ThD.4 High Performance 1.53 μm InGaAsP/InP Surface Emitting Distributed Feedback Laser Diodes with Monolithic Integrated Microlens

B. Stegmüller, H. Westermeier, W. Thulke, G. Franz and D. Sacher
Siemens AG, Corporate Research and Development,
Otto-Hahn-Ring 6, W-8000 Munich 83, Germany

Laser diodes with emission directed perpendicular to the substrate allow construction of monolithic two-dimensional laser arrays. These devices are expected to be used as light sources for multichannel light communiction systems and optical processing systems.

Efficient light coupling between lasers and external optics requires a small output divergence. This has been achieved by lasers which include the use of a vertical cavity[1] and a standard horizontal cavity with an integrated bifocal microlens deflecting the light perpendicular to the axis of the cavity using a 45° mirror [2], respectively. However, growth of the high-reflectivity multilayer structure and the high-gain quantum well structure of vertical cavity lasers operating at room temperature has to be controlled very precisely [1] by MBE or MOVPE . The bifocal microlens of the laser with the horizontal cavity has to provide both optical feedback and beam collimation [2].

We report on the performance of InGaAsP/InP surface emitting laser diodes with a DFB grating and integrated microlens providing separately optical feedback and beam collimation, respectively. A first order DFB grating has been defined holographically and formed by wet chemical etching. A layer structure appropriate for planar buried-ridge structure (PBRS) lasers has been overgrown by LPE. Subsequent to the fabrication process of PBRS lasers as reported previously [3] mirror-like planes with an inclination angle of 45° have been etched by application of an alcoholic bromine containing solution at 16°C under stirring. Etch rates are 800nm/min resulting in a V-groove (Fig. 1) with 4.2μm depth and 8.5μm width.

Microlenses have been etched out of the n-InP substrate (Fig. 1) using an ion beam process with nitrogen. Masks have been made of thick photoresists (double spin-on process). Its ability to flow at elevated temperatures has been taken advantage of resulting in spherical calottes. These transform into the semiconductor in nearly 1:1 scale.

The active layer structure in the V-groove has been protected by a thin Al_2O_3 layer whereas the microlens has been anti-reflection (AR) coated by a $\lambda/4$-Al_2O_3 layer. After sputtering the n- and p-contact, respectively, the wafers have been cleaved in devices with a standard edge-emitting and surface-emitting performance as well.

From p-side down mounted devices with 0.9μm×250μm cavities a minimum cw-threshold current at room temperature as low as 11mA has been obtained. Light output power up to at least 5mW has been measured parallel and perpendicular to the axis of the cavity as well (Fig. 2).

Comparison between the output beam divergence perpendicular the substrate measured from lasers with a microlens (65µm sphere radius) and that of a plane surface of the substrate (infinite sphere radius) shows the effective beam collimation of the microlens (Fig. 3). Due to a small (~3°) deviation of the V-groove planes from the 45° inclination angle the surface emitting light emits in a direction which deviates about 20° from the normal to the substrate plane. Thus, improvement of the surface emitting light far-field direction is needed.

In conclusion, monolithic integration of a microlens with a DFB laser diode has been developed. Room temperature operation performance of these devices has been demonstrated. Far-field pattern of the surface emitting light has to be improved. These surface emitting DFB lasers will be useful in monolithic two-dimensional applications.

References:

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[3] W.Thulke, and A.Zach, "High-temperature operation of planar buried-ridge structure lasers at 1.5µm", Electron. Lett. 24, pp. 992-993 (1988).

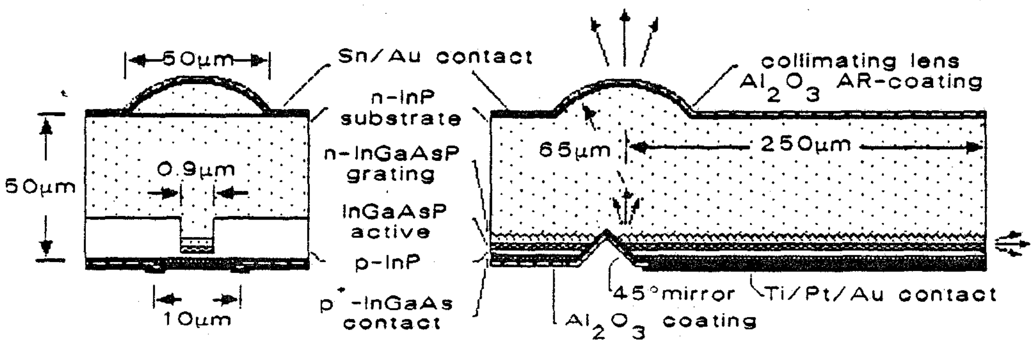

Fig. 1 Transverse and longitudinal cross-section of surface emitting laser

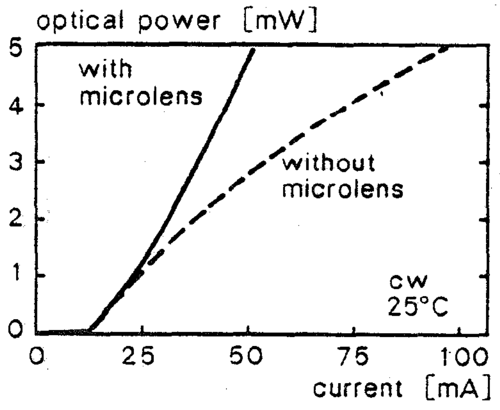

Fig. 2 P-I characteristic measured normal to the substrate plane

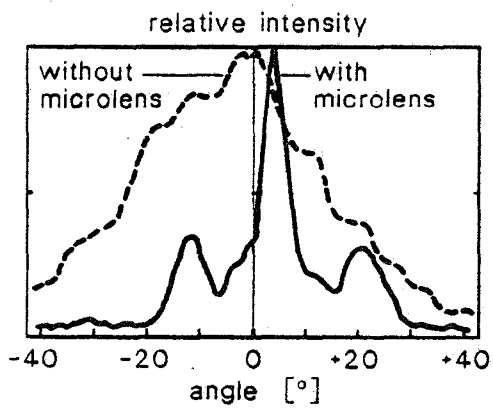

Fig. 3 far-field pattern measured normal to the substrate plane