

Optical Transceiver Testing Using the VIAMI Solutions™ Multiple Application Platform (MAP-200)

An optical transceiver is a single, packaged device that works as a transmitter and receiver. It is an important part of optical network equipment that converts electrical signals to optical signals and vice versa. Optical transceivers are widely deployed today in synchronous optical networking/synchronous digital hierarchy (SONET/SDH), Gigabit Ethernet (GigE) and Fibre Channel (FC) optical networks. Optical transceiver manufacturers must perform a set of tests to ensure compliance with the defined specifications. This paper addresses the testing of two key optical parameters: transmitter optical power and receiver sensitivity, using the VIAMI Multiple Application Platform (MAP-200).

Optical Transceiver Overview

Several standards bodies govern optical transceiver specifications. The Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T) and Telcordia are the two major standards organizations for telecom, while the Institute of Electrical and Electronic Engineers (IEEE) and the American National Standard Institute (ANSI) are the major standards organizations for datacom. In addition, several transceiver manufacturers have established a multi-source agreement (MSA) to ensure interoperability. The scope of the MSA includes mechanical, electrical and optical specifications. In today's market, transceivers with bit rates below 10 Gb/s come in two primary form factors: small form-factor (SFF) and small form-factor pluggable (SFP). The 10-Gb/s transceiver market has also seen a wide variety of other form factors including 300 pins, small form-factor pluggable plus (SFP+), 10-Gigabit SFP (XFP), X2, XPAK, and XENPAK as a bigger footprint is needed to accommodate the more complex electronics.

An optical transceiver data sheet usually includes mechanical, electrical, and optical specifications. To guarantee compliance to specifications and industry standards, testing of the electrical and optical parameters is an essential step in the manufacturing process. Optical parameters can be further divided into two categories: transmitter and receiver. Table 1 shows some of the main parameters specified by transceiver manufacturers.

Transmitter Optical Parameters	Receiver Optical Parameters
Average Optical Power	Receiver Sensitivity
Extinction Ratio	Stressed Receiver Sensitivity
Optical Modulation Amplitude	Dispersion Penalty
Center Wavelength	Receiver Overload
Spectral Width	Loss of Signal/Signal Detect Assert/De-Assert
Optical Eye	Loss of Signal/Signal Detect Hysteresis

Table 1. Main parameters specified by transceiver manufacturers

The following section discusses testing of transmitter average optical power and receiver sensitivity. These two parameters are used in link power budget analysis at the system level to determine the power margin of an optical link. This margin is allocated for connector, splice, fiber losses, and system margin.

Transmitter Average Optical Power Measurement

The transmitter port of an optical transceiver consists of a light source and associated electronic circuitry. Semiconductor-based light emitting diodes (LEDs) and laser diodes are used as light sources in optical transceivers. LEDs and vertical cavity surface emitting lasers (VCSELs) are commonly used in the transmitters for local and premises networks while Fabry-Perot (FP) lasers and distributed feedback (DFB) lasers are used in the transmitters for Metro and long-haul networks.

In optical communication, light sources are intensity modulated, which is a process of applying varied current to the laser to change the output power level. As illustrated in Figure 1, a finite power level represents logic zero rather than a true complete absence of power.

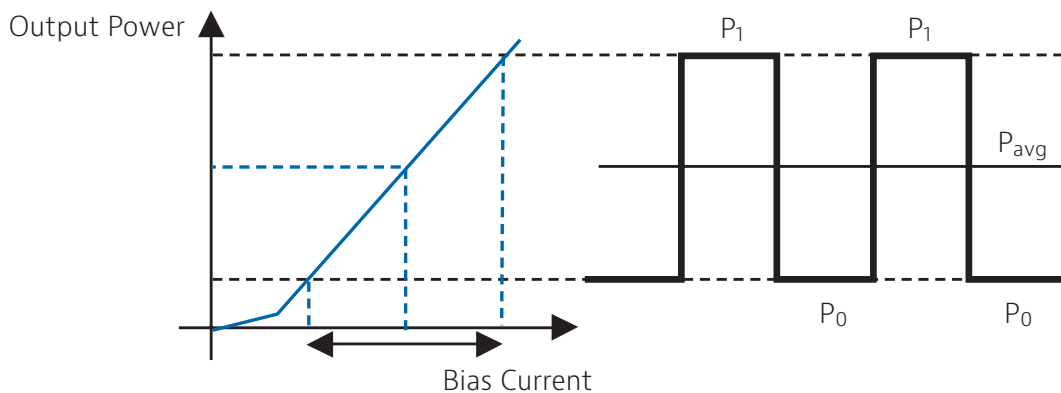


Figure 1. Optical Modulation on Laser

Data transmission up to 10 Gb/s uses the non-return-to-zero (NRZ) modulation scheme. In the NRZ data stream, there is equal probability of logic 1 and logic 0 over a long period of time. Transmitter average optical power, P_{avg} is a measure of the average energy of logic 1, P_1 , and logic 0, P_0 , coupled into the fiber over a period of time.

$$P_{avg} = \frac{(P_1 + P_0)}{2}$$

Average optical power is measured with an optical power meter. The measurement unit is usually expressed in dBm, a logarithmic ratio of power level to 1mW.

$$P_{dBm} = 10 \times \log_{10} \left(\frac{P_{mW}}{1mW} \right)$$

Transmitter average optical power measurement is a typical production test performed to ensure that the transmitter meets the specified performance, as Figure 2 shows. This measurement is usually taken using a suitable length of a pseudo-random bit sequence (PRBS) data stream at a specific data rate. Figure 3 illustrates the VIAVI solution.

