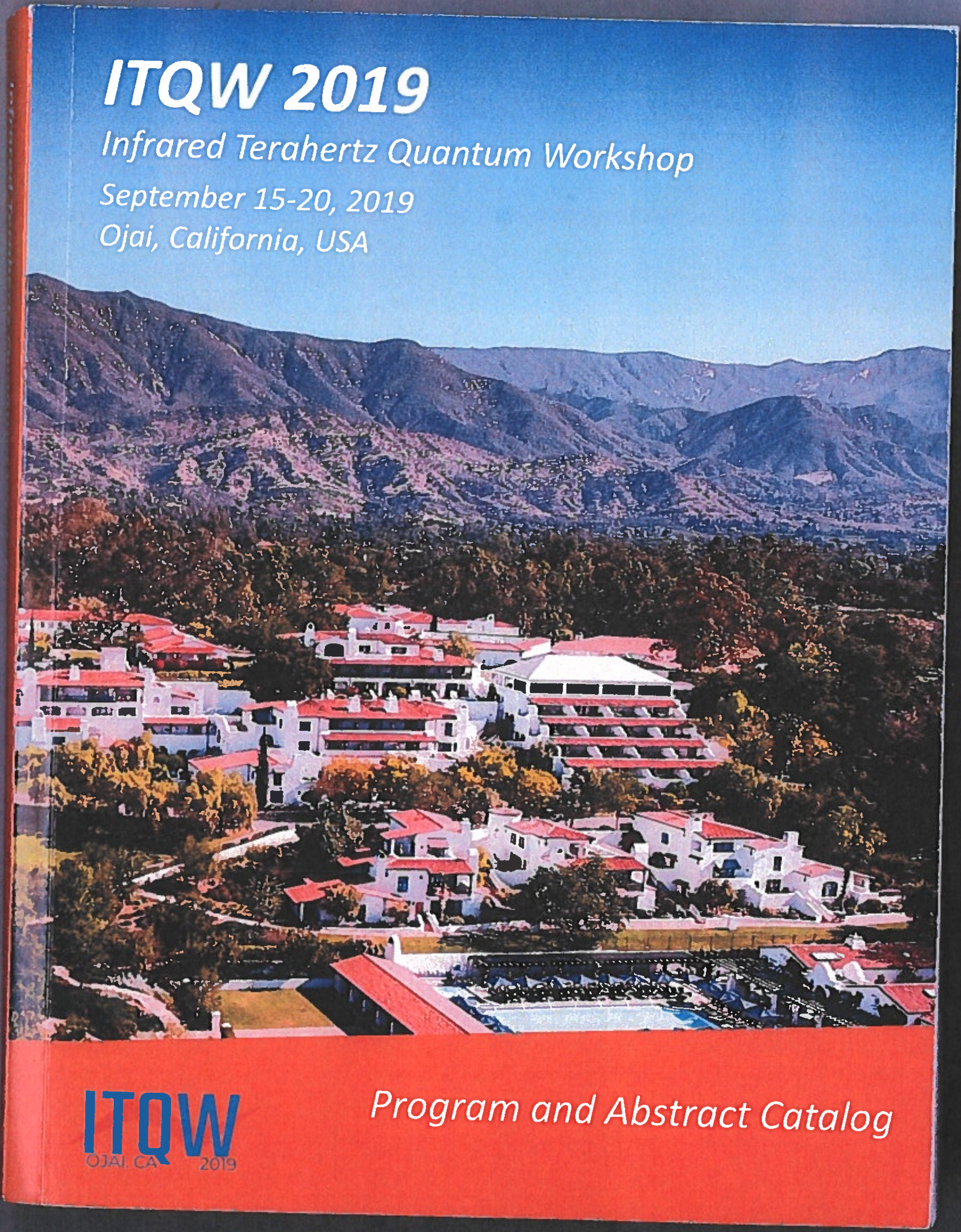

ITQW 2019

Infrared Terahertz Quantum Workshop

September 15-20, 2019
Ojai, California, USA

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Program and Abstract Catalog

+ Schönhuber
Poster Seite 250

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Infrared Terahertz Quantum Workshop
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Frequency comb dynamics of ultrafast quantum dot lasers

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Short Abstract Here, we investigate the temporal dynamics of ultrafast quantum dot laser (QDL) frequency combs using both quadratic and linear autocorrelation techniques. In the passively mode-locked regime, the QDL is found to emit a train of 10 ps long pulses, confirmed independently by both autocorrelation techniques. By carefully tuning the driving conditions of the QDL, we find another frequency comb regime, which was previously observed in mid-infrared semiconductor laser frequency combs and appears to be universal.

