Characterization of Semiconductor Lasers for Radiation Hard High Speed Transceivers

Sérgio Silva, Luís Amaral, Stephane Detraz, Paulo Moreira, Spyridon Papadopolos, Ioannis Papakonstantinou, Henrique Salgado, Christophe Sigaud, Csaba Soos, Pavel Stejskal, Jan Troska, François Vasey

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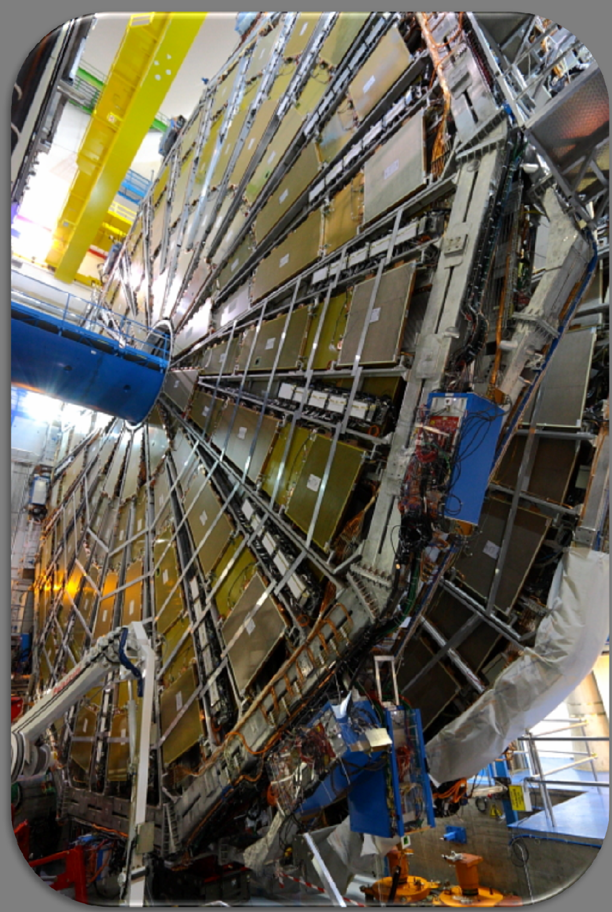
Abstract: **In the context of the versatile link project, a set of semiconductor lasers were studied and modelled aiming at the optimization of the laser driver circuit. High frequency measurements of the laser diode devices in terms of reflected and transmission characteristics were made and used to support the development of a model that can be applied to study their input impedance characteristics and light modulation properties. Furthermore the interaction between the laser driver, interconnect network and the laser device itself can be studied using this model. Simulation results and measured data show good agreement, therefore validating the laser model and methodology used.**

Large Hadron Collider at CERN:

- Largest particle accelerator for high-energy physics research.
- An upgrade of the current LHC (Super LHC), planned for 2013-18.
- A tracking detector operating at the Super LHC will require ten times more readout data bandwidth and radiation tolerance than at the current LHC detectors.
- Necessary to design a digital transceiver capable of operating at high speed (multiple GBits/s) in harsh environment:
  - High radiation levels
  - High magnetic fields
  - Low temperatures

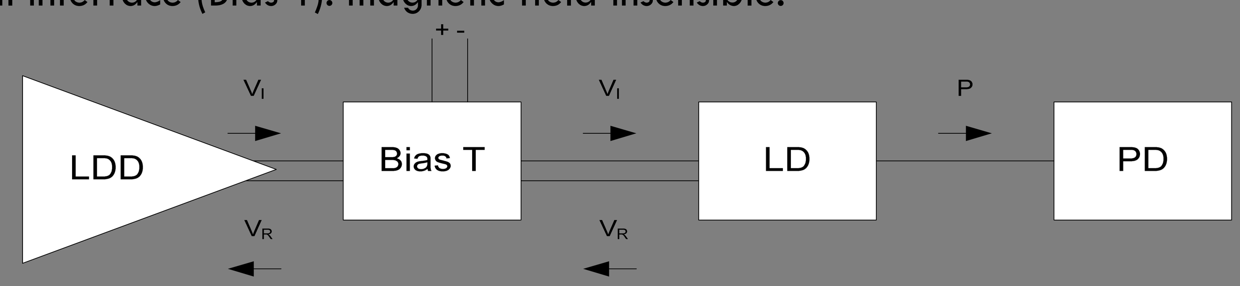


Radiation-hard optical link for the experiments system outline:

- Fast read-out capabilities.
- Transmission of command instructions and synchronization signals.
- Based essentially on COTS: qualify for rad-hard.

