AWG Parameters Definition and Discussion

Anis Rahman, Ph. D.

11/02/01

Measurement of AWGs: Main Parameters

When defining the performance of an AWG, the starting point is its spectral response for both the transverse electric (TE) and the transverse magnetic (TM) polarization states. Alternatively, the maximum and minimum transmission points of each polarization state over the wavelength range of interest can be used to obtain equivalent information.

The insertion of an optical component into an optical system leads to system performance degradation via losses. In the case of an AWG, this manifests itself as bit error rate (BER) degradation and reduced system-power as a result of loss, crosstalk and dispersion inherent in the AWG and its connecterization process. When determining the suitability of an AWG for a particular application, a number of parameters relating to both the amplitude and phase response of the device must be considered.

There are a number of methods used to obtain the spectral response of an AWG. The most common is to connect a tunable laser and a polarization controller to the input waveguide and one or more power meters (detectors) to the output waveguides. The laser sweeps through the wavelength range of interest while the detectors read the response of the AWG. TE and TM measurements can be obtained by setting the input polarization state to TE and then to TM using the polarization controller and recording one scan for each state.

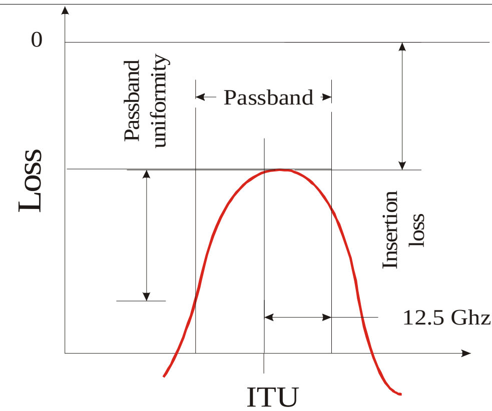
A common practice in commercial equipment implementations, however, is the deployment of Mueller Matrix method [1]. Here the spectral response of an AWG is measured over four different polarization states and the minimum, the maximum, the average amplitude response and the polarization dependent loss (PDL) corresponding to each wavelength are recorded. The AWG parameters are then extracted by analyzing [2] the spectra and the worst-case value of each parameter is taken as the specification. The

Mueller method is the slower of the two techniques since it requires the laser to scan four times rather than two. The Mueller method's advantage, however, it does not require the absolute state of polarization to be controlled. This measurement method is adhered by most AWG vendors; however, the way that vendors specify the performance of a device from these curves differs widely. In what follows, an attempt is made to define the AWG parameters in a comprehensive fashion so that these definitions may be taken as standard [3]. Table 1 summarizes the most common parameters and their typical values (not product specification).

The Most Common Definitions

The most common method of measurements involve obtaining spectral response corresponding to four different polarization states over the C-band and/or L-band and then calculating the min, max and average insertion loss and PDL corresponding to each wavelength. Other parameters are then extracted by analyzing the wavelength response curves or "spectra." The following are the most common definition of the respective parameters.

ITU Passband. The International telecommunications Union (ITU) has adapted a standard for optical communication that specifies that certain standard frequencies be used to identify and specify WDM channels. ITU channels begin at 190.00 THz (channel 0, 1577.86 nm) and increments by 0.10 THz for each subsequent channels. It usually spans over the C-band (1520-1570 nm). The ***passband*** is the specified bandwidth symmetric around the ITU grid frequency where AWG parameters are defined. For example, for 100GHz spacing, the passband is defined as 25 GHz.

