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9 W output power from a 808 nm tapered diode laser in pulse mode operation with nearly diffraction-limited beam quality

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***Abstract*—808 nm tapered diode lasers are fabricated based on a SLOC structure with very small divergence of 18°. 14 W overall output power with 9 W of nearly diffraction-limited beam quality are presented.**

I. INTRODUCTION

High-power tapered laser and gain media for CW applications are well-known. At 808 nm tapered devices are requested as pump sources for solid state lasers, for material treatment, and as pump sources for non-linear processes. In CW operation 808 nm tapered lasers consisting of an index-guided straight section and a gain-guided tapered section have revealed nearly diffraction-limited beam quality up to P = 4.4 W [1]. Typically, for fluorescence diagnostics wavelengths in the visible blue and UV range and a short pulse excitation are requested. Tapered lasers with very narrow vertical far field allow simplified coupling to external cavities and reduce the facet load which is both desirable for transformation of optical power by SHG. The performance of tapered lasers with very small vertical divergence of 18° FWHM was investigated. An output power of 9 W with nearly diffraction-limited beam quality was achieved, as well as a very high output power of 14 W which is the highest reported power in the wavelength range around 800 nm.

II. LASER STRUCTURE

The super-large optical-cavity structure (SLOC) described in [2] consists of a tensile-strained GaAsP single quantum well embedded in a 3 µm thick $Al_{0.45}Ga_{0.55}As$ waveguide and highly doped $Al_{0.7}Ga_{0.3}As$ cladding layers. The layer sequence is completed by a highly doped p-GaAs contact layer. The epitaxial layers were grown by low pressure MOVPE on (100) n-GaAs substrates. The tapered lasers consist of index-guided straight sections with a length of 1000 µm and gain-guided tapered sections. The latter were 3 mm long and had a full taper angle φ_{TR} of 4°. The front facet was antireflection coated ($R_f \cong 1\%$), the rear facet was high-reflection coated ($R_r \cong 94\%$). The lasers were mounted p-side (epi-side) down on CuW submounts and, thereafter, on C-mounts.

III. RESULTS

Measurements on the electro-optical parameters of the low-divergence structure reveal no significant deterioration of the laser performance in comparison with larger vertical divergence [2]; e.g., threshold current I_{th}, slope efficiency S and characteristic temperature T_0 obtained on uncoated BA lasers show almost no significant difference between the far field angles of Θ = 18° and Θ = 26°. Also, the internal efficiency for the low-divergence structure still reaches η_i = 0.88, whereas the internal losses α_i = 0.7 cm^{-1} are low.

Figure 1 illustrates the vertical divergence angle measured as low as 18.3° FWHM. It is significantly lower than for standard diodes with typically Θ > 30° FWHM.

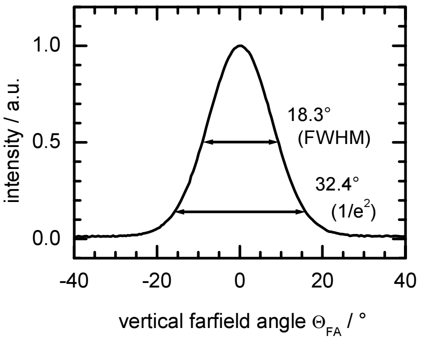

Figure 1: Vertical far field profile of the structure used for the 808 nm tapered lasers.

The power-current characteristics at T = 25 °C in pulse mode operation with a pulse length t_{pulse} = 100 ns and a repetition rate f_{rep} = 25 Hz is shown in figure 2. The threshold current of the laser is 1300 mA, the slope efficiency has a high value of 1.3 WA^{-1} above threshold; taken from threshold to P = 11 W it is still 1.2 WA^{-1}. The maximum output power obtained is as high as 14 W.

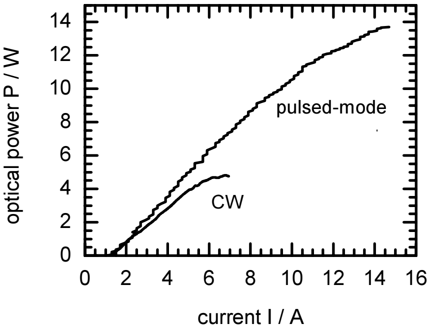

Figure 2: Power-current characteristics of 808 nm tapered laser with L = 4 mm at T = 25°C; t_{pulse} = 100ns (f_{rep} = 25 Hz) and CW mode.

