Edge Emitting InP based Quantum Cascade Microlasers with Deeply Etched Bragg Mirrors

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***Abstract*—Edge emitting quantum cascade microlasers based on InP have been fabricated and investigated. To manage the mirror losses of the short cavity devices, deeply etched Bragg-mirrors have been manufactured at the end of the resonator. To achieve the requested high aspect ratio, an optimized plasma dry etch process has been developed which allows monilithic device fabrication in a single etch step. The resonator length of 155 μm leads to a large Fabry-Perot modes spacing, which suppresses other longitudinal modes and single mode operation with side mode suppression ratio of 16 dB at 80 K has been observed.**

I. INTRODUCTION

The idea of fabricating microlasers on quantum cascade laser structures is not strikingly new. In 1998, C. Gmachl et al. already reported on semiconductor microcylinder lasers [1]. Also quantum cascade whispering-gallery-mode disk lasers have been reported [2], [3]. These microlasers are characterized by long effective cavity lengths due to trapping of photons by total internal reflection. To fabricate edge emitting ridge waveguide microlasers, highly reflective mirrors are required to manage the mirror losses. A convenient way to fabricate highly reflective mirrors in the 10 μm spectral region is to etch deep Bragg mirrors. This has been successfully used in quantum cascade lasers based on GaAs [4], [5]. However, the fabrication of comparable devices on InP was found to be very challenging due to the required high etching depths up to 7 μm. Decreasing the cavity lengths provides the opportunity of single-mode operation due to the increasing Fabry-Perot mode spacing of the laser resonator. Recently, K. Kennedy et al. reported distributed feedback lasers with deeply etched lateral gratings on InP based on a two-step etching process. In this work, however, we demonstrate quantum-cascade microlasers with high structural quality Bragg mirrors and cavities as short as 155 μm fabricated in a one-step etching process.

II. DEVICE LAYOUT AND FABRICATION

The quantum-cascade laser structure is based on a 2-LO-phonon design the active region [7] consisting of 35 periods of 22 lattice matched InAlAs/InGaAs layers each, which are embedded in an asymmetrical InGaAs-core. The structure is grown on a lowly doped InP-substrate by a gas source MBE-system. The deeply etched Bragg mirrors are of third order. The thickness of the semiconductor vs. the air gaps is chosen to be 3.9 μm and 1.9 μm, respectively. The laser ridges and the Bragg reflectors are defined by electron beam lithography and subsequent inductively coupled plasma etching. A Cl/Ar-mixture is used for deep etching up to 7 μm and to provide perpendicular edges (s. inset Fig. 1).

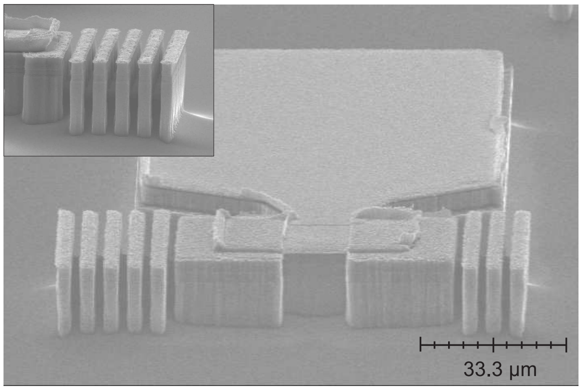

Fig. 1. Scanning electron microscope picture of a 100 μm long microlaser with distributed bragg-reflectors at both ends of the laser resonator.

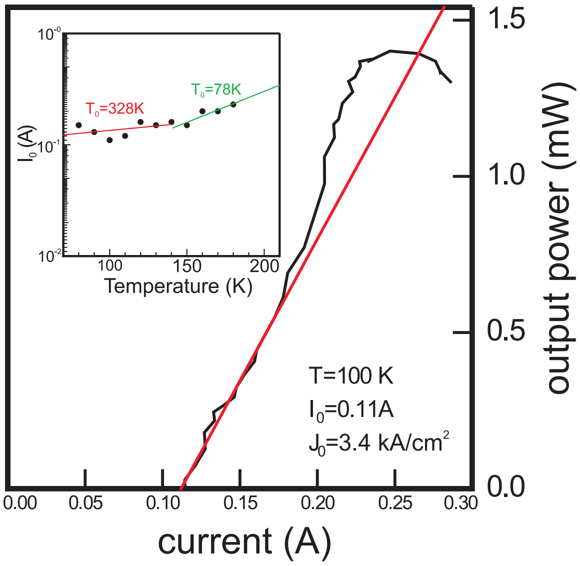

Fig. 2. Light output characteristics of a 155 μm long microlaser. The threshold currents show good stability up to the maximum operation temperature of 190 K for this device (s. inset).

III. RESULTS

A scanning electron microscope picture of a 100 μm long laser ridge with Bragg-reflectors at both ends is shown in

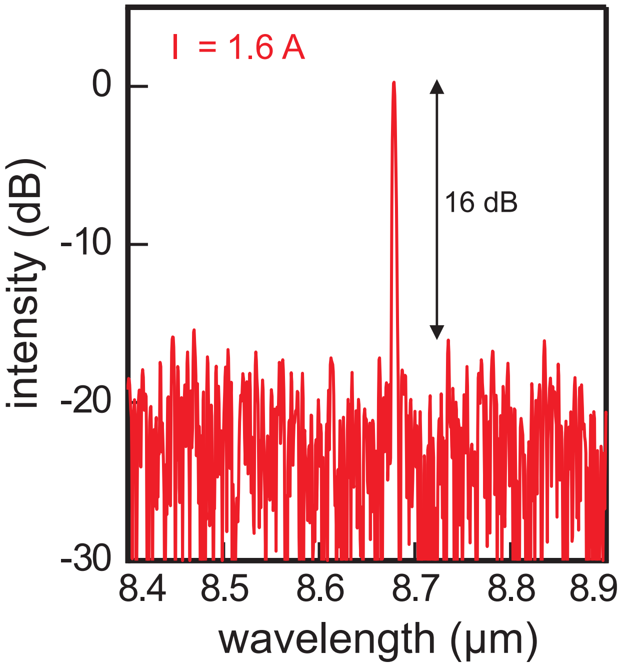

Fig. 3. High resolution singlemode spectrum of a 155 μm long microlaser at 80 K.

figure 1. The picture shows smooth, perpendicular edges and high depths which is a proof of the good quality of the etching-process and the accuracy achieved with chosen etching parameters. The light output characteristic of a 155 μm long microlaser as well as temperature dependence of the threshold current are shown in figure 2. At 100 K a threshold current of 110 mA and typical output powers in the mW range are observed for the device. The relatively low output power can be attributed to the high reflectivity of the Bragg reflectors. As shown in Fig. 3, single mode operation with a high side mode suppression ratio of 16 dB is achieved for a heat sink temperature of 80 K and a driving current of 1.6 A. The maximum operating temperature of the 155 μm long device is about 190 K.

IV. CONCLUSION

In conclusion, we have fabricated edge-emitting InP-based microlasers with deeply etched Bragg mirrors. For the fabrication of the devices a single dry etch process has been developed. Output powers in the mW range and maximum operation temperature of about 190 K are currently obtained. Both device parameters should be adjustable by controlling the mirror reflectivity and the cavity length. The 155 μm long device allows single mode operation with a side mode suppression ratio of 16 dB at 80 K due to a large Fabry-Perot mode spacing.

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