Nearly-diffraction limited 980nm tapered diode lasers with an output power of 6.7 W

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***Abstract*—High-power tapered diode lasers emitting at 980 nm with electrically separated straight and tapered sections have been fabricated. A high beam quality at an output power of 6.7 W was achieved.**

I. INTRODUCTION

HIGH-brightness electrically pumped semiconductor lasers are key components in emerging laser technologies. The most promising design are tapered lasers. These devices consist of an index guided straight section and a gain guided tapered section. In the wavelength range 735-1550 nm the approach has been successfully realised for output power up to 5 W [1-4]. Improvement of beam parameters can be performed by optimising the device geometry, especially the length of the straight index guided ridge waveguide (RW) section, as described in Ref. [5].

In this paper tapered lasers with an output power of $P = 6.7$ W and nearly diffraction limited beam quality are presented. In Order to optimize beam quality and output power in a first step a careful pre-selection of the length of the RW section was carried out. Additionally the current flowing through the RW and tapered sections can be separately controlled. The latter allows a rather independent control of output power and beam quality. In this paper the capability of separately controllable electrodes will be demonstrated. Typical power-current and beam characteristics are presented.

II. DEVICE STRUCTURE AND FABRICATION

A schematic view of a tapered laser is shown in Fig. 1. The vertical laser structure grown by metal-organic chemical vapour epitaxy (MOVPE) consists of a super large optical cavity (SLOC) where a very broad 3.6 µm thick $Al_{0.45}Ga_{0.55}As$ waveguide is embedded in $Al_{0.70}Ga_{0.30}As$ cladding layers. The active region is composed of a compressively strained InGaAs single quantum well sandwiched between tensile-strained GaAsP. This structure has an excellent small vertical far field angle of 18.4° (full width a half maximum) shown in Fig. 2.

The fabrication of tapered lasers uses a combination of well-established technological processes for RW and broad area lasers. The fundamental mode RW section was formed by reactive ion etching. The RW width is 3 µm and the etch depth was chosen depending on the desired effective index step

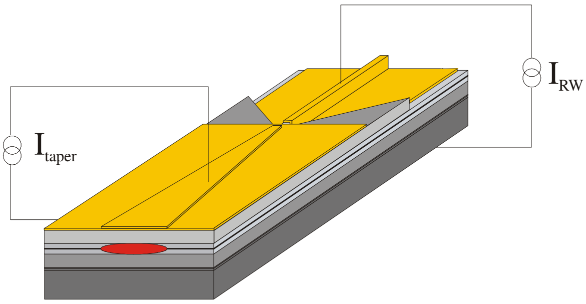

Fig. 1: Schematic three dimensional view of a tapered laser

The RW length L_{RW} is 1350 µm. The tapered section was manufactured as a low mesa structure. The total taper angle ϕ is 6°. A total laser length $L = 4$ mm was chosen to achieve a high output power. The facets were anti- and high-reflection coated ($R_f \approx 1\%$, $R_r \approx 95\%$). The devices were mounted p-up on C-mounts for the measurements.

III. RESULTS

The power-current characteristics, the position of the beam waist, and the intensity profiles in the beam waist and the lateral far-field were measured. All experiments were performed at $T = 25$°C. Into the tapered section, current pulses with a duration of 1 µs and repetition rate of 25 Hz were injected. The RW section was operated in continuous-wave (CW) mode.

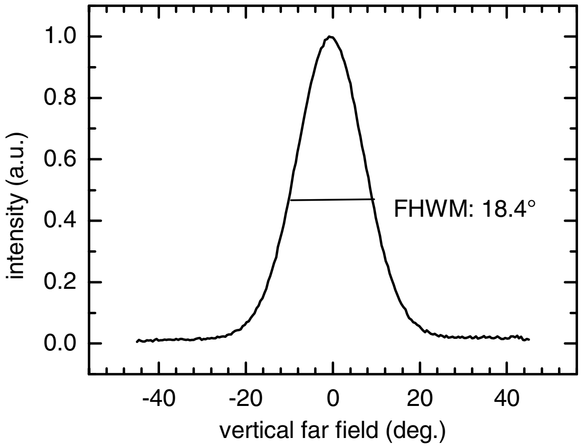

Fig. 2: Profile of vertical far field intensity.