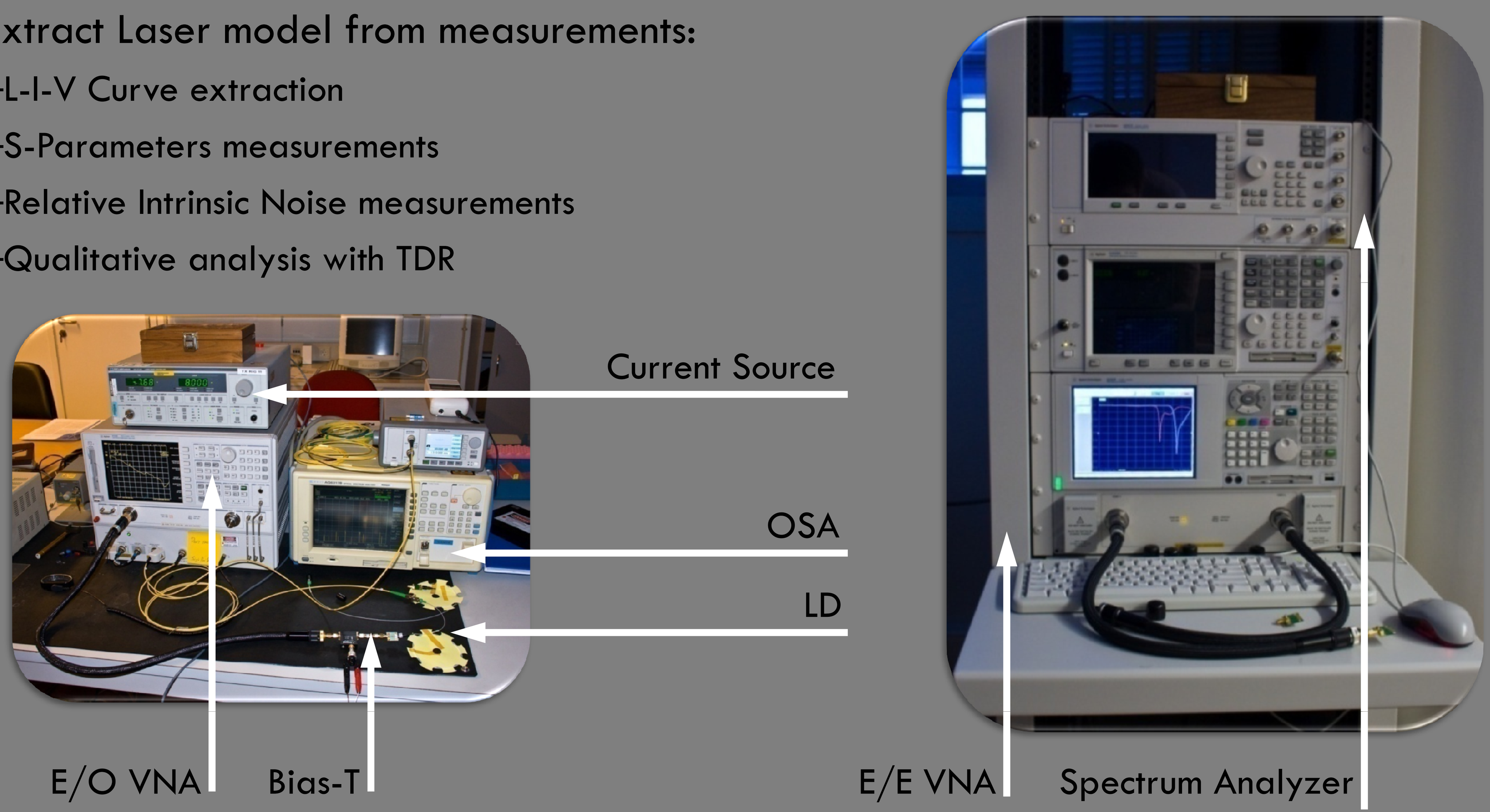
Interaction between LASER and driver should be characterized:

- Electrical impedance mismatch should be kept < 10%
- Design a matching network
- Study peaking circuit / Pre-Emphasis
- DC electrical interface (Bias-T): magnetic field insensible.