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Also, in CW mode a high output power of almost 5 W is achieved from the single emitter; the slope efficiency above threshold is 1.2 WA^{-1}. The power-current characteristics for CW mode is depicted in figure 2, too.

The beam quality measurements of beam waist, near- and far field were performed applying the method of the moving slit (ISO standard 11146, Annex A). Additionally, the astigmatism was measured. For the beam quality, the beam waist width and shape are the most relevant parameters. In pulse mode, a clearly pronounced main lobe with only small side lobes even at P = 9 W is achieved as shown in figure 3. In connection with the far field width of 12.4° a low beam propagation ratio $M^2_{1/e2}$ of 2.6 is obtained. Even at P = 11 W the value of $M^2_{1/e2}$ still does not exceed 3.2 . The power in the central lobe reaches 73% at P = 11 W; also, it remains very stable over a wide range of power, as can be seen in figure 4. In CW mode, nearly diffraction-limited beam quality of M^2 = 1.5 is achieved up to 3 W.

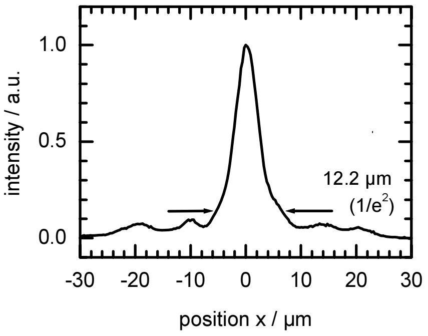

Figure 3: Lateral beam waist of 808 nm tapered diode laser at P = 9W; T = 25°C, t_{pulse} = 100ns, f_{rep} = 25 Hz.

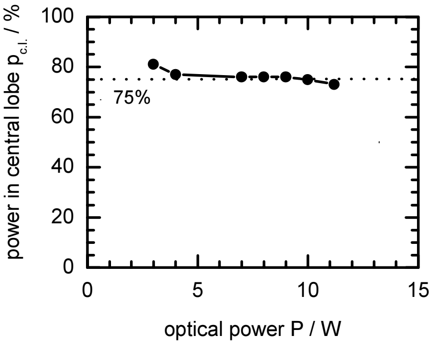

Figure 4: Power in lateral central lobe of 808 nm tapered diode laser at T = 25°C; t_{pulse} = 100ns, f_{rep} = 25 Hz.

Additionally, the variation of the astigmatism in pulse mode is lower than 50 µm for 3 W ≤ P ≤ 11 W (figure 5). This property makes these diodes especially suitable for the applications mentioned above due to simplified and stable beam shaping.

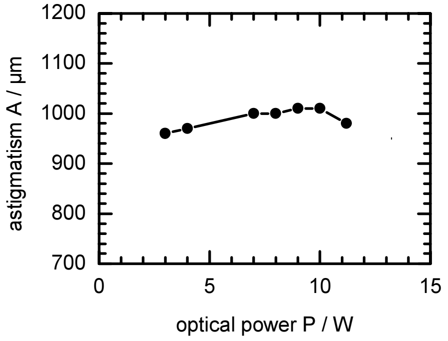

Figure 5: Astigmatism of 808 nm tapered diode laser at T = 25°C; t_{pulse} = 100ns, f_{rep} = 25 Hz.

IV. CONCLUSION

We have manufactured and characterized 808 nm tapered lasers with small vertical far field divergence of 18°. A very high output power of 14 W in pulse mode operation and a nearly diffraction-limited beam quality of $M^2_{1/e2}$ = 2.6 at P = 9 W was achieved. At P = 11 W the value of M^2 still remains around 3; even at this output power the proportion in the central lobe is 73%. The nearly diffraction-limited beam quality in both pulsed and CW mode at high output power makes these diodes suitable for applications like fluorescence diagnostics and material processing as well. Due to the small variation of the astigmatism with power, these diodes are promising candidates for nonlinear frequency conversion in an external cavity setup.

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