Semiconductor optical amplifiers: modeling and analysis for optical access networks

A. R. Totović[1], J. V. Crnjanski[2], M. M. Krstić[2] and D. M. Gvozdić[2]
[1]*Wireless and Photonic Systems and Networks (WinPhoS) Research Group, CIRI - Center for Interdisciplinary Research and Innovation, Aristotle University of Thessaloniki (AUTH), Thessaloniki, Greece*
[2]*School of Electrical Engineering, University of Belgrade, Belgrade, Serbia*
e-mail: angelina@auth.gr

The continuous upgrade of the existing communication network infrastructure to support novel advanced broadband services led to penetration of optical technologies to the access layer striving to reach the end-user. To implement a resilient and future-proof network, solutions that support high throughput at high data rates in an energy-efficient and low-cost manner are required. It has been recognized that passive optical networks (PONs) are an excellent candidate for the access layer due to service transparency, energy-efficiency, acceptable cost and high security [1]. On the road towards next generation stage 2 PON (NG-PON2), numerous solutions are proposed, of which vast majority relies on semiconductor optical amplifiers (SOAs), especially, reflective SOAs (RSOAs) implemented in optical network units (ONUs) at user premises [1]. The dynamics of their operation offers multiple operating regimes, both linear and nonlinear, resulting in attractive devices that have a well-established production process and are easy to integrate [2]. Finally, the ability to operate SOAs in any of the O-, S- or C-band, makes them compatible with widely adopted wavelength-division multiplexed PONs (WDM-PONs), together with hybrid wireless/wired Radio-over-Fiber (RoF) networks [3,4].

To maximize the benefits offered by SOA, both design- and usage-wise, it is necessary to understand the interrelation of its performance metrics parameters, both in steady-state and dynamic regime, and its material, geometrical, and operational parameters. The model proposed in this manuscript is built using a bottom up abstraction approach from detailed material and geometrical parameter dependencies on photon energy and carrier density, and accounts many commonly overlooked effects influencing SOAs performance: nonlinear gain suppression, residual reflectivity of facets, phase modulation, distributed model of modulation current etc. [2] Using the proposed model and its variations depending on the simulation needs, we confirm that commonly introduced approximations are valid only in limited ranges of input optical powers, bias currents and active region lengths. We analyze spectral properties of the SOA output, its steady-state gain vs. input power and bias current characteristic, as well as –3dB small signal bandwidth. We discuss the E/O (re)modulation performance of traveling-wave (TW-) and RSOA at different down- and upstream bitrates for both RZ/NRZ modulation formats. Finally, we present a novel solution for colorless multilevel signal transmitter using two RSOAs with orthogonal optical signals, able to generate 4-QAM optical signal [5].

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