Example Measurement Setup

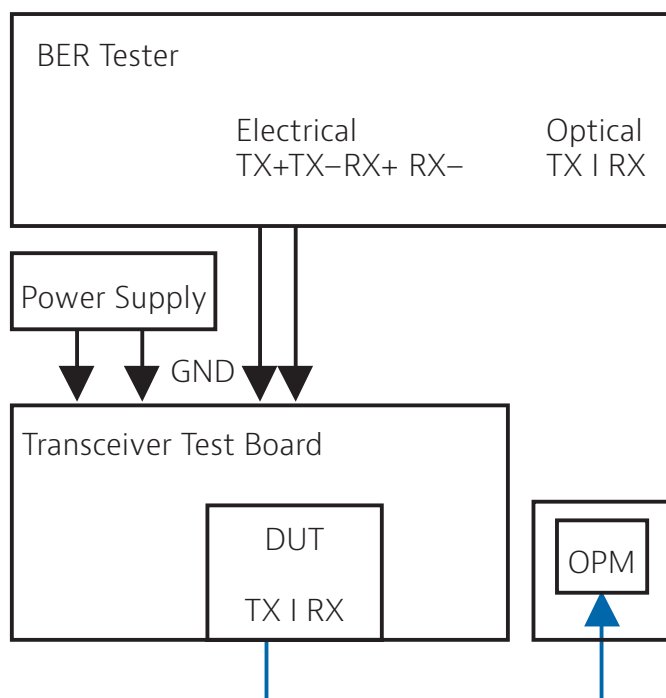


Figure 2. Typical setup of transmitter average optical power measurement



Figure 3. VIAVI MAP-200 Variable Optical Attenuator, Optical Power Meter Modules, and MAP-230 Mainframe

Finally, the choice of photodiode material used in a power meter is important since semiconductor properties determine the wavelength range over which the device will operate. Both Indium Gallium Arsenide (InGaAs) and Germanium (Ge) photodiodes can be used for power measurements in the 800 to 1650 nm wavelength range. Ge is presently the lower-cost solution; therefore, applications such as parallel optic transmitter power measurements, which require a larger detector area a Ge-based power meter is more cost-effective. An InGaAs-based power meter is more suitable for measurements at 1625 nm than a Ge-based power meter, as Ge responsivity drops off rapidly at 1600 nm. More sophisticated power meters calibrate in small increments over a wide wavelength for improved measurement accuracy.

VIAMI offers two types of MAP Optical Power Meters: a 3 mm InGaAs detector and a 10 mm Ge detector.



Figure 4. VIAMI 3 mm InGaAs Power Meter with Dual Detector Configuration and MAP-280 Mainframe

Receiver Sensitivity Measurement

The receiver portion of an optical transceiver contains a photodiode that performs the optical-to-electrical conversion and electronic circuitry to correctly interpret the bits received. The most common photodiodes used in an optical transceiver are semiconductor-based pin photodiode and avalanche photodiode (APD).

$$\text{BER} = \frac{N_e}{N_t} = \frac{N_e}{DT}$$

The most critical figure of merit for optical links is the bit error rate (BER). The BER is the ratio of error bits N_e to the bits sent N_t over a certain time interval T . The time interval T is also known as the gating time.

Where D is the data rate expressed in bits per second (bps) a BER of 10^{-9} means that for every billion bits sent there is one bit in error. Typical error rates for optical communication range from 10^{-9} to 10^{-12} . Receiver sensitivity is defined as the minimum optical power required to yield a specific bit error rate.

BER is a statistical analysis. To render a statistically valid measurement, the number of errors should be in the order of 10s. For low BER, the measurement can be very long to be practical for high volume manufacturing.

Example:

For BER of 10⁻⁹ to get 10 errors at 155.52 Mbps (STM-1/OC-3), 64 seconds of gating time is required.

$$T = \frac{10}{155.52 \times 10^6 \times 10^{-9}} = 64 \text{ s}$$

For BER of 10⁻¹² to get 10 errors at 155.52 Mbps (STM-1/OC-3), about 18 hours of gating time is required.

$$T = \frac{10}{155.52 \times 10^6 \times 10^{-12}} = 64300 \text{ s}$$

Because of impracticality in the manufacturing environment, receiver sensitivity is usually tested within reasonable gating time at higher BER. Figure 5 displays a plot of BER versus optical input power, known as the waterfall plot. Sensitivity measurements at higher BER can be fitted to the waterfall plot and the sensitivity at the required BER can be extrapolated.

