Quantum cascade external cavity laser systems in the mid-infrared spectral range

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Abstract: Quantum cascade laser (QCL) are an excellent tool for MIR-spectroscopy. We report on the design an realization of antireflection coated pulsed and cw-QCL in external cavity (EC) configurations and investigate their performance.

OCIS codes: (140.3600) Lasers, tunable; (140.5960) Semiconductor lasers.

Summary

QCL have become a well established radiation source in the MIR region. Spectroscopic applications such as process monitoring and environmental measurements can take advantage of the near room temperature (RT) operation possible with these devices and the much stronger linestrengths of the fundamental molecular absorption in the MIR compared to the NIR range. QCL systems have already shown their higher sensitivity for trace gas detection. To overcome tuning behavior drawbacks of such lasers, EC-QCL were investigated by several groups [1-3]. In this paper we investigate the behavior of antireflection coated QCL in external cavities and present our newest results on the EC-QCL like tuning behaviour and spectral properties.

The investigated samples are based on compressively strained GaInAs quantum wells and tensile strained AlInAs barriers giving rise to an increased conduction band offset compared to lattice-matched $Ga_{0.47}In_{0.53}As/Al_{0.48}In_{0.52}As$ heterostructures [4]. The individual layer thicknesses and compositions are chosen such that the overall strain is compensated. For the active regions a four quantum well design with “double longitudinal-optical phonon relaxation” [5] together with incorporated AlAs blocking barriers and strain-compensating InAs layers [6] is employed similar to the design published in [7] In pulsed mode (100 ns pulse length, 1 kHz repetition rate) devices with uncoated facets can be operated up to a heat-sink temperature of 390 K (117 °C). The operating voltage is around 10 V. At 300 K lasing is observed at an emission wavelength of 5.34 µm. The device is operated at a temperature of 88 K for cw operation using a 24 V battery current source. For pulsed operation, the device is operated at 260 K. Delayed optical feedback induces instabilities in the laser emission of the QCL. This indicates that QCLs are as sensitive to optical feedback as interband semiconductor lasers. In order to achieve stable laser emission, optical feedback should be either avoided or spectrally controlled by an optical grating. For the final goal of the realisation of a very compact EC-QCL, we have chosen to use grating feedback in a Littrow [1,2] configuration. The light from both facets is collimated by a ZnSe lens. To achieve a laser system with the best possible performance, the EC-QCL must have a high quality anti-reflection coating [8] on the front facet of the QCL, and low-noise high-resolution electronics. The quality of the EC-QCL is strongly dependent on the quality of the anti-reflection coating of the QCL’s front facet. To achieve an anti-reflection coating below 1%, we sputtered a $\lambda/4$ multiple-layer on the front facet of the QCL. The threshold after coating is 1.9 A, while it was 1.3 A before coating, that is a threshold shift of about 40%. Newest results on the coating are presented and the spectral properties of the EC-QCL are presented.

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