Y-coupled Quantum Cascade Lasers

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Y-coupled cavity quantum cascade lasers have been processed from GaAs/AlGaAs and InP/InGaAs/AlAs/AlInAs wafers. Farfields of these samples were investigated. A phase coherence between the two coupled ridges was observed which results in the farfield pattern of a double slit experiment. Coherent coupling gives perspectives for high power laser arrays.

Introduction

Quantum cascade lasers (QCLs) have been intensively investigated since their first demonstration in 1994 by J. Faist *et al.* [1]. QCLs are now able to cover a broad spectrum from a few microns wavelength to the THZ regime. As mid-infrared sensing applications require high power coherent light sources, coherently coupled QCL arrays are desirable.

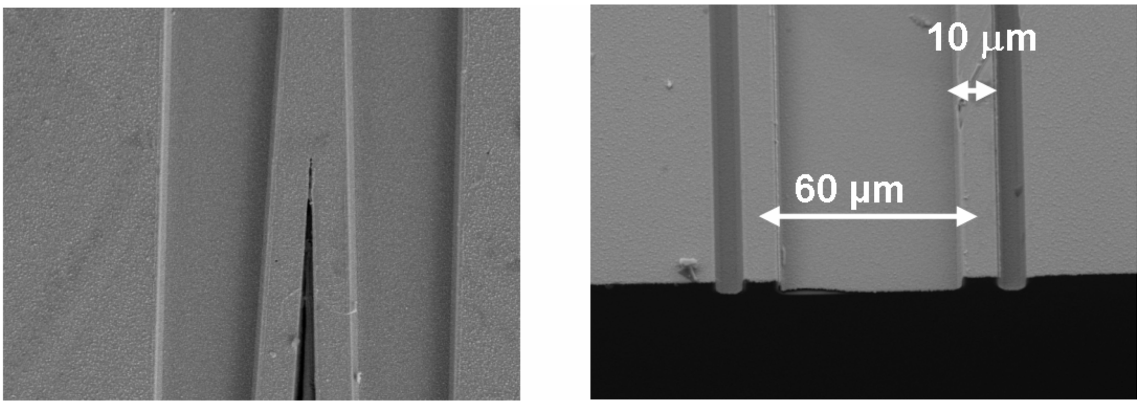


Fig. 1: SEM pictures of the InP based sample. Merging of two 10 µm ridges into one single 10 µm ridge (left). Double facet side of the sample (right).

Processing

Two QCL structures were used for the experiments. The first one is a GaAs/AlGaAs active region structure with a double plasmon waveguide [2]. Its emission spectrum peaks at about 10.5 µm at room temperature (RT). The second structure is a strain-compensated InGaAs/AlAs active region structure with an InP based waveguide [3] and an emission wavelength of about 4.3 µm at RT.

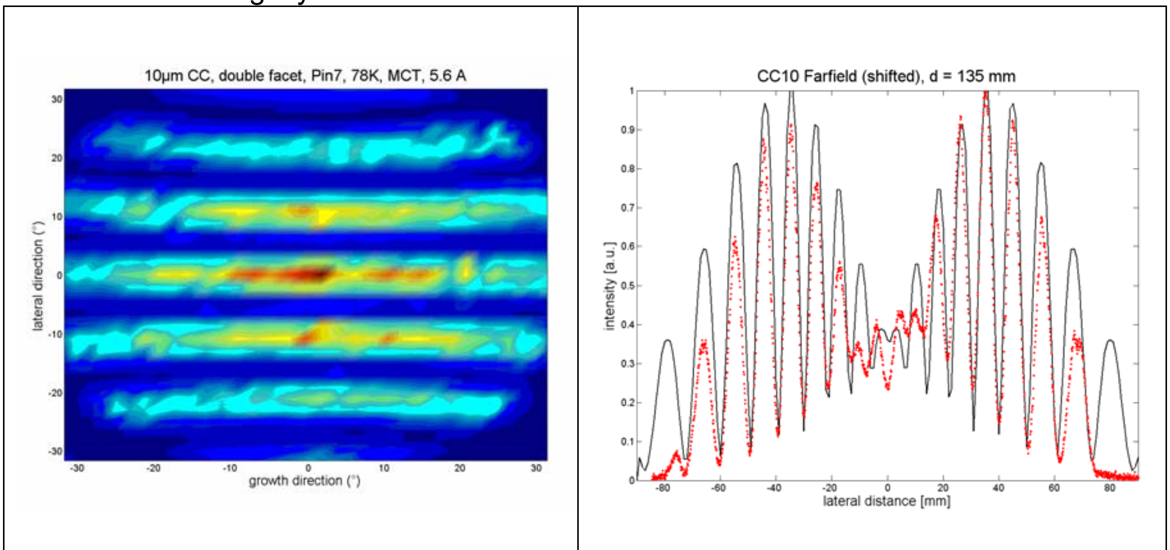
Y-coupled ridges were etched using reactive ion etching (RIE). Thereafter, a 300 nm thick SiN_x insulating layer was deposited by plasma enhanced chemical vapor deposition (PECVD). Windows were opened on top of the ridges, followed by evaporated Ge/Au/Ni/Au (150/300/140/1500 nm) top contacts. 500 nm Ti/Au extended contact pads finished the top side processing. For the back side contact again Ge/Au/Ni/Au (150/300/140/1500 nm) was deposited. The samples were then installed into an N_2 flow cryostat, where they were analyzed at 78 K.

Figure 1 shows SEM pictures of the processed samples. The left picture illustrates the merging point, where the two 10 µm wide ridges meet and overlap to form a single 10 µm ridge. A cleaved facet of the adjacent coupled ridges is shown on the right hand side. All measurements were operated in pulsed mode with a pulse length of 100 ns at 5 kHz repetition rate.

Results

An infrared MCT detector was mounted on a 2-dimensional driving stage for lateral farfield measurements. On the left Fig. 2 shows a 2D farfield of a GaAs based laser, where a sharp interference pattern is observed in lateral direction. Due to a high level of coherence the data reveal angles of constructive and destructive interference between the two coherent sources. Experimental data were nicely fitted with theoretical values [4], where the propagation of the calculated nearfield was summed for each point of the far screen.

The right hand side of Fig. 2 shows the farfield of an InP based device. InP based samples show reduced coherence. As the wavelength is shorter, the interference pattern shows a qualitatively different behavior. Fitting the results was possible by considering more degrees of freedom than for the GaAs based samples. For GaAs devices, only the fundamental lateral mode in the coupled ridges had to be considered. However, at least the fundamental and the first harmonic mode are present in the InP devices to yield the observed farfield profiles. Additionally, the intensity of each ridge was found out to be slightly different.



GaAs	InP

Fig. 2: 2-dimensional farfield measurement at the double facet side of a GaAs sample (left) and 1-dimensional farfield data of an InP sample (right) with simulated profile (solid line).

Conclusion

In conclusion, coherent Y-coupled QCLs have been demonstrated for InP/AlGaAs and InP/InGaAs/AlAs/AlInAs materials. Farfield measurements of the GaAs based devices show a sharp interference pattern, which can be theoretically derived. In the InP based coupled cavities, lateral modes of higher order are present in the waveguide, which results in a reduction of coherence observed in the farfields.

References

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[3] M. P. Semtsiv *et al.*: 'Circular-beam cross section quantum-cascade laser' (to be published)

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