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Traveling wave model of an AWG-based multiwavelength laser

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***Abstract*— This work presents a traveling wave model description of an arrayed waveguide grating (AWG) based multiwavelength laser. The purpose is to design a device with frequency spacing of 70 GHz between channels at 1550 nm central wavelength, aiming to dimension the required channel bandwidth to achieve a target side mode suppression ratio (SMSR) among longitudinal modes.**

I. INTRODUCTION

An Arrayed Waveguide Grating (AWG) is a complex passive component that is commonly used to build multiwavelength lasers. As shown on Fig. 1, the cavity of such a laser is defined between two cleaved facet mirrors (M) of the chip. The AWG acts as an intra-cavity filter, selecting the lasing wavelengths [1], which depend on the passband location of each channel of the AWG. Within each channel, the cavity losses are minimal for the specific wavelength corresponding to its particular passband. As shown on Fig. 1, every single channel is activated by biasing a separate SOA, and biasing more than one SOA simultaneously results lasing at the corresponding channel wavelengths.

Due to the size of the AWG, the cavity defined between the two mirrors (M) is usually in the order of several millimeters and therefore a longitudinal mode spacing in the order of tenths of GHz. This is an important issue, since within each individual wavelength channel, several longitudinal modes compete for gain over the AWG channel bandwidth, which should be as sufficiently narrow in order to have just one lasing wavelength. Narrowing this channel imposes design restrictions, as in this passive device, all of its functional parameters are linked to the physical dimensions in the AWG [2].

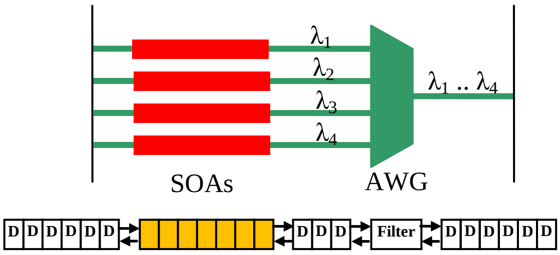

Figure. 1. Schematic of an AWGL and equivalent model.

II. AWG MODEL

An AWG is usually specified by functional characteristics such as number of channels, central frequency and channel spacing, -3 dB channel bandwidth, free spectral range, maximum insertion loss of the central channel or maximum non-uniformity. The AWG has many degrees of design freedom and a specific approach has to be followed for its design to provide the physical dimensions of the device (such as the number and length increment of the array waveguides) that achieve the specifications. We have used the method proposed in [2] to obtain the frequency response of the AWG. The initial specifications are a central wavelength $\lambda_c = 1550$ nm, channel spacing $\Delta\lambda = 0.56$ nm (70 GHz) and a free spectral range FSR = 8.96 nm (1.12 THz), and the transfer function response of the AWG is presented in Fig. 2.

In order to develop a traveling wave model (TWM), we have developed an equivalent description using a multistage digital filter on Matlab©. This filter captures the filtering effect of the AWG channel selection, with the condition of having a linear phase (acts as a time delay). A FIR's filters bank were used in this design to adjust the filter parameters (filter order, stop-band and pass-band attenuation, filter bandwidth, etc.) and match the AWG's response. The digital filter response is depicted in Fig. 3, in which the origin in the x-axis represents the center frequency of the traveling wave simulation (193 THz), and the maximum normalized frequency represents half of the simulated bandwidth (16.216 THz). A spacing frequency of 70 GHz corresponds to a normalized frequency of 0.0043167 and, a FSR = 1.1187 THz corresponds to a normalized frequency of 0.069.

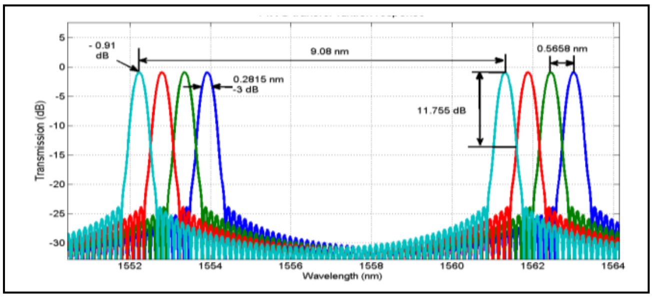

Figure. 2. AWG's transfer function on Matlab with design rules based on [1].

