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# Semiconductor Laser Modulation Response

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***Abstract***

*This project is based on laser emission the nature of the optical power output from the laser depending upon various parameters of the laser and the input signal is observed. So in circuit we use a pseudo-random sequence generator, which produces sequence which is only known to sender and receiver and purely random to others, non-return-to-zero pulse generator is used which feeds NRZ pulses to the laser, which is the driving signal to the laser, the laser thus producing optical output depending upon the driving current (NRZ signal), as we know laser is a non- linear device producing harmonics at the output also along with the desired signal. The light output at laser's output is fed to the photo diode for conversion back to the electric domain which now also includes harmonics, so a low pass Bessel filter is connected after photo diode to reduce harmonics and get output at some desired range of frequencies, which produces fiddle bits at the output with more q-factor, more eye height and lesser bit error rate possible. When using a directly modulated laser for high-speed transmission systems, the modulation frequency can be no larger than the frequency of the relaxation oscillations. The relaxation oscillation depends on both carrier lifetime and photon lifetime. The relaxation oscillation frequency increases with the laser bias current. In this lesson, we will demonstrate the performance of the high speed system while using the modulation frequency and increasing resonance frequency (through the improvement in the system performance) with the laser bias current.*

***Keywords**: Optical communication, OptiSystem, Semiconductor LASER, Modulation.*

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## 1. Introduction

Optical communication systems are increasing in complexity on an almost daily basis. The design and analysis of these systems, which normally include nonlinear devices and non-Gaussian noise sources, are highly complex and extremely time-intensive. As a result, these tasks can now only be performed efficiently and effectively with the help of advanced new software tools. In an industry where cost effectiveness and productivity are imperative for success, the award winning OptiSystem can minimize time requirements and decrease cost related to the design of optical systems, links, and components. OptiSystem is an innovative, rapidly evolving, and powerful software design tool that enables users to plan, test, and simulate. It offers transmission layer optical communication system design and planning from component to system level, and visually presents analysis and scenarios. Its integration with other Optiwave products and design tools of industry leading electronic design automation software all contribute to OptiSystem speeding your product to market and reducing the payback period.

OptiSystem is an innovative optical communication system simulation package that designs, tests, and optimizes virtually any type of optical link in the physical layer of a broad spectrum of optical networks. OptiSystem is a stand-alone product that does not rely on other simulation frameworks. It is a system level simulator based on the realistic modeling of fiber-optic communication systems. It possesses a powerful new simulation environment and a truly hierarchical definition of components and systems. Its capabilities can be extended easily with the addition of user components, and can be seamlessly interfaced to a wide range of tools. OptiSystem is a comprehensive software design suite that enables users to plan, test, and simulate optical links in the transmission layer of modern optical networks. Optiwave software is very useful one. It helps in simulation of the optic-circuits, which can then to be used by design engineers to evaluate the effect of different parameters and the efficiency of the designed system. It also helps the marketing teams of component and system vendors to powerfully and cost-effectively demonstrate their products. It reduces the investment cost incurred for the research as the software offers conditions close to the real one.

## 2. LASER

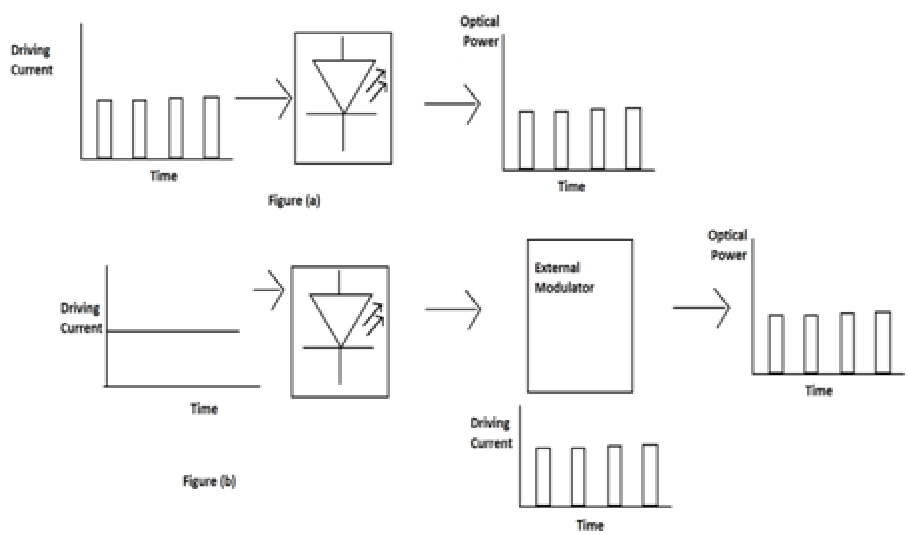



Fig. 1(a): The Driving current to Laser is the Modulating signal, so it turns Laser On and Off (b): Driving current to Laser is constant and Light thus emitted is modulated by external modulator