1. Introduction

Optical frequency combs (OFC) are of paramount importance for time metrology, spectroscopy and optical telecommunication. The advent of semiconductor laser OFCs holds promises for the photonic integration of electrically pumped and all-solid-state OFCs. To date, the nonlinear effects of gain and dispersion are challenging to control and lead to complex temporal dynamics in semiconductor laser OFCs. Here, we present a comprehensive study of the frequency comb dynamics in an ultrafast quantum dot laser (QDL).

The investigated device is a 4 mm long laser ridge consisting of four sections (Fig. 1a). In this geometry, the quantum dot active material offers an elegant way to generate mode-locked pulses: by applying negative bias to a short section of the laser, the active region becomes a saturable absorber with exponentially decreasing absorption recovery time [1]. In this way, both the gain medium and a fast saturable absorber can be conveniently integrated into a single laser ridge, which acts as a passively mode-locked OFC source. The intensity autocorrelation of the QDL at -3.8 V absorber section bias is displays in Fig. 1b. It shows that the QDL emits isolated pulses with a full width at half maximum (FWHM) of roughly 10 ps, assuming a Gaussian pulse shape. At the same gain section current, the laser dynamics can be changed completely by increasing the absorber bias to 0 V. In this regime, the amplitude of the beatnote deacreases by more than 30 dB. The intensity autocorrelation shows an almost constant signal over a delay of 60 ps (Fig. 1b, bottom).

In order to further investigate the laser dynamics, we employ a linear and phase-sensitive autocorrelation technique called 'shifted wave interference Fourier transform spectroscopy' (SWIFTS) [2], which allows to reconstruct the temporal output of the QDL. In the passively mode-locked regime, the entire emission spectrum of the QDL is phase-coherent and its intermodal difference phases cover a range of $0.22 \cdot 2\pi$. As a consequence, the reconstructed time signal shows pulses with a FWHM of 8.9 ps, in good agreement with the intensity autocorrelation in Fig. 1b. The pulse width is mainly determined by a long trailing edge. Furthermore, the reconstructed instantaneous wavenumber reveals that the pulses are linearly chirped.

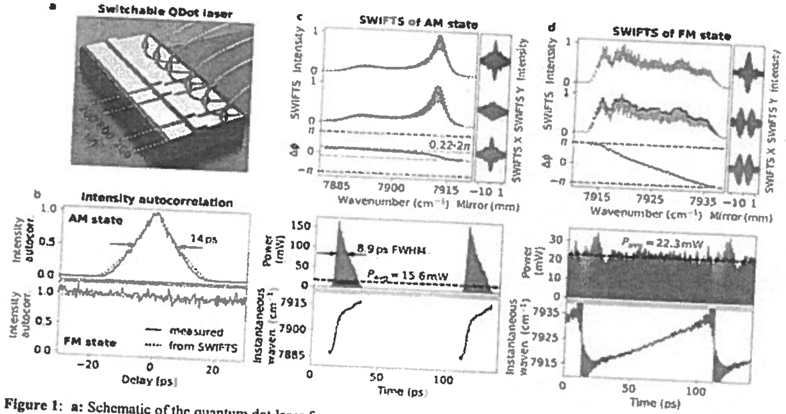

Figure 1: **a:** Schematic of the quantum dot laser frequency comb. The laser ridge consists of two 200 µm short absorber sections and two 800 µm and 3100 µm long gain sections. b: intensity autocorrelation traces at 160 mA gain current and -3.8 V absorber bias (top) as well as 0 V absorber bias (bottom). c: SWIFTS characterization of the laser dynamics at -3.8 V absorber bias. Blue: intensity spectrum. Red: coherence spectrum. Green: intermodal difference phases. Inset on the right: center burst of the intensity and SWIFTS interferograms d: SWIFTS characterization at 0 V absorber bias.

At 0 V absorber bias (Fig. 1d), the laser dynamics change drastically. In this regime, both SWIFTS quadratures show a minimum at zero-path difference of the FTIR mirrors, which is an indicator the the suppression of amplitude modulation. The intermodal difference phases are linearly splayed over a range of exactly 2π. This particular frequency comb state was observed in mid-infrared quantum and interband cascade lasers [3,4] and seems to occur universally in semiconductor laser frequency combs. Its origin was found in the interplay of dispersion, Kerr effect and spatial hole burning. The reconstructed waveform of this state shows an almost constant intensity. In contrast, the instantaneous frequency linearly chirps through the entire emission spectrum exactly once per cavity roundtrip period.

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