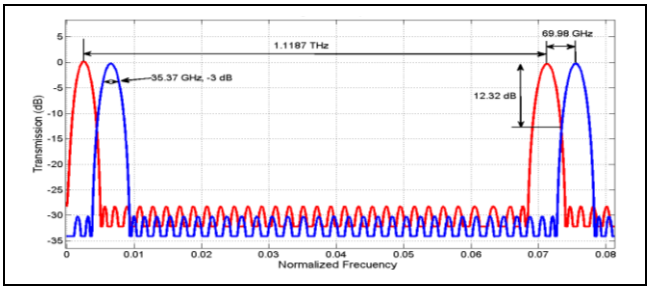

Figure. 3. Matlab AWG equivalent digital filter response.

III. MULTIWAVELENGTH LASER MODEL

We have developed a traveling wave model to describe an AWG-based multi-wavelength laser (or AWGL). The traveling wave model as described in [4] has been used to describe two elementary building blocks: the passive waveguide and the SOAs. As shown on Fig. 1, each channel has an SOA, simulated using 256 sections. This has determined the step size ($\Delta z = 2.26$ µm) for the passive waveguides, in which the light is propagated introducing the corresponding delay and sets the total cavity length. The -3 dB gain bandwidth of the SOA is set about 170 GHz. Other important parameters that were used in the simulation are: group index = 3.7, $\Gamma = 0.35$, $N_o = 1.5x10^{18}$ cm^{-1}, $\alpha = 2800$ m^{-1} and $\varepsilon = 0.05$, following the model structure described in [4]. The spontaneous emission has been modeled as a random noise with linear distribution. The AWG is included through the equivalent digital filter determined on the previous section to effectively introduce the intra-cavity filter effect selecting the lasing wavelengths [5]. Biasing one SOA at 2 I_{th}, we observe the single channel on the common output as shown in Fig. 4, having single mode operation with a side-mode suppression ratio (SMSR) better than 30 dB and a FSR = 1.11784 THz. The figure shows also the result of biasing the adjacent channel. When both SOAs are biased simultaneously, we observe the two wavelengths as shown in Fig. 5 with the target channel spacing between them of $\Delta F_{ch} = 70.15$ GHz. This model allows us to analyze the SMSR factor among the longitudinal modes in a single channel depending on the channel bandwidth. This is shown on Fig. 6 for different SOA bias current levels.

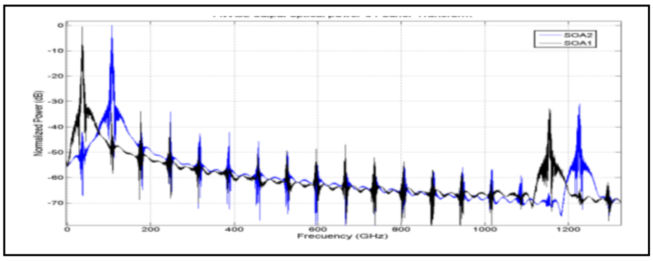

Figure. 4. Simulated optical output spectrum biasing a single channel of the AWGL. The side mode suppression ratio is better than 30 dB.

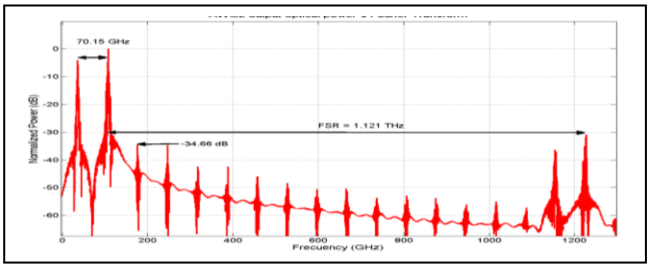

Figure. 5. Simulated optical output spectrum when biasing two adjacent channels of the AWGL.

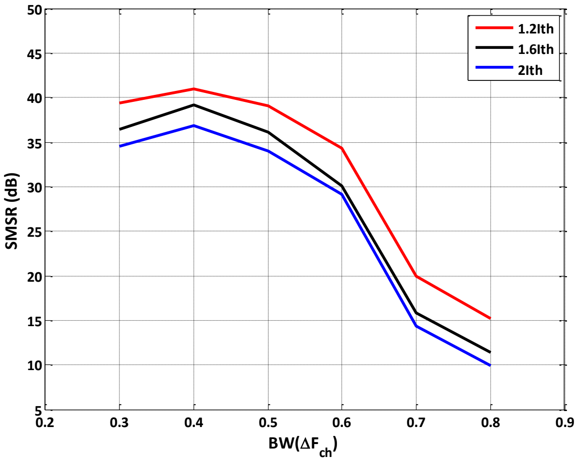

Figure. 6. SMSR among longitudinal modes in the AWGL. The channel bandwidth (BW) is scaled to the channel spacing on the AWG.

ACKNOWLEDGMENT

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