Extended-cavity single-frequency semiconductor lasers using ring filters in low-loss SiN technology

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Extended-cavity semiconductor lasers with high spectral purity and wide spectral coverage are important for a large range of applications including fiber-optic communications [1], optical sensing [2], or applications in space, for instance in atomic clocks [3]. Monolithic diode lasers for such tasks, e.g., distributed feedback (DFB) lasers and distributed Bragg reflector (DBR) lasers, approach their limits since they typically show either a small tuning range [4] or considerable spectral linewidths