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High Performance 10^0 Angle-Facet Laser Amplifiers

Z. Wang, J. Farré, B. Mikkelsen, L. Eskildsen, K.E. Stubkjaer,
A.J. Collar* and G.D. Henshall

Technical University of Denmark, DK-2800 Lyngby, Denmark
*STC Technology Ltd., Harlow, Essex, CM17 9NA, U.K.

The first 10° angle-facet semiconductor laser amplifiers (SLA's), with facet reflectivities as low as 10^{-5} are described. These reflectivities improve the 10^{-4} obtained for 7° angle-facet SLA's [1], [2]. Further, in support of the 10° angle the influence of the facet angle on coupling efficiency and gain ripple is analysed both theoretically and experimentally.

The devices fabricated were based upon the 1.5 μm wavelength ridge waveguide laser [3] as illustrated in Fig. 1. Ridges were formed 3.3 μm wide, at angles of 10° to the facet normal by a CH_4/H_2 RIE process. A larger angling of the facets results in a smaller fraction of the power reflected from the facet being coupled back into the waveguide, yielding a lower modal reflectivity. The use of the dry etching technique avoids the problems of mask undercut for off axis ridges. Wafers grown by LPE were used, with 0.15 μm thick active layers, and 0.3 μm thick anti-meltback layers. To reduce the facet reflectivity further a single layer quarter wavelength anti-reflection coating is applied. This is formed by electron beam evaporation of a commercially available compound (substance 1) manufactured by Merck. Figure 2 shows a measured spectral gain-ripple of 0.025 dB at a single-pass gain of 21 dB. This corresponds to a modal reflectivity of $1 \cdot 10^{-5}$, which is comparable to the best reflectivity reported while the employed AR-coating technique is relatively simple.

The coupling efficiency between fiber and amplifier is as important as the modal reflectivity. For the 10° devices, we have obtained coupling efficiencies to tapered lens-ended fibers of -3.3 dB. This is close to the coupling efficiencies for normal-facet devices as seen from Fig. 3, which gives the theoretically and experimentally determined excess coupling losses as a function of the facet angle. Results for three different lens radii of the tapered lens-ended fiber are given. A lens radius of 11 μm provides the best results for the waveguide structure employed. The excess coupling losses of 0.2-0.5 dB for 10° angled devices are acceptable in view of the low modal reflectivities obtained.

Higher-order transverse modes can cause a higher modal reflectivity because of coupling between the modes at the facets. The gain-ripple vs. facet angle with and without the presence of the first-order mode is derived from a three-dimensional model [4] as shown in Fig. 4. The single-pass gains for the fundamental and the first-order modes are 25 dB and 15 dB, respectively. As seen, the excess gain-ripple due to the first-order mode is nearly eliminated by angling the facet at 10°, implying that the 10° devices are more immune to higher-order modes, should they be present.

In conclusion, 10° angle-facet SLA's are reported. The larger angling ensures a lower gain ripple, while maintaining a coupling efficiency as high as -3.3 dB.

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References:

[1] A.J. Collar et al., Tech. Dig. of 11th IEEE Int. Semiconductor Laser Conf., PD6, Boston 1988.

[2] C.E. Zah et al., *ibid.*, PD7, 1988.

[3] C. Armistead et al., Electron. Lett., vol. 22, p. 1145, 1986.

[4] Z. Wang et al., Electron. Lett., vol. 25, p. 1139, 1989.

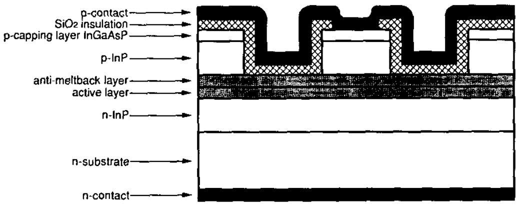

Figure 1: Schematic cross-section of the ridge waveguide structure.

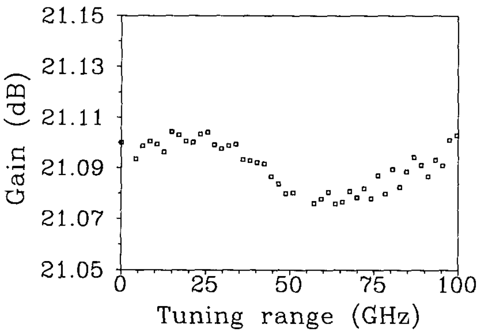

Figure 2: Gain vs. input frequency for a 10° angle-facet SLA.

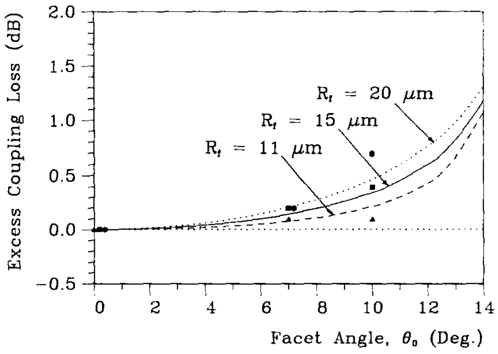

Figure 3: Theoretical and experimental excess coupling loss vs. facet angle.
The lens radii, R_f, for the tapered lens-ended fibers are: 11 μm (---, ▲), 15 μm (—,■) and 20 μm (····,●).

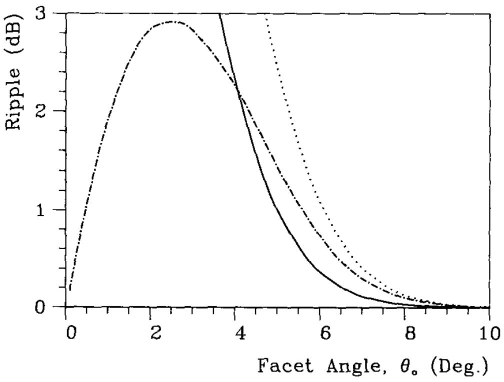

Figure 4: Gain ripple vs. facet angle for 25 dB single-pass gain.
Fundamental mode (—), fundamental and first-order mode (·····), excess ripple due to first-order mode (·–·–·–).