Abstracts

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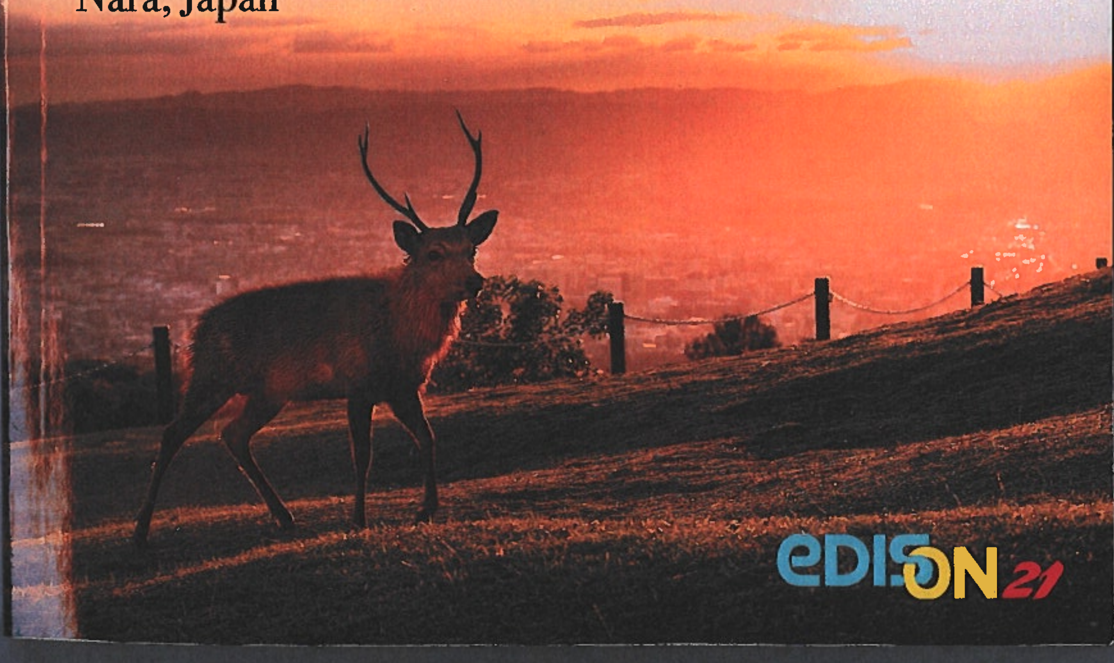

Monolithic Frequency Comb Generation and High-speed Detection based on Interband Cascade Structures

E. Gornik[1], J. Hillbrand[1], A. M. Andrews[2], R. Weih[3], S. Höfling[4], G. Strasser[1], and B. Schwarz[1]

[1]*Institute of Solid State Electronics, TU Wien, 1040 Wien, Austria*

[2]*Center for Micro- and Nanostructures, TU Wien, 1040 Wien, Austria*

[3]*Nanoplus Nanosystems and Technologies GmbH, 97218 Gerbrunn, Germany*

[4]*Technische Physik, Physikalisches Institut, University Wuerzburg, Am Hubland, 97074 Wuerzburg, Germany*

erich.gornik@tuwien.ac.at

Frequency combs are sources of coherent light whose spectrum is composed of a multitude of equidistant lines. Originally developed in the near-infrared region, frequency combs enabled unprecedented precision of applications such as time metrology and frequency synthesis. Nowadays, the mid-infrared region is attracting a lot of research interest. No other spectral region provides the same sensitivity or selectivity for molecular fingerprinting. Semiconductor lasers like quantum cascade lasers (QCL) and interband cascade lasers (ICL) are particularly appealing for frequency comb generation because they are electrically pumped and have a small footprint. In contrast to traditional frequency combs based on mode-locked lasers that emit short pulses, QCL frequency combs show a temporal profile that is characterized by strong frequency modulation and suppression of amplitude modulation. In this work, we present a new monolithic frequency comb sensing platform based on ICLs. We demonstrate self-starting frequency comb operation of ICLs based on the inherent gain non-linearity. In contrast to QCLs, the gain in ICLs is provided by an interband transition rather than an intersubband transition. Despite the fact that the laser transition lifetime differs by more than two orders of magnitude compared to QCLs, ICLs can respond to beatings between laser modes (Fig. 1a). We investigate the laser dynamics of the ICL frequency comb using a linear autocorrelation technique (Fig. 1b). The observed phases of the comb modes are strikingly similar to QCLs. Our experiments reveal that ICL frequency combs are characterized by a strong suppression of amplitude modulation. We further show that ICL combs can be locked to an external RF oscillator while maintaining full intermodal phase coherence. This allows an all-electric control and stabilization of the frequency comb against the harsh conditions, which are omnipresent in real-life applications. Finally, we highlight the unique detection functionality naturally provided by the ICL material, which can be used to directly integrate sensitive multi-heterodyne detectors. Hence,the ICL based monolithic platform provides both frequency comb generation and high-speed detection functionality.

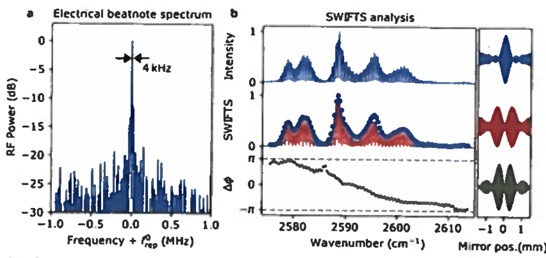

Fig. 1. **a**: Beatnote of the frequency comb modes at the cavity roundtrip frequency. Due to the fast carrier dynamics of the ICL, the beatnote can be extracted directly from the driving current of the laser with RF probes. The FWHM of the beatnote is as narrow as 4 kHz indicating that the laser operates in the frequency comb regime. **b**: Analysis of the frequency comb using SWIFTS. blue: intensity spectrum. red: coherence spectrum. green: intermodal difference phases.

References

[1] B. Schwarz, J. Hillbrand, M. Beiser, A. M. Andrews, G. Strasser, H. Detz, A. Schade, R. Weih, and S. Höfling, arXiv:1812.03879v (2018).

[2] A. Hugi, G. Villares, S. Blaser, H. C. Liu, and J. Faist,(2012). Nature, 492(7428), 229.