Transmission error floor mechanisms in high-power 10Gb/s electroabsorption modulators

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High-power electroabsorption modulators (EAM's) are essential elements for the overall size reduction in transponders for wavelength-division multiplexed (WDM) fiber optic networks. Owing to the intrinsic high insertion loss nature of an EAM, optoelectronic integration of semiconductor optical amplifiers (SOA) and modulators is highly desirable. In fact, there have been a number of publications with lossless devices with EA's integrated with an SOA.[1,2] However, there remains a great demand for increased output power operation, higher extinction ratio and lower dispersion penalty. This leads naturally to high nonuniform photocurrent generation and a difficult control of pre-chirping for fiber transmission. Moreover, systems relying on high internal stimulated emission tend to result in severe instabilities which cause noise in the receiver chain that can create a bit error rate which is independent of receiving power, known as the error floor.

We have developed at T-Networks high performance EAM's monolithically integrated with SOA's. World record performance with ac- and dc-coupled devices for operation in TDM and WDM systems is obtained with hybrid integration of DFB lasers. ITU grid operation, temperature wavelength tunability with a wide wavelength range, as well as uncooled operation has been demonstrated. In order to achieve this performance, it is fundamental to understand the physics involved in the instabilities causing the error floor.

In this presentation we will review our recent results with dc- and ac-coupled SOA's integrated with EAM's. Subsequently, we will describe both experimentally and theoretically, the important mechanisms in which the error floor develops. First, we will show how an increased photon lifetime in the integrated device leads to severe instability that affects both the dispersion penalty and the extinction ratio of these devices. We will also describe how the bit pattern affects the build-up of such instability. Finally, we will describe how nonlinear behavior in the unsaturated regime of operation for the SOA reveals potential dynamic effects related to error floor.

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1 J. E. Johnson, L. J.-P. Ketelsen, J. A. Grenko, *et al.*, "Monolithically integrated semi-conductor optical amplifier and eletro-absorption modulator with dual-waveguide spot-size converter input", *IEEE J. Select. Topics Quantum Electron.* **6**, 19 (2000).

2 K. Asaka, Y. Suzaki, Y. Kawaguchi, S. Kondo, Y. Noguchi, H. Okamoto, R. Iga, and S. Oku, "Lossless electroabsorption modulator monolithically integrated with a semiconductor optical amplifier and a passive waveguide", to appear in *IEEE Photonics Technol. Lett.* (2003).