Extract Laser model from measurements:

- L-I-V Curve extraction
- S-Parameters measurements
- Relative Intrinsic Noise measurements
- Qualitative analysis with TDR

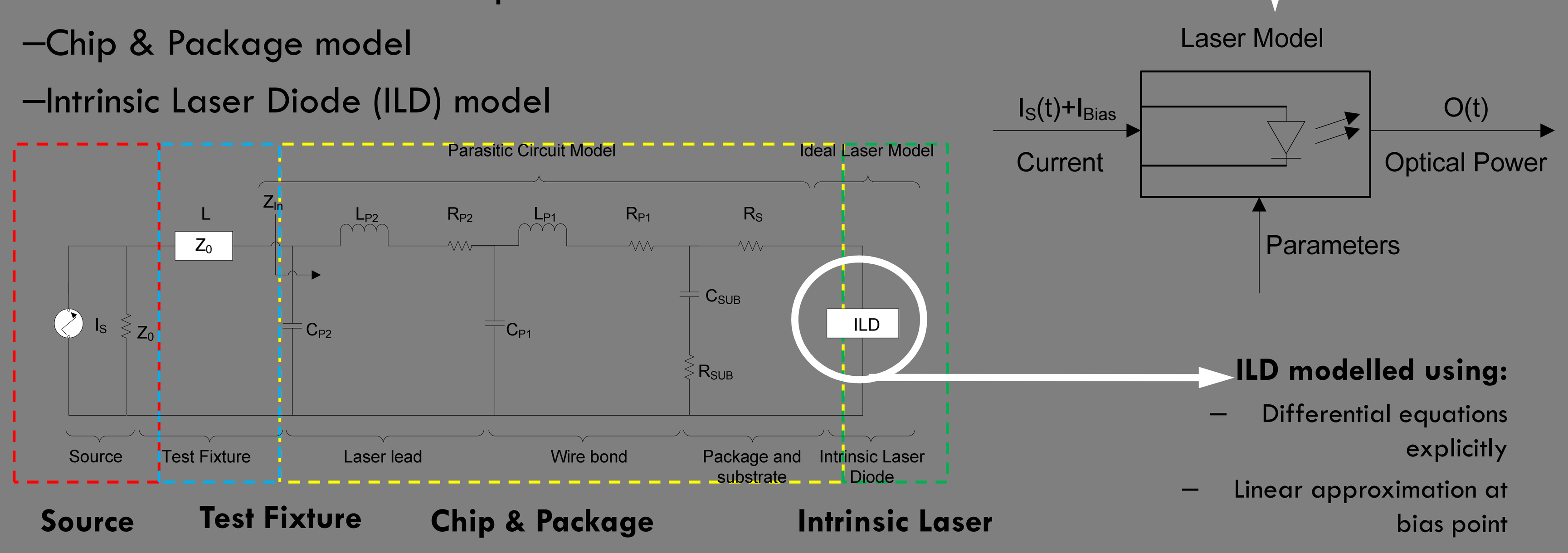


Requirements of the LASER model:

