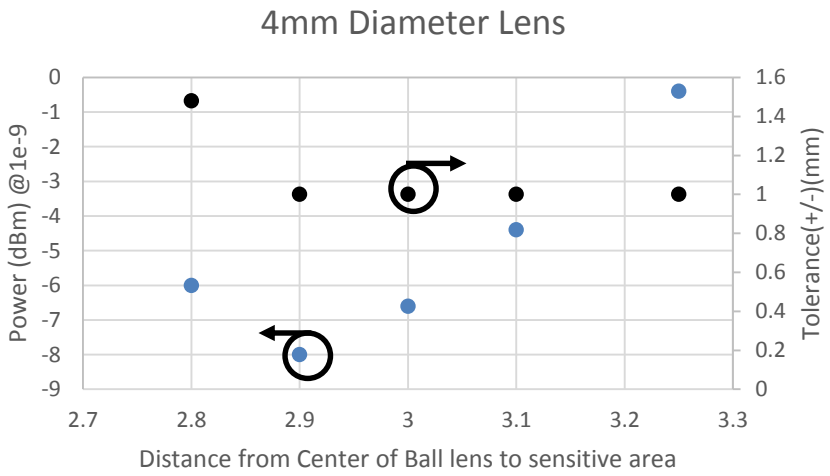


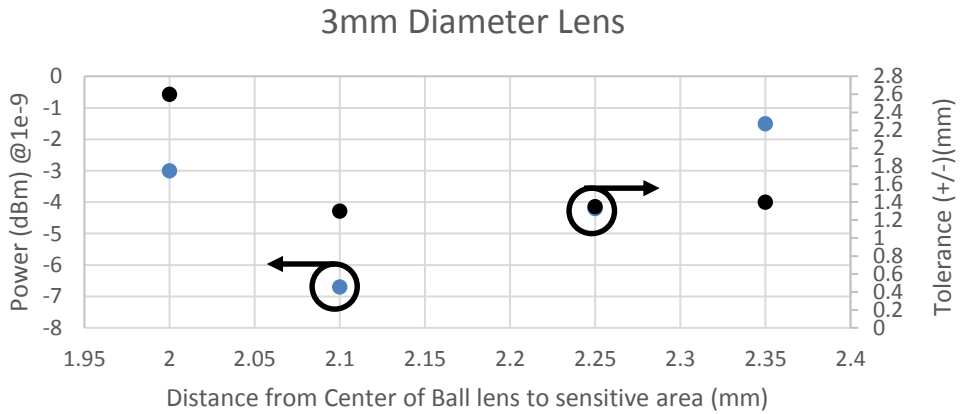




Launched power and Tolerance Values for 2.5 Gb/s at L = 10 cm (power rescaled by 1 dB)







Results Discussion

- The Table provide the summary for the minimum transmitted power and tolerance when photodiode sensitive area will be at right focal point of ball lens.

- 4mm diameter lens can be used in our design as it can require -8dBm of launched power to obtain BER of 1×10^{-9} with tolerance of +\- 1mm (3dB power penalty).

Summary Best Possible Values			
	5mm	4mm	3mm
Transmitted Power*(dBm)	-9.6	-8	-6.7
Tolerance (mm)	+\-0.8	+\-1	+\-1.3

* Power to obtain BER of 1×10^{-9}

Lab Facilities at SSSA For OWC Characterization

i. Signal Generators :
   - Pattern Generators:
     - With data rate up to 12.5Gbps
     - PRBS $(2^7 \ to \ 2^{31})$
   - Arbitrary Waveform Generator:
     - 12GS/s with 12 bit resolution, 10GS/s with 14 bit resolution

ii. Signal Quality Analyzer:
   - BER Tester (With and without internal clock recovery)
     - Data rate up to 12.5Gbps
   - Real Time Sampling Oscilloscope (40GS/s, 13GHz)
   - Digital Storage Oscilloscope

