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Quantum dot 850 nm VCSELs with extreme high temperature stability operating at bit rates up to 25 Gbit/s at 150 °C

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1. Introduction

The number of mobile devices and connections grew to 8.4 billion in 2017 and is expected to grow further as the autonomous driving, mobile internet, cloud computing and the internet of things continue to emerge. In view of this growth, the speed and energy efficiency of data processing, data transfer and data storage become particularly important for the economy. As the productivity of processors approximately doubles each year the exchange of information between different processors and between processors and periphery devices should match this trend too. In this context the relevance of the interconnects and the share of the energy demanded by the data links in datacenters and server farms increases [1]. In all major Datacom standards, the data rate per single channel approximately doubles each two years, while the number of channels per link doubles each 5 years. For new links the same port size is to be maintained while the intra-channel distance decreases. Consequently, the copper links meet fundamental difficulties due to high signal losses at elevated frequencies of the electrical signal and the related increase in the cross-talk. Such links require extreme tolerances, become more expensive and energy-consuming and, consequently, optical solutions continuously penetrate to shorter distances, where exponentially larger number of interconnects is deployed. 850 nm Vertical Cavity Surface-Emitting Lasers (VCSELs) in combination with multimode fiber are the standard solutions for data links at distances up to 100 m and represent compact low-cost energy-efficient solution.

With penetration of optical links to the board and further towards the chip level, high-sped 850 nm VCSELs should be capable to operate reliably at significantly higher ambient temperatures, as presently defined by the datacom module temperature (70 °C). This is particularly true for high performance computing, where the interconnects play a key role in the overall architecture and on-board optical assemblies are already applied in volume. Furthermore, industrial, automotive and ultimate-brightness sensing applications also need devices capable to operation well above 100 °C. Present automotive applications require reliable high-speed operation of the modules at ambient temperatures of up to 105 °C and higher [2]. Optical fiber or optical waveguide-based communication links for on-board assemblies are also expected to reliably operate at temperatures close and above 100 °C [3].

For high speed operation of standard VCSELs at high temperatures the threshold current density has to be increased to compensate thermal population of higher lying energy states of nonequilibrium carriers in the valence and conduction bands and the leakage of a non-equilibrium carriers from the gain region into the cladding layers, where they recombine mostly nonradiatively. Such threshold current increase combined with elevated ambient temperature can further decrease the lifetime of the devices, making practical applications hardly possible unless degradation-related effects in VCSELs [4,5] are strongly reduced. For the same reason of the decrease in the modal gain a significant heating of the device results in a decrease of the modulation bandwidth. Such effects cannot be compensated by a higher current density due to the current-induced overheating of the device resulting in the optical power drop with current (roll-over effect) and due to strongly accelerated degradation processes.

Many studies were carried out on VCSELs operating at temperatures up to ~85 °C, since the operation in this temperature range provides a margin for additional heating of the chip in a module, which should be suitable for a maximum case temperature of 70 °C, as specified for the

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