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Coupled-Cavity Vertical-Cavity Surface-Emitting Lasers for High-Speed Data Communication

PhD thesis summary

Constantly growing number of services like: high speed Internet, video streaming and conferencing, remote monitoring or ultra-high definition video are the driving force for the next generation networks. Limitations of the copper or coax cable bandwidths are already being reached, and in the long term perspective of expected traffic evolution, only optical networks and interconnects can provide enough capacity and flexibility to satisfy the needs. It is therefore most important to develop not only high bandwidth and low-power, but also low-cost semiconductor lasers.

The main goal of this PhD thesis work is to develop the new concept of coupled-cavity Vertical-Cavity Surface-Emitting Lasers (VCSELs) for high data rate exceeding 40Gb/s (40 GHz modulation frequency) transmission in the short (800-1000nm) wavelength range. This particular type of structure build from two coupled optical cavities allows integrating laser light source with modulator already in the growth process, which significantly reduces the manufacturing complexity and therefore device cost.

At first the thesis presents an overview of contemporary high speed modulators and integrated VCSEL-modulators. Our work then focusses on optimization of integrated VCSELs with two coupled cavities: an active one providing lasing and a second one serving as electro-optical modulator. Such reverse biased electro-optical modulation of the second cavity allows generation of ultra-high data rates not limited by the carrier dynamics and with much reduced chirp. Full optical and electrical analysis, in self developed software, is used to optimize the structure. We demonstrate an optimized design of electro-optically modulated coupled-cavity VCSEL with lumped electrodes theoretically able of achieving 100 GHz modulation bandwidth. To even further increase this high speed, we develop a novel concept of a coupled-cavity VCSEL structure incorporating traveling wave electrical configuration. This new coupled-cavity VCSEL design theoretically pushes the modulation frequency limit up to ~350 GHz. The last part of the thesis presents our experimental results on coupled cavity VCSEL spectral, threshold and temperature characteristics. Furthermore, we carry out detailed comparison of the experimental data with suitable models to elucidate the underlying physics of the devices.