A laser is a device that emits light through a process of optical amplification based on the stimulated emission of electromagnetic radiation. The term “laser” originated as an acronym for “Light Amplification by Stimulated Emission of Radiation”. Laser is distinguished from other light sources by their coherence. Spatial coherence is typically expressed through the output being a narrow beam, which is diffraction-limited. Laser beams can be focused to very tiny spots, achieving a very high irradiance, or they can have very low divergence in order to concentrate their power at a great distance. As we know optical links for data flows offered much more advantages over the conventional metal links and are being used as transmission medium. As only light can flow through these links we require an electro-optic converter at sending end and optic-electro converter at receiving end for signal conversion. We require a source which can convert high frequency electrical signal to optical domain. Laser is the best known modulation source of optical light, which can be coupled to the optical link with lower losses. Generally two techniques in for modulation are defined:

- External modulation: A continuous wave laser is used to emit light, and external modulator switches the light "ON" or "OFF".
- Direct modulation: The driving signal is fed to laser and light is emitted when "MARK" is sent and no light when "SPACE" it be sent.

Important parameters consideration about the laser to be used:
*Speed*: The speed of operation is required to be high as input data frequency is high, so the laser should be able to switch between states immediately.

*Extinction ratio*: It is the ratio of the power level corresponding to "MARK" to the power level corresponding to "SPACE".

$ER = P1/P0$
P1 – Power Level for MARK
P0 – Power Level for SPACE

The value of ER should be high for easy recognition of MARK and SPACE; otherwise if high power is transmitted but ER is less, the power transmitted is useless as probability of error at receiver is much more. Power Penality at Output is $\delta ER = 10 \log10 [(ER+1)/(ER-1)]$.

*Frequency chirp*: When an external field is applied as driving signal which forces changes in the charge density in the laser medium resulting in the changes in the refractive index and hence the phase of the output changes with time.

$$\omega (t) = \omega o + d\varphi/dt$$

$d\varphi/dt$ – equivalent to the change in signal intensity. The instantaneous frequency depends upon phase change; this undesired frequency modulation is known as frequency chirping. In optical fiber different frequency components travel in optical fiber link with different velocities resulting in pulse broadening at output.