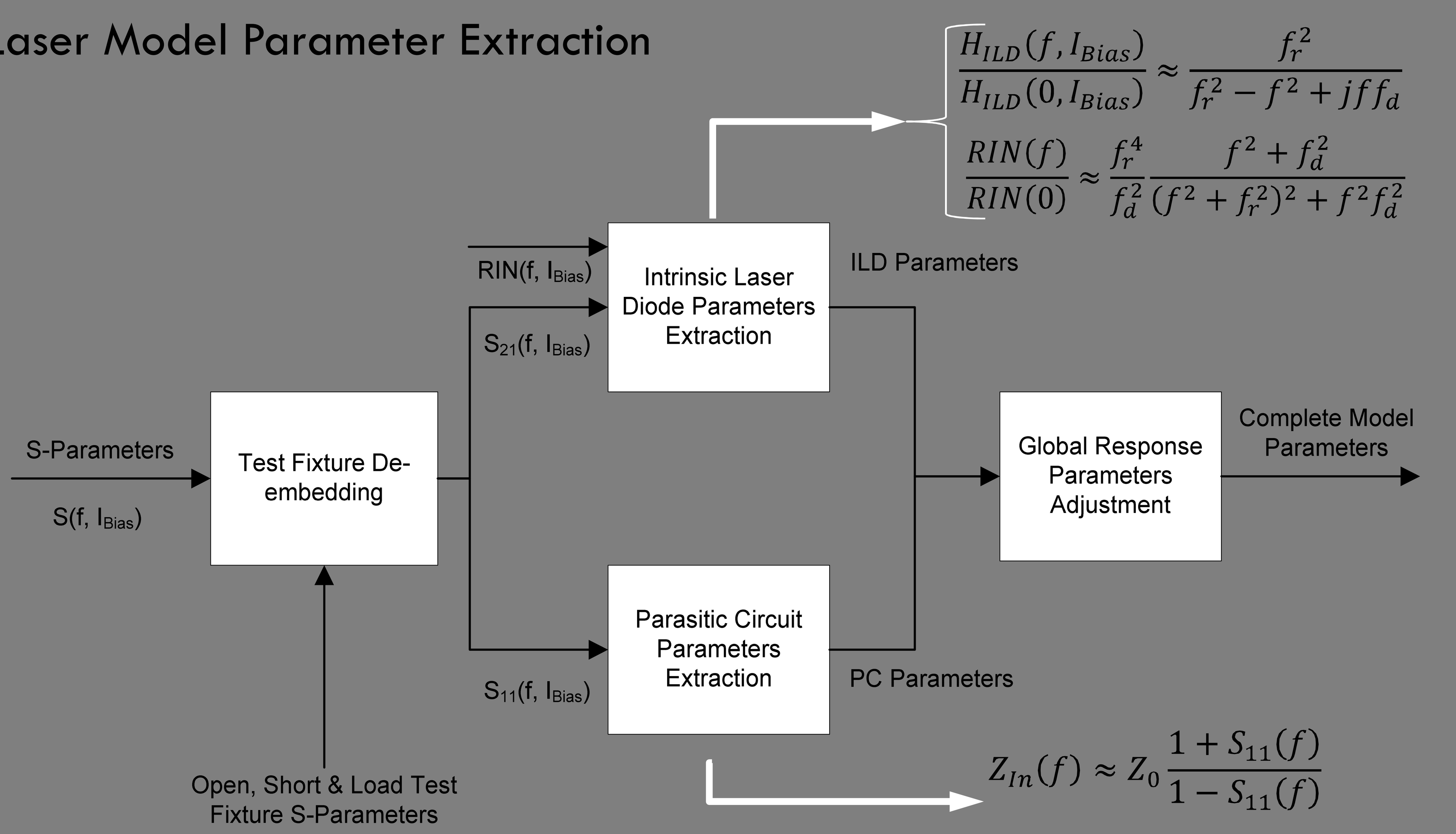
- Should give an accurate representation of the static behavior
- Should represent the real device input impedance (within the bandwidth of interest)
- Should mimic the dynamic performance of the real laser

Measurements lead to simplified laser model:

