100W-output power from passively cooled laser bar with 30% filling factor

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940 nm laser bars with optimised layer structures will be reported. 100 W output power, wall plug efficiency above 60 % and a vertical divergence of 27° FWHM were achieved despite mounting on passively cooled heat sinks only.

Introduction

Laser bars with high output power and low cost per Watt are key devices in industrial laser based material processing. State of the art laser bars have output powers of 50 … 60 W on actively cooled (i.e., micro channel) heat sinks. Due to high costs and limited reliability of these heat sinks there is a need for devices reaching at least the same output power and life time on passively cooled heat sinks. This paper presents laser bars with a very high efficiency and a cw output power higher than 85 W appropriate for lateral beam shaping without the need of active cooling by micro channel heat sinks.

Design and fabrication

The MOVPE grown lasers have a waveguide structure of $Al_{0.35}Ga_{0.65}As/Al_{0.7}Ga_{0.3}As$ and an active InGaAs quantum well embedded in GaAsP barriers. Careful design of the layer thicknesses and doping profile results in a high slope efficiency and a low series resistance. In Fig. 1 the slope efficiency of broad area lasers with 100 µm stripe width and cleaved facets is plotted versus the resonator length. From this dependence the internal efficiency is determined to 99 % and the internal losses to $< 1\ cm^{-1}$. The transparency current density is about 75 A/cm² and the fast axis divergence is 27° (FWHM).

Laser bars having nineteen 150 µm broad emitters with a resonator length of 1.5 mm were fabricated. The filling factor is 30%. The facets were passivated as described in Ref. [1] and coated for 10 % and 94 % reflectivity. The bars were soldered p-down first onto CuW heat spreaders using hard AuSn solder and then onto standard Cu heat sinks (CCP) using PbSn. The n-contact was made by wire bonding (see Fig. 2). This mounting scheme results in a comparatively high thermal resistance of 1.8 K/W.

Results

Fig. 3 shows the voltage-, power-, and efficiency-current characteristics of a mounted laser bar in cw operation at 15°C. The laser bar has a threshold current of 7 A and a slope efficiency of 1.12 W/A. At an operating current of 100 A it emits more than 90 W. The measured series resistance of only 3 mΩ leads to a very high wall plug efficiency of 65 % at about 60 W. The emission wavelength is around 940 nm. The relatively high thermal resistance causes the junction temperature to be increased to about 80°C.
Due to the limited maximum power supply of 100 A we decreased the temperature to evaluate the limits in output power. Fig. 4 shows the output power at a driving current of 100 A between 25°C and -5°C The power at 100 A increases from 86 W at 25°C to 101 W at –5°C. After these measurements the initial power-current characteristic was reproduced and no degradation was found. A lifetime test was started in the constant power mode at 25°C. After 50 h burn-in at 40 W the power was increased to 60 W. After additional 250 h at 60 W without degradation the power was again raised up to 70 W (Fig. 5). This test is still in progress. Up to now only a minor increase of the excitation current was measured.

Summary

We present 940 nm laser bars mounted on passive heat sinks with maximal output powers between 85 W and 100 W despite the low filling factor of 30%. The wall plug efficiency is above 60 %. First lifetime studies show a significant potential of the laser bars at power levels comparable to actively cooled bars. Even higher power values can be expected by a reduction of the thermal resistance.

[1] P. Ressel, G. Erbert, G. Beister, C. Dzionk, G. Tränkle, "Simple but effective passivation process for the mirror facets of high-power semiconductor diode lasers", CLEO Europe/EQEC, 22-27 June 2003, München, Germany, Europhysics Conference Abstracts **27E**, CC4-02-TUE.