### *Direct Current Modulation of Semiconductor Laser*

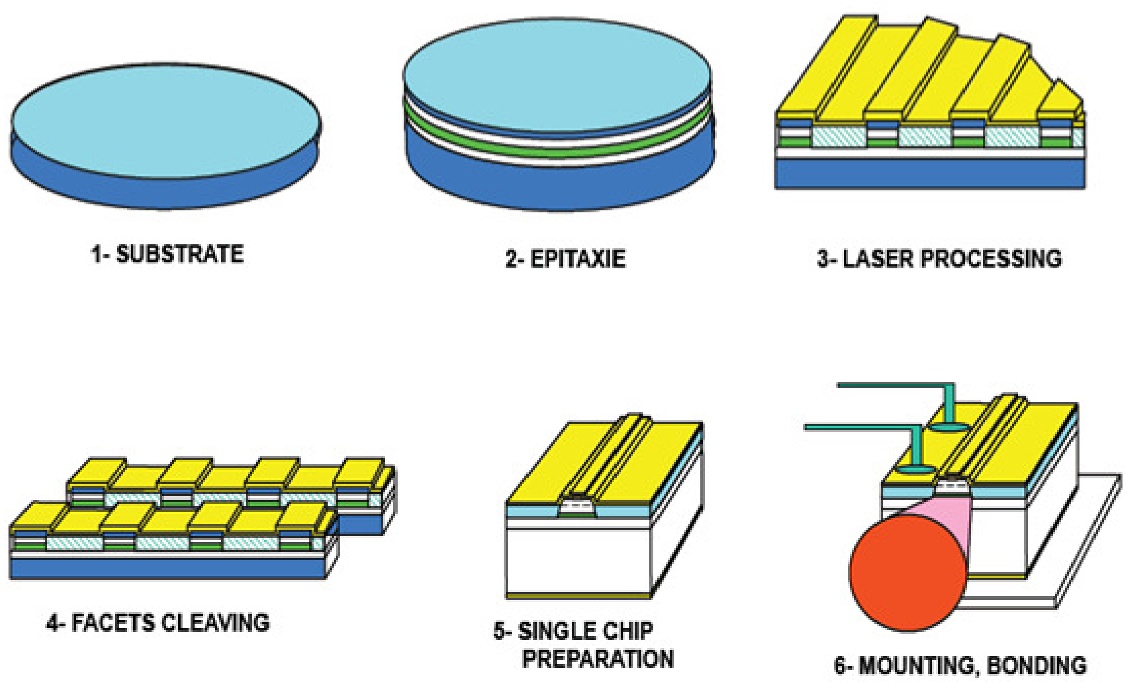
As stated before output power of laser depends upon the current injected. When laser is turned ON there is no output for some time, as it takes time to build up population inversion in laser, as current increases the population inversion is achieved this current is known as threshold current at which population inversion achieved. The laser output then increases almost linearly with the input current. Varying current depending on data we can convert electrical signal in to the optical signal which is to be transmitted. For data rates of less than approximately 10 Gb/s (typically 2.5 Gb/s), the process of imposing information on a laser-emitted light stream can be realized by direct modulation. The modulation frequency can be no larger than the frequency of the relaxation oscillations of the laser field. The relaxation oscillation occurs at approximately.

$$f_{res} = \frac{1}{2\pi} \frac{1}{(\tau_{sp}\tau_{ph})^{\frac{1}{2}}} \left(\frac{I}{I_{th}} - 1\right)^{\frac{1}{2}}$$

*Characteristics of semiconductor lasers*

- Capable of emitting high powers (e.g. continuous wave ~ W).
- A relatively directional output beam (compared with LEDs) permits high coupling efficiency (~ 50 %) into single-mode fibers.
- A relatively narrow spectral width of the emitted light allows operation at high bit rates (~ 10 Gb/s), as fiber dispersion becomes less critical for such an optical source.

## 3. Fabrication Steps for Semiconductor Laser




Default parameters Ith = 33.45mA, Tsp = 1ns, Tph = 3ps, Frequency=193.099 THz

Observation is taken at three different data rates, sweeping the Bias current from 60mA to 180mA and Bit Rate 1 Gbps to 1.2 Gbps.