<table>
<tr>
<td>The Passband Uniformity of a channel is the maximum that the transmission can change within the passband of the selected channel.</td>
<td>
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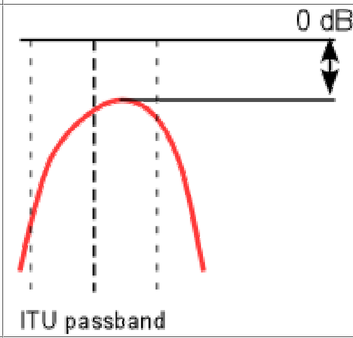
<tr>
<td>The Insertion Loss of a device is the minimum transmission within any passband for all polarization states. It represents the worst possible loss through the device as shown in the Figure. It is always a negative number.</td>
<td>
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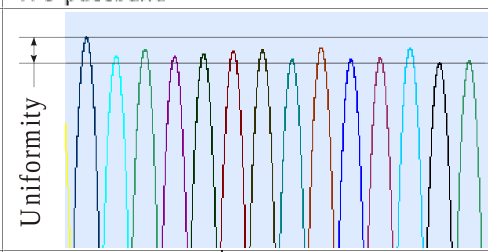
<td>The Insertion Loss Uniformity of a device is the difference between the insertion loss of the best-case and worst-case channels.</td>
<td>
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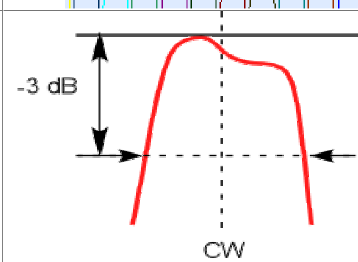
<tr>
<td>Center Wavelength: Average of wavelengths where transmission has dropped 3 dB from the peak transmission.</td>
<td>
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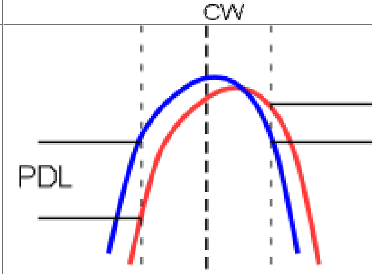
<tr>
<td>The Polarization Dependent Loss of a device is the maximum that the transmission can vary over all polarization states at a fixed wavelength over the entire passband.</td>
<td>
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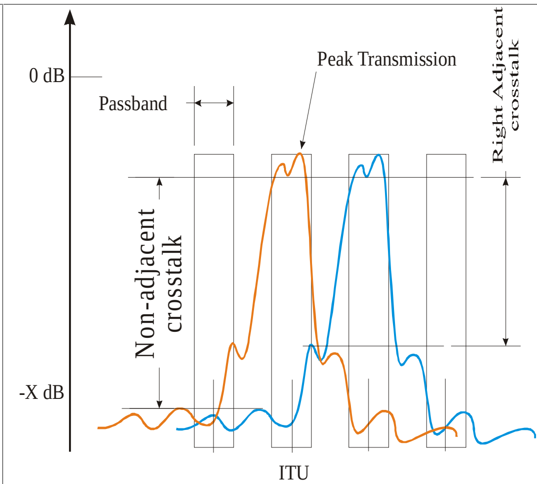
<table>
<tr><td>The Adjacent Crosstalk of a channel is the highest transmission within an adjacent passband referenced to the lowest transmission within the selected channel passband. The highest and lowest transmissions are determined for any (possibly different) polarization states within each passband as shown in the adjacent Figure.</td><td>
</td></tr>
<tr><td colspan="2">The Non-adjacent Crosstalk of a channel is the highest transmission within a non-adjacent passband referenced to the lowest transmission within the selected channel passband. The highest and lowest transmissions are determined for any (possibly different) polarization states within each passband.</td></tr>
<tr><td colspan="2">The Maximum Integrated Crosstalk of a channel is the sum of the maximum crosstalk values from all other channels. This occurs when all signals independently align with the wavelengths and polarizations of maximum crosstalk. Maximum integrated crosstalk is most applicable to very narrow spectral signals since all of the optical power must be precisely at the wavelengths of maximum crosstalk.</td></tr>
<tr><td colspan="2">The Average Integrated Crosstalk of a channel is the sum of the average crosstalks from all other channels. The average crosstalk of a channel is the mean of the maximum transmission in the passband of that channel. Crosstalk values are referenced to the mean of the minimum transmission in the chosen channel passband. Average integrated crosstalk represents the worst-case total crosstalk that could occur for a signal with its power distributed uniformly across the passband. It is a more appropriate measure of crosstalk for high bit rate signals because these higher bit rates cause the power in the signal to be spread across a wider spectrum.</td></tr>
<tr><td colspan="2">The Chromatic Dispersion of a device is the worst-case dispersion within any passband for all polarization states.</td></tr>
<tr><td colspan="2">The Differential Group Delay of a device is the maximum difference in group-delay between all polarization states within any passband.</td></tr>
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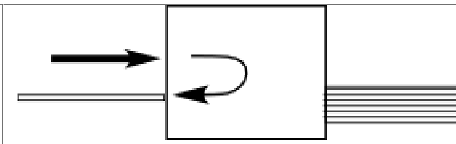
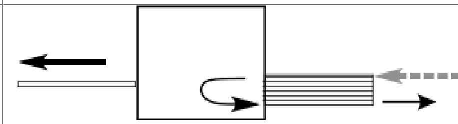
The **Return Loss** of a channel is the maximum reflected signal within the passband of the selected channel for any polarization state, referenced to the incident signal level. Note that this parameter includes the input channel in addition to all output channels.	
The **Directivity** of a channel is the maximum signal from that channel measured at any other than the selected channel within any clear window for all polarization states, referenced to the incident signal level.	

Table 1. Typical AWG parameters

Specification	Value	Unit
No. Channels	32, 40	
Channel spacing	100	GHz
Channel wavelengths	1520-1570	nm
Clear window	25 (0.1)	GHz (nm)
Insertion loss	5.5	dB
Insertion loss uniformity	1.5	dB
PDL	0.5	dB
Passband uniformity	1.5	dB
Adjacent crosstalk	25	dB
Non-adjacent crosstalk	30	dB
Integrated average (total) crosstalk	20	dB
Return loss	45	dB
Directivity	50	dB
Chromatic dispersion	10	ps/nm
Differential group delay	0.5	ps

References

1. W. A. Shurcliff, “Polarized Light: Production and Use,” *Harvard University Press*, Cambridge, MA, 1966; Dennis Derickson, “Fiber Optic Test and Measurement,” *Prentice Hall*, Upper Saddle River, NJ, 1998.