Lab Facilities at SSSA For OWC Characterization

- Travel Stages:
  - 3 axis roller block (resolution up to $5\mu m$)
  - Two axis Linear Translation stage.
- Other Equipment's
  - Laser Sources (Tunable and fixed wavelength) at 1300 to 1500nm.
  - MZ Modulators.
  - Laser Drivers.
  - Optical Spectrum Analyzers
  - Electrical Spectrum Analyzers

CERN Secondment (Irradiation test for Optical Components)

- Laser, Photodiodes, TIA, optics should be radiation hard in order to use them in particle physics detectors.
- Normally all the components are tested with neutron, pions and gamma radiations.
- Main aim of secondment is to be part of research team at CERN to perform irradiation tests of optical components and their characterization.

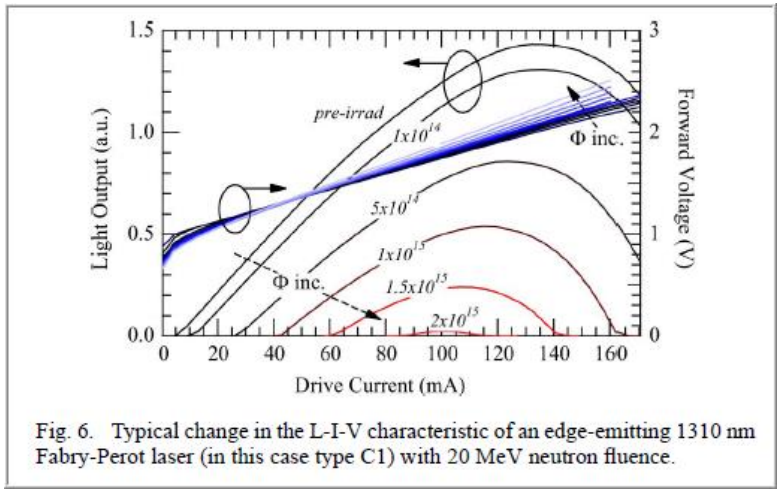


Fig. 6. Typical change in the L-I-V characteristic of an edge-emitting 1310 nm Fabry-Perot laser (in this case type C1) with 20 MeV neutron fluence.

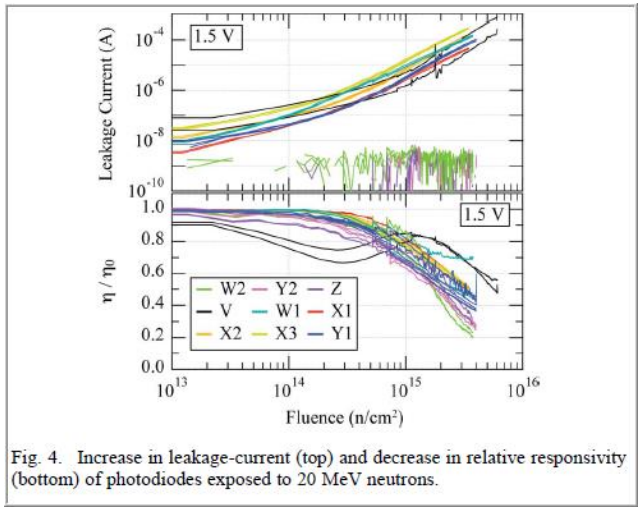


Fig. 4. Increase in leakage-current (top) and decrease in relative responsivity (bottom) of photodiodes exposed to 20 MeV neutrons.

Conclusion

- Initial working on wavelength selection and tolerance to misalignment study is completed.
- We studied the OWC setup using VCSEL and photodiode with focusing ball lens for data rate of 2.5 Gb/s
- We performed simulations using ray tracing software and studied the improvement in tolerance to misalignment by using larger diameter ball lens (3mm, 4mm, 5mm).
- 4mm diameter can be a good option as it needs -8dBm launched power with tolerance to misalignment of +\- 1mm
- Discussed lab facilities to characterize OWC.
- CERN secondment: to perform irradiation tests for optical components.

Thanks

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