*Output:*

Bias Current =180 mA

Maximum Q-Factor: 76.3614

Minimum BER: 0

Eye Height: 0.00601414

### *Project Layout*

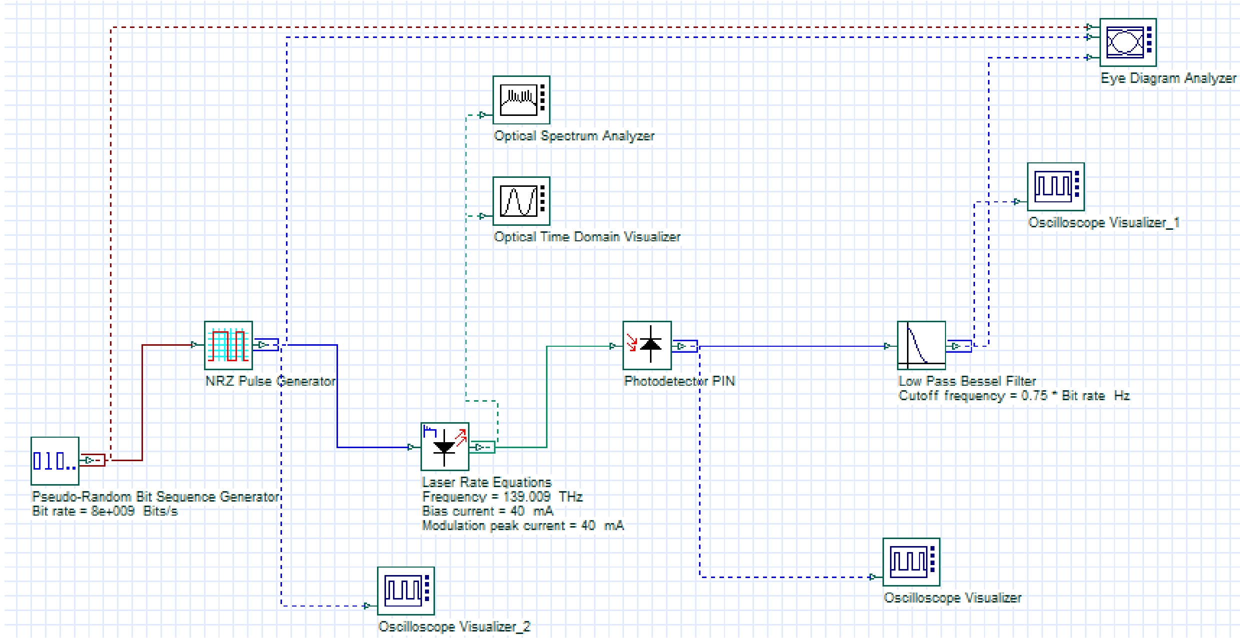



Fig. 2. Layout of Semiconductor Laser Modulation Response

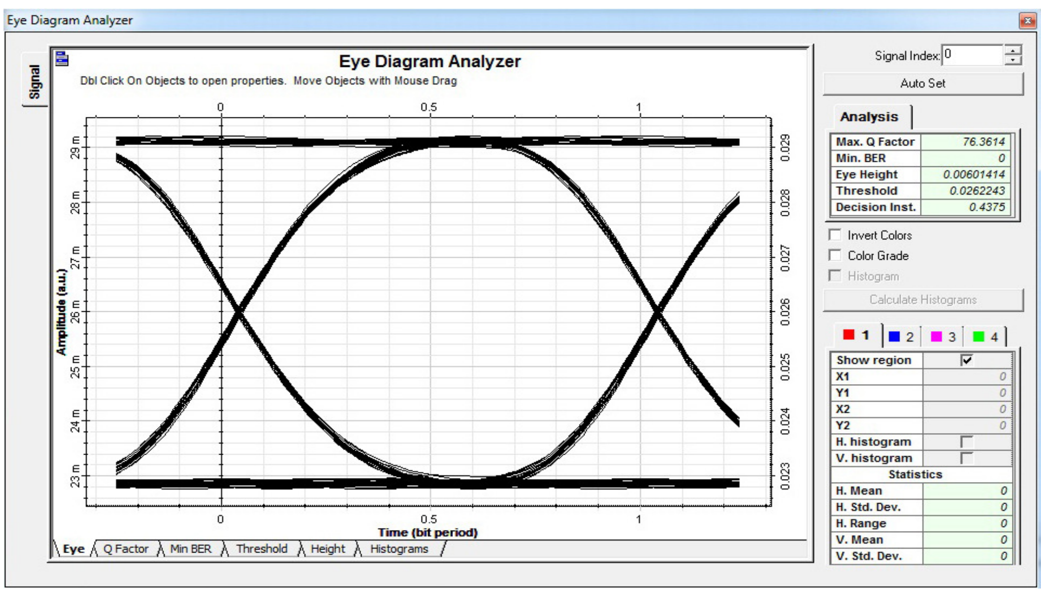



Fig. 3: Eye Diagram Output Screen

## 4. Conclusion

Plot the graph between Q-Factor vs Bias Current, Minimum BER vs Bias Current, and Eye Height vs Bias Current. The ability of semiconductor lasers to be modulated directly at high speed is among the unique features of those lasers which make them especially desirable sources for optical communication systems. We have shown the dependence of the performance of the high speed system on the modulation frequency and the laser bias current.

## 5. Future Prospects

Apart from their applied relevance, study of the dynamics of semiconductor lasers helps us to understand at least some of the universal features of nonlinear systems. Such a study also presents an opportunity to have a better understanding of the specific material and device level properties of the semiconductor laser. Thus, the semiconductor laser based study of nonlinear dynamics combines the aspects of material science and fundamental semiconductor physics with quantum opt.ics awl nonlinear dynamics. This is one of the reasons why we feel this area of research so exciting and promising for the future.

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