- Chip & Package model
- Intrinsic Laser Diode (ILD) model



Laser Model Parameter Extraction

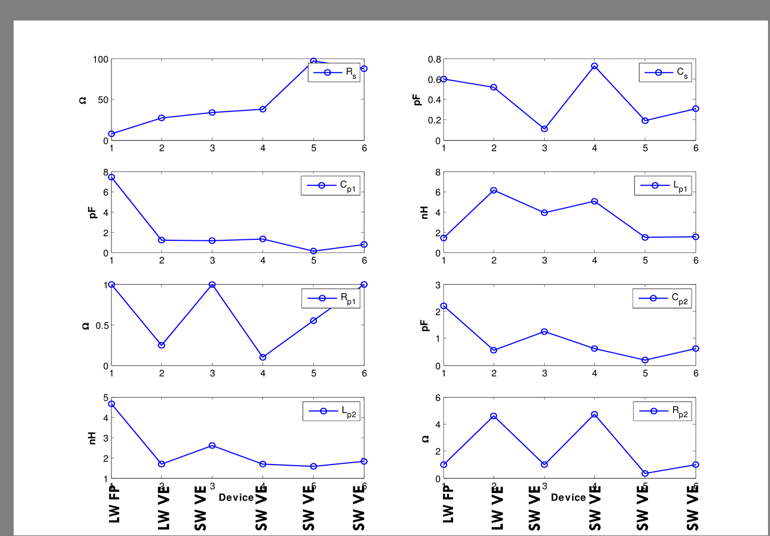


$$\frac{H_{ILD}(f, I_{Bias})}{H_{ILD}(0, I_{Bias})} \approx \frac{f_r^2}{f_r^2 - f^2 + jff_d}$$

$$\frac{RIN(f)}{RIN(0)} \approx \frac{f_r^4}{f_d^2} \frac{f^2 + f_d^2}{(f^2 + f_r^2)^2 + f^2 f_d^2}$$

$$Z_{in}(f) \approx Z_0 \frac{1 + S_{11}(f)}{1 - S_{11}(f)}$$

Parasitic Circuit Parameters

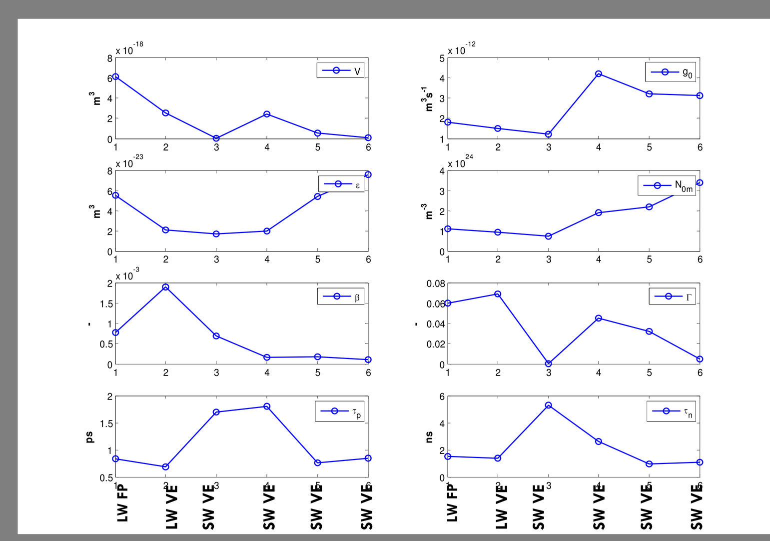


Parameters obtained for a set of FP, SW VCSELs and LW VCSELs Lasers

Good parasitic model fit:

- Active area resistance higher for the VCSELs
- Active area resistance even higher for the SW-VCSELs
- Remaining parameters similar: identical packages

