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Observation of Dynamics in a 5 GHz Passively Mode-locked InAs/InP (100) Quantum Dot Ring Laser at 1.5 µm

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In this paper we present the first observation of passive mode-locking in a quantum dot (QD) ring laser operating at wavelengths around 1.5 µm. The InAs/InP QD laser structure is grown on n-type (100) InP substrates by metal-organic vapor-phase epitaxy [1]. Lasers with a ring configuration are realized using the fabrication technology presented in [2]. The device consists of an 18-mm long (electrically pumped) ring cavity, corresponding to a 5-GHz roundtrip frequency. The ridge waveguide width is 2 µm. A saturable absorber (SA) section with a length of 300 µm is located in the cavity. The position of the SA in the ring is opposite to a directional coupler which couples 5% - 10% of the light to the output waveguides. The output waveguides end with angled facets that have been anti-reflection coated to suppress feedback into the cavity.

Modelocking is indicated by the observation of peaks of over 50 dB in the RF-spectrum from the 50-GHz photodiode signal of the laser output, for injection currents of 720 mA to 890 mA and an SA bias voltage of -1 V. The width of the (fundamental) RF-peak at -20 dB is between 300 kHz and 400 kHz in this range, which is almost half the width as observed with Fabry-Pérot-type lasers of the same QD material [2]. A detailed view of the RF spectrum is shown in Fig. 1. Mode-locking is confirmed further by an autocorrelator measurement, showing a 55-ps duration signal at FWHM. The supermodulation of the RF-spectrum shown in Fig. 1 suggests that there is some detailed structure present in the pulse shape, which is not visible in the autocorrelator trace. These observations are in line with our previous observations on FP-type QD lasers. We thus expect the pulses to be highly chirped and we are currently investigating the temporal pulse shape with the technique presented in [2]. Similar dynamical behavior has been observed in single section FP-type quantum dash lasers at 1.55µm [3].

The optical spectra of both laser outputs, counterclockwise (CCW) and clockwise (CW) propagation, are given in Fig. 2a) and b) for a range injection currents. The CW-spectrum shows three groups of laser modes for injection currents of 720 mA to 890 mA. We ascribe the spectral features to lasing transitions from the electron ground and excited dot states as well as gain competition effects. When the CW and CCW spectra are compared it can be seen that they are complementary, i.e. the CCW spectrum fills in the gaps of the CW spectrum. This is more clearly depicted in Fig. 2c. This means that the CW and CCW signals have different wavelengths and consequently that these are generated by different sets of quantum dots, with different sizes. This is a unique feature of these QD ring lasers and we expect to present a more detailed picture on the power exchange and distribution between the CW and CCW propagating fields.

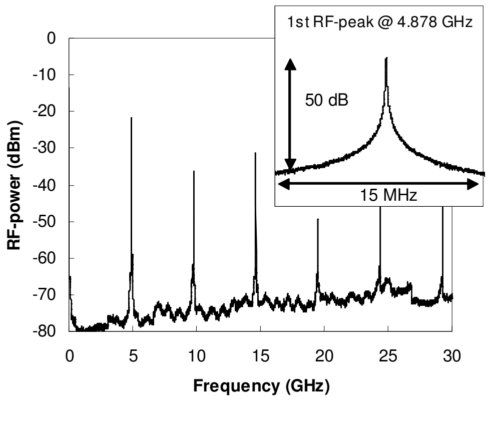

Fig. 1 RF-spectrum at injection current of 820 mA and SA bias voltage of -1 V. The inset shows a detailed view of the spectrum around the first RF-peak. The electrical bandwidths used are 3 MHz and 50 kHz respectively.

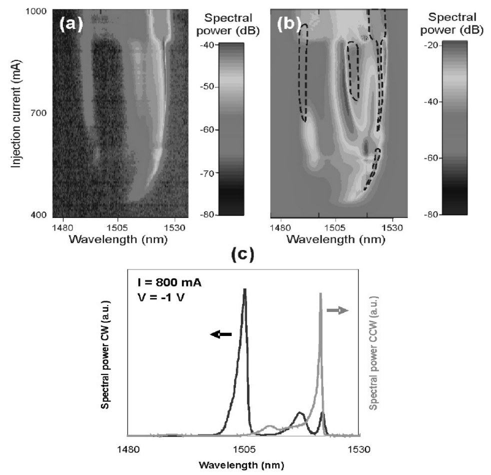

Fig. 2 Optical spectra of the CCW (a) and CW (b) (grey scale in dB). The dashed line in (b) indicates an outline of features in the CCW spectra. V_{SA} = -1 V. In (c), spectra at 800mA are shown in a linear intensity scale.

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