IQCLSW
2014

International Quantum Cascade Lasers School & Workshop

Policoro, Italy, 7-14 September 2014

QCLs: 20 years of discoveries
1994-2014

Growth and Processing of QCLs: from Material Aspects to Integrated Optics

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1. Introduction

Quantum cascade lasers (QCLs) have become powerful, versatile and desirable light sources, emitting in a wide range from the mid-infrared to the terahertz spectral region. Therefore, such lasers are suitable for many applications in science, medicine and industry. In spite of the developments during the last 20 years in this lively field there is still room for further improvement in terms of materials, material combinations, and growth. In addition, various cavity concepts have been developed, partly exploited, and might open broader applications and novel markets. This talk tends to cover both aspects, growth and processing of QCLs.

2. Material Growth

In the first part of the talk, symmetric (THz) quantum cascade laser active regions are introduced and used to study material and growth related effects on the device performance [1]. Material related differences will be emphasized: InGaAs-based heterostructures provide the advantage of a higher optical gain but require thinner barriers, which lead to a higher sensitivity to growth or material induced imperfections. While interface roughness scattering is shown to be the dominant mechanism in InGaAs/GaAsSb based devices [3], GaAs/AlGaAs QCLs are mainly influenced by dopant diffusion during epitaxial growth [2]. This concept therefore delivers valuable feedback, complimentary to X-ray diffraction or transmission electron microscopy, to allow further optimization of active region design and epitaxial growth [4].

3. Processing

In the second part of the talk, as an example for advanced processing, Ring Cavity QCLs will be introduced. Surface and substrate emitting rings show higher slope-efficiencies, lower thresholds and approx. 20 times narrower emission beams compared to equivalent Fabry-Pérot devices. In addition, such rings can be arranged to arrays presenting an on-chip spectrometer [5, 6]. Conventional Ring-QCLs show azimuthal polarization characteristics and exhibit an intensity minimum in the far field center. Further processing, introducing phase shifts in the rings, allows to create far fields with central intensity maxima [7]. Using substrate emission and on-chip meta-material fabricated directly onto the substrate below the laser the divergence of the emission beam can be further decreased and the peak intensity can be increased [8]. In these rings the simultaneous control of the polarization and the divergence of the emitted beam by advanced processing is possible.

4. References

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