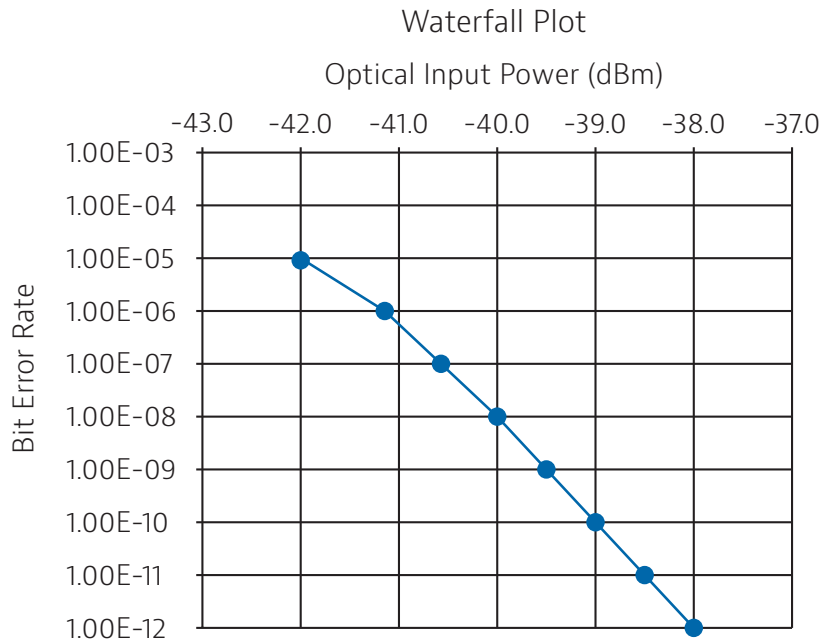


Figure 5. BER versus optical input power, known as the waterfall plot

Typically, receiver sensitivity is measured in the manufacturing environment by repeatedly transmitting and receiving a suitable length of a PRBS data stream, as Figure 6 shows. A BER Tester (BERT) generates a PRBS data stream at the user-specified data rate. The PRBS signal from a reference transmitter travels through an optical attenuator to the receiver of the device under test (DUT). The receiver of the DUT converts the optical signal to an electrical signal. The electrical signal is then sent to the BERT to determine whether the received data matches the transmitted data, thus deriving the BER. The attenuation is increased or decreased until the specific BER is achieved during the gating period. The power level is the sensitivity at the specified BER. There are two ways of measuring the power level: switch the optical signal after the attenuator (with an optical switch) from the receiver to the power meter for the measurement, or more sophisticated optical attenuators come with an integrated optical power meter that monitors the power level at the output of the attenuator.

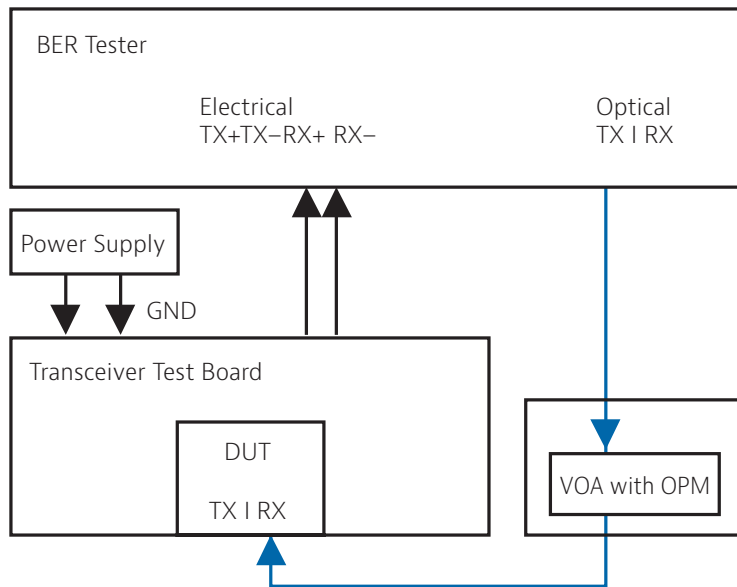


Figure 6. Typical setup for receiver sensitivity measurement

Figure 7 shows the VIAVI MAP Variable Optical Attenuator, which provides the industry's highest performance optical power level control solution with the lowest optical impairments and the fastest transition speed in its class (up to 25 dB/s).



Figure 7. VIAVI MAP Variable Optical Attenuator

Summary

This application note provided a detailed review of the measurement of transmitter average output power and receiver sensitivity. It also discussed the parameters that are important to system engineers for determining link power budget. Transceivers produced today are tested based on the parameters mentioned in this paper to ensure that they meet required specifications. This paper provided a review of the typical test setup using the VIAVI MAP-200 for performing measurements in a manufacturing environment.