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Dynamics-induced asymmetries in the nonlinear gain of semiconductor lasers on multimode operation

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Semiconductor lasers are known for their tendency to operate in multimode regime. From an applications point of view, originally multimode operation was considered to be detrimental, for example because it deteriorates the spectral purity of signals in an optical telecommunications link. On the other hand, multimode operation is well-suited for WDM applications and is currently becoming a 'hot topic' in the technical community. The multimode operation of the laser attracted attention after the observation of remarkable operational regimes such as the cascade of modes turning on and off in well defined sequences as shown by Yacomotti et al. [1]. Moreover, the multimode chaotic output field of a perturbed semiconductor laser, due to its large degrees of freedom, can be exploited as secure carrier of information via chaotic encryption methods [2] where currently a complex optical chaotic emitter is in demand. Today, obtaining better understanding of multimode dynamics of semiconductor lasers is a hot, and potentially very profitable, scientific topic.

It is usually assumed that the laser spectrum reflects the shape of the gain curve of the semiconductor material: the device would operate mostly in the close vicinity of the maximum of the gain curve. Other modes might arise as result of spontaneous emission and internal modal dynamics, but the device would ultimately "choose" operation at the maximum of the gain curve. However, it has been experimentally shown by Bogatov already in 1975, that the gain curve of a semiconductor laser modifies its shape when more than one field component is present in the laser cavity [3].

In this paper, we show how the "Bogatov effect" can be included in a robust way into a multimode rate equations model that takes account of multi-wave mixing effects through dynamical gratings burned in the carrier distribution. We reveal how this dynamics might induce changes in the shape of the gain curve which ultimately manifests itself as operation of the laser on modes that do not correspond to the maximum of the gain curve. We also discuss the crucial role played by the carrier diffusion and introduce an intuitive visual approach to identify the phase-matching conditions that lead to the Bogatov effect. This information may be used to identify and interpret any eventual carrier dynamics induced bifurcation in the spectrum of the multimode laser.

References:

- [1] A. M. Yacomotti, L. Furfaro, X. Hachair, F. Pedaci, M. Giudici, J. Tredicce, J. Javaloyes, S. Balle, E. A. Viktorov and Paul Mandel, *Phys. Rev. A* 69, pp. 053816 (2004).
- [2] A. Argyris, D. Syvridis, L. Larger, V. Annovazzi-Lodi, P. Colet, I. Fischer, J. Garcia-Ojalvo, C. R. Mirasso, L. Pesquera and K. A. Shore, *Nature* 437, pp. 343-346 (2005),
- [3] A.P. Bogatov, P.G. Eliseev, B.N. Sverdlov *SOV J QUANTUM ELECTRON* 4, pp. 1275-1276, (1975)