Planar optics has been suggested as an approach to build compact free-space optical interconnections [1]. A planar optical system consists of a transparent substrate with integrated microoptical components and of the optoelectronic components mounted on top of the substrate by hybrid integration techniques. Large arrays of vertical cavity surface emitting laser diodes (VCSEL) provide the desirable dense optical input into a planar optical system. But these diode arrays are responsible for a heat dissipation in the order of several W/cm², and they are temperature sensitive themselves. The microcavity of a VCSEL can be considered as a Fabry-Perot resonator. The wavelength shift depends on the temperature related shift of the refractive index and of the length of the cavity. The band gap of the active laser material is temperature sensitive, too. With increasing temperature a divergence between the resonator’s peak wavelength and the band gap wavelength occurs. This results in a loss of optical power at high temperatures (thermal roll-over point).

We have investigated the temperature dependent output of an 8x8 array of VCSELs and the effect of cooling [2]. Two things are important: (1) To keep the average temperature at a reasonable level, heat convection is necessary. (2) Heat spreading is necessary to avoid large temperature gradients across the array and to support the cooling effect of convection. Different setups were investigated: the VCSEL chip on the substrate, the chip with a diamond heat spreader on top, the VCSEL chip with the heat spreader and a silicon fin structure without air flow (natural convection) and with air flow (forced convection), see fig.1. The VCSEL chip was flip-chip bonded onto a glass substrate. We have used a CVD diamond, the fins in silicon were etched with RIE.

Without additional cooling, a temperature rise of up to 90°C in the VCSEL cavity was observed. The thermal roll-over point is at 300mW input power (fig.2(d)). Enhanced natural convection shifts the point to 390mW by the diamond heat spreader (fig.2(c)) and to 460mW by the heatspread layer combined with the silicon cooler (fig.2(b)). But both setups have a low effect on the optical output power. Forced convection with the diamond heat spreader and the silicon cooler reduced the maximum temperature rise to about 40°C. In this case, the optical output was nearly doubled, see fig. 2(a).

References: