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Design environment for active photonic integrated circuits improves the DML

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We present an advanced design environment for the development and simulation of modern photonic integrated circuits (PICs) including active components. Several PIC design environments have been developed targeting passive PICs. But InP PICs in particular can include SOAs and diode lasers. There are many excellent tools available for modelling SOAs and diode lasers but cannot be readily extended to model PICs. The environment is used to design a novel efficiency-enhanced DML (direct modulated laser).

The design environment is capable of detailed modelling of an SOA for active components and a rigorous Maxwell Equation solver for passive components, with models for all the components brought together at circuit level using a travelling wave time domain model PicWave [1,2]. Note that all laser diode devices can be modelled as an SOA plus mirrors or one sort or another. Indeed the SOA can form part of a much larger active PIC.

Modelling of an SOA is divided into two parts. First the heterostructure is modelled in detail using Harold, originally developed by University of Madrid [3]. This implements a self-consistent drift-diffusion model with a parabolic-band gain model and produces a set of material functions: gain g(Nqw, lambda, T), where Nqw is a the quantum well electron density (assumed equal to hole density), carrier lifetime tau(Nqw,T) and a capture-escape model, so that Nqw can be computed for a given injection current. These material functions are then exported into a time-domain travelling wave simulator PicWave [refs], which is able to simulate quickly.

The SOA model, while being required to maintain fast execution, still includes many physical phenomena, including lateral current spreading, carrier diffusion, non-Lorentzian gain, and bulk-to-well capture dynamics. The latter is illustrated in Figure 1 and shows the importance of a multi-carrier model in getting the dynamics of a diode laser correct.

Recently Finisar proposed a method of improving the performance of a DML by adding a modulated SOA after it [4]. A DML can approach 2x the efficiency of a laser with external modulator, since when a “0” is transmitted the DML current is low. However to attain speed of a DML, the “0” state must not switch the laser completely off. Contrast can be regained by following it with a modulated SOA that is switched to low current during “0” bits, absorbing any residual power coming out the DML in “0” state.

A related approach can dramatically improve a DML/SOA setup even without gating (absorbing regime), eliminating the effect of saturation.

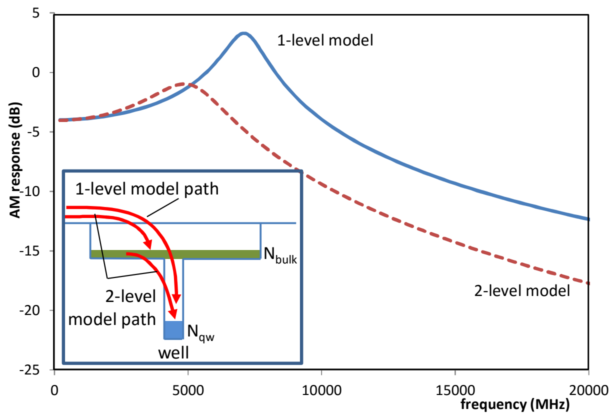

Fig. 1. Modulation response of an InGaAsP Fabry Perot QW laser, with a 1-level and 2-level carrier model. The bulk carrier reservoir substantially reduces the modulation bandwidth of the laser.

This is illustrated in Figure 2, modelled using a 2-level carrier model. Due to saturation effects a DC-driven SOA can severely degrade the eye. Modulating the SOA improves matters. Since the SOA experiences non-uniform gain saturation along it's length, better results are obtained by tailoring the modulation current ΔJ(z) to the optical intensity profile P(z). The "split SOA" in Fig 2 approximates this showing further improvement.

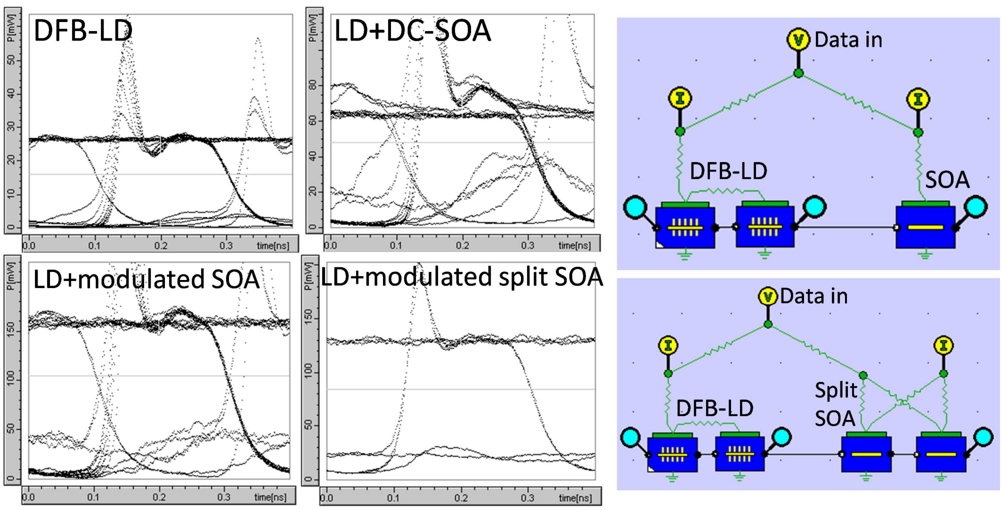

Fig. 2. Eye diagrams for a DFB-LD/modulated-SOA InGaAP transmitter, with 5GB/s NRZ data in. Top right and bottom-right show schematics of the LD+SOA and LD+split-SOA circuits respectively.

[1] L. M. Zhang, S. F. Yu, M. C. Nowell, D. D. Marcenac, J. E. Carroll, and R. G. S. Plumb, "Dynamic analysis of radiation and side-mode supression in a second-order DFB laser using time-domain large-signal travelling wave model", JQE, 30, pp. 1389-1395, 1994
[2] 1 Proc. SPIE v5, 5722-69, "Design and simulation of widely tunable lasers using a time domain travelling wave model",2004
[3] 1 Proc. SPIE 3889, pp. 96-106 "Modeling of facet heating in high power laser diodes", 2000
[4] 1 Y. Matsui, US Patent 2013/0308959 "Directly modulated laser for PON applications", 2013