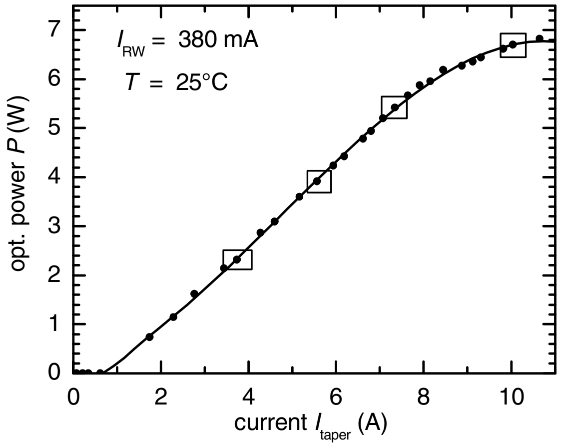

Fig. 3: Power-current characteristic of a 980nm tapered laser with $L = 4$ mm, $L_{RW} = 1350$ µm, $\phi = 6°$, $R_f = 1\%$. The bullets correspond to the measured points, the line is fit using a 3rd order polynom. The large squares mark the power levels where the beam quality was measured.

The best beam quality for a taper current of 10 A was achieved at a RW current of 380 mA.

The power-current characteristic keeping the RW current fixed to 380 mA is shown in Fig. 3. The threshold current is 0.98 A and the slope efficiency has a value of 0.83 W/A up to a power of 5 W. A maximum output power of $P = 6.8$ W was obtained at $I = 10.5$ A.

At four power levels the lateral beam waist profiles were measured. The results are shown in Fig. 4. The optical power P_c contained in the central lobe amounts to more than 70%. Even at $P = 6.7$ W, 71% of the power is inside the central Gaussian-like lobe.

The beam quality parameters are compiled in Table 1. To evaluate the beam quality of tapered lasers, the beam propagation ratio M^2 was calculated from the $1/e^2$ widths of the measured intensity profiles of the beam waist and the far field. At each investigated power level the width of the beam waist is smaller than 6 µm and the M^2 values are smaller than 1.4. These record low M^2 values up to 6.7 W illustrate the nearly diffraction limited properties of this laser.

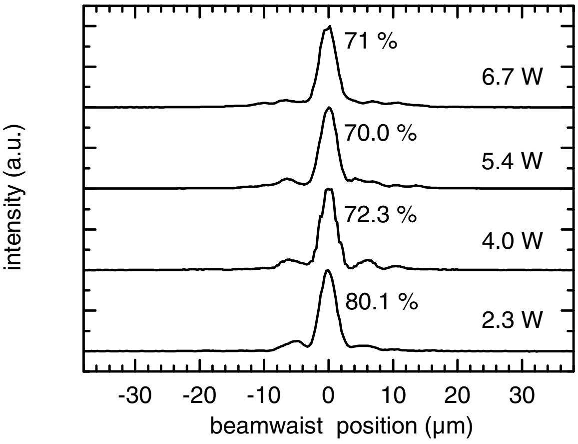

Fig. 4: Profiles of beam waist intensity at different output powers for the laser from Fig. 3. The relative power in the central lobe P_c is also indicated. The heat-sink temperature was $T = 25$°C.

TABLE 1

Compilation of beam parameters. The widths of beam waist (BW) and far field (FF) and the M^2 value were measured at the $1/e^2$ level

P / W	BW / µm	FF / deg.	M^2	P_c/%
2.3	5.1	18.6	1.30	80.1
4.0	4.8	19.8	1.32	72.3
5.4	5.2	18.8	1.35	70.0
6.7	5.5	18.1	1.37	71.0

Beside the experiments at 980 nm also experiments with 1060 nm lasers using similar structures were carried out. Under comparable operating conditions a maximum output power of P = 6.3 W and a M^2 value of about 2.3 at 5 W were achieved. These results demonstrate that the concept can be successfully applied in the wavelength range between 950 nm and 1100 nm.

IV. CONCLUSION

With these experiments the potential of tapered lasers with electrically separated RW and tapered sections was proved. Output powers up to 6.7 W with an excellent beam quality was achieved using 4 mm long devices. The combination of small vertical divergence and good lateral beam quaility allows an effective coupling of the laser light into fibers.

The results were obtained in pulsed mode due to the lack of structured sub-mounts for a p-down mounting. Results using p-down mounted devices will be shown on the conference.

ACKNOWLEDGMENT

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