ILD Parameters

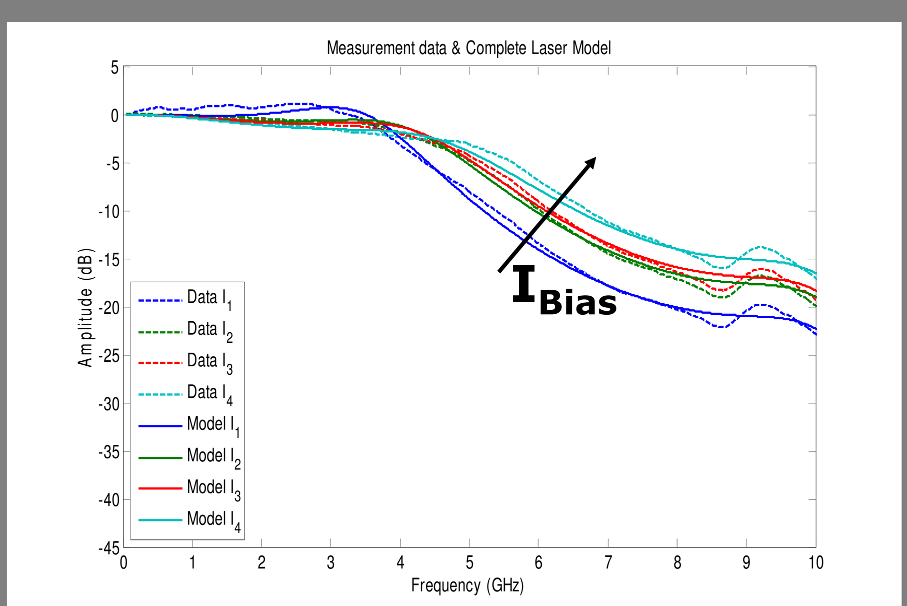


Parameters obtained for a set of FP, SW VCSELs and LW VCSELs Lasers

Good ILD model fit:

- The FP laser (1) has the highest active volume value
- The VCSEL LW laser (2) has an active volume that is larger than the SW lasers
- The high BW (1, 2, 5 and 6) show simultaneously low photon and carrier lifetimes.

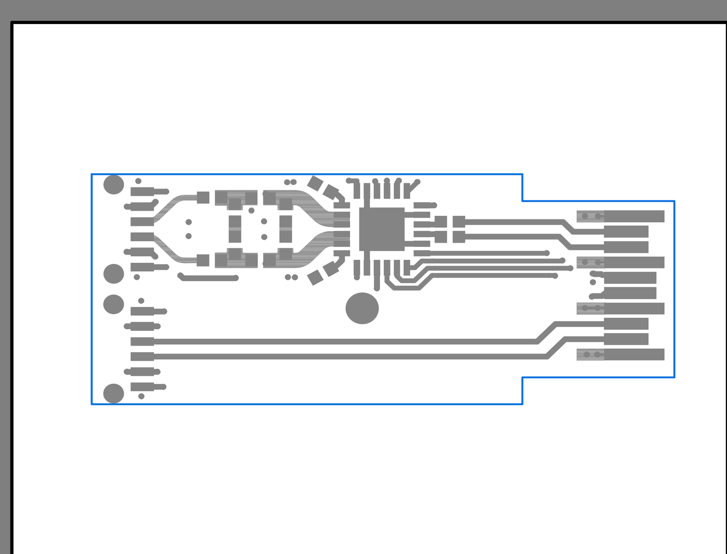
Measured data vs. Model fit

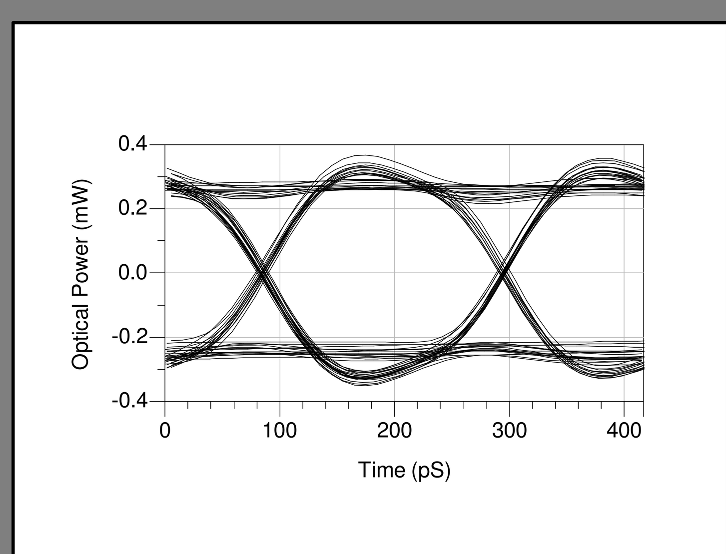


Good model fit:

- Modelled transfer function follows closely the measurements
- Clear dependence on bias
- Bandwidth increases as bias increases

Design of the SFP (transceiver) prototype:





Predict the performance of the system by using the laser driver, electric network simulation and laser model

Conclusion: **Using simple assumptions, a broadly applicable model was developed that can be used with many different types of semiconductor lasers. This model is modular in order to separate the analysis made for package parasitic from the laser parameters. Very good agreement between the model and the measurements was obtained, which is fundamental for a correct study of the design of a robust transceiver with demanding requirements.**