ITQW 2019

Infrared Terahertz Quantum Workshop

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Program and Abstract Catalog

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High frequency modulation of mid-IR ring and ridge DFB Quantum Cascade Lasers

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Short Abstract The fast modulation characteristics of quantum cascade lasers (QCLs) up to the MHz-/GHz-range give insight into their dynamical properties and act as a prerequisite for experiments like e.g. the injection locking of frequency combs [1], spectroscopic measurements [2] or optical free-space telecommunication applications [3]. In this paper we present the first analysis of the high frequency modulation characteristics of mid-IR DFB-*ring* QCLs in comparison to DFB-*ridge* QCLs from the same gain material including showing the existence of the (quasi) single-sideband ((q)SSB) regime.

1. Introduction

While the electrical and optical response to direct current modulation in the MHz-/GHz-range has already been investigated in mid-IR QCLs in a ridge-waveguide configuration [4,5], ring-QCLs still lack such a detailed analysis. This is in particular relevant, since single mode surface-emitting ring-DFB QCLs show significant potential in array integration [6], farfield modifications [7] and monolithic ring-in-ring laser-detector schemes [8].
We measure for the first time the optical response of such ring-devices emitting in the mid-IR spectral region around 7.56 µm wavelength by applying a CH_4-based frequency-to-amplitude conversion technique as presented in [9]. We compare those results to the same measurements using ridge-DFB devices from the identical gain material [9]. In contrast to the ring-devices, which have a 2[nd]-order DFB-grating implemented in their waveguide structure for singlemode surface emission, the ridge-devices use 1[st]-order gratings in an edge-emission configuration.

2. Results

Figure 1(a) shows the experimental setup including the electrical current path (red arrows) for the high frequency current modulation ("Signal Generator") and the DC current injection ("QCL Driver") using a regular bias tee. After passing through the sample gas cell filled with CH_4, the signal is analyzed on a fast detector and down-mixed with a reference-signal from the signal generator to be fed into the lock-in amplifier with its cut-off of 100 kHz. By fitting the spectral data obtained from the lock-in amplifier using a theoretical model [9] adopted from [10] we obtain the following results: in the investigated frequency range between 800 kHz and 160 MHz we observe a decreasing frequency tuning amplitude Δf normalized by the intensity modulation index m with increasing modulation frequency. In particular the ring-devices consistently show slightly higher values when comparing them close to lasing threshold (148 mA) to the similar ridge devices also close to their lasing onset (245 mA) and at higher values ~20-25% above lasing threshold (ring: 185 mA vs ridge: 297 mA).
In addition, we observe the existence of the so-called SSB regime in the sideband-ratio, where

one 1[st]-order sideband vanishes while the other one can still be observed. This special FM-state and its precursor, the qSSB, where the sideband ratio (SR = $|E_{-1}|/|E_{+1}|$) reaches values of above 15 dB, is an interesting feature in QC devices, which is not observed in regular near-IR diode laser [9, 10]. It can be used for various applications like spectroscopic measurements [2] and optical free-space telecommunication [3] and can be observed in our devices for modulation frequencies above ~100 MHz (see Fig. 1(c)). In this case the ring devices show higher SRs than the ridge-QCLs for comparable driving conditions.

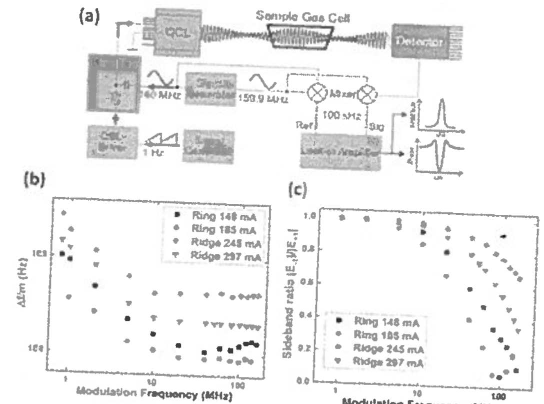

Figure 1: (a) Experimental setup applying the frequency-to-amplitude conversion technique. (b) Frequency tuning amplitude over intensity modulation index as function of modulation frequency between 800 kHz and 160 MHz. (c) Sideband ratio ($|E_{-1}|/|E_{+1}|$) in the same modulation range.

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