ABSTRACT

The thesis focuses on different methods to overcome the limitations of the Vertical Cavity Surface Emitting Lasers (VCSELs) based optical interconnects utilized in the high speed short-reach links (data interconnects) in datacenters and supercomputers. Three methods to increase performance of the VCSEL based data interconnects are investigated. First, the increase of the maximum data throughput of the optical interconnects is studied. Discrete Multi-Tone (DMT) modulation format is proposed for VCSEL-based interconnects. With the use of single-mode VCSEL and DMT modulation, record data transmission up to 224 Gb/s is demonstrated. Next, improvement of the energy efficiency of short reach interconnects is investigated. Utilization of the on-off keying non-return-to-zero (NRZ) modulation allows realization of the energy efficient electronic circuits, without energy hungry signal equalization and processing. As a demonstration of the effectiveness of this method, a complete VCSEL-based NRZ-modulated optical link capable of 71 Gb/s at 3,4 pJ/bit energy efficiency was demonstrated. Secondly, the increase of the transmission reach of the data interconnects was studied. To reduce the spectral width of the VCSELs and thus reduce the limiting effect of the dispersion on the maximum transmission reach through MMF, a new leaky VCSEL design was investigated. Simulations of the leaky VCSELs operation were performed. The results of the simulations were confirmed by experimental data and successful data transmission with the leaky VCSELs up to 1 km of MMF at 25 Gb/s was shown. Finally, the increase of the VCSEL temperature operating range for data transmission in automotive and industrial applications was studied. The use of Quantum-Dots (QD) in the active region of VCSELs is proposed and realized. QD VCSEL characterization as well as data transmission experiments at record temperatures were performed. The presented methods significantly increase the data rate, transmission reach, energy efficiency, and temperature operating range of short-reach data interconnects. Results of the presented research can be applied in the next generation of data interconnects.

Keywords: transmission, optical fiber, modulation, VCSEL