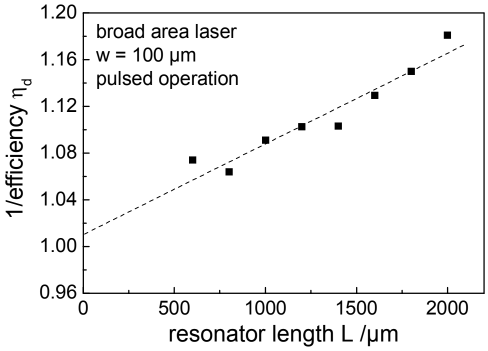

Fig. 1 reciprocal differential efficiency of broad area lasers in dependence on the laser length

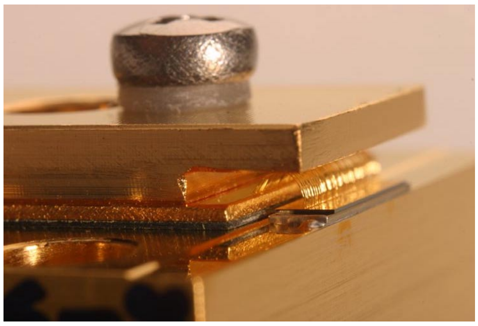

Fig. 2: laser bar mounted on CuW heat spreader and passive Cu cooler

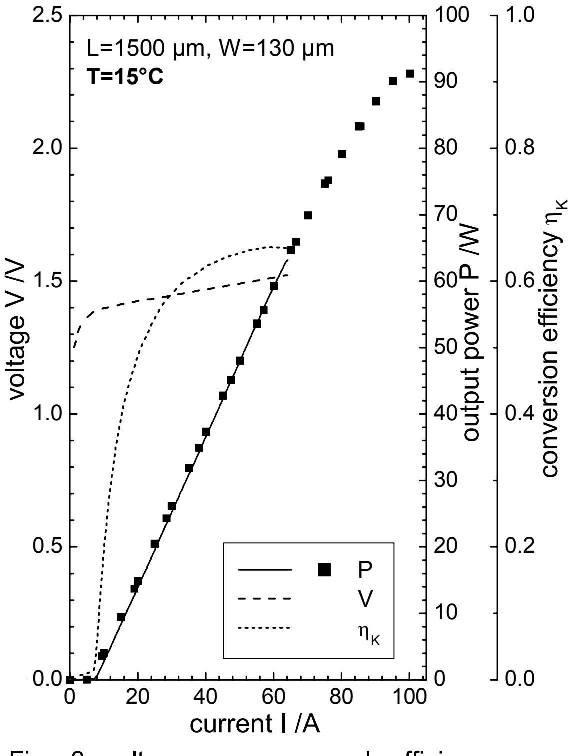

Fig. 3 voltage-, power-, and efficiency-current characteristics of a mounted laser bar in cw operation at 15°C.

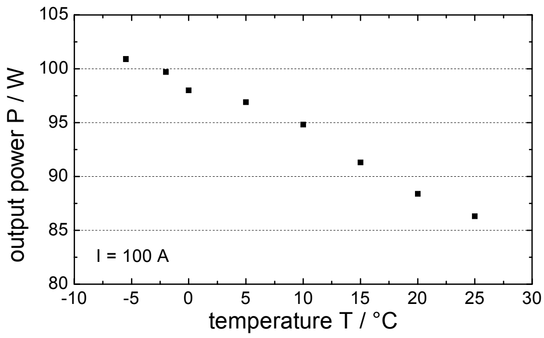

Fig. 4 cw output power of mounted laser bar at 100 A operating current in dependence on the operating temperature

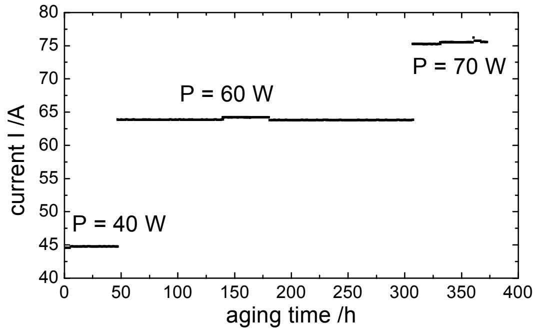

Fig. 5 lifetime test of a passively cooled laser bar with constant power of 40 W, 60 W and 70 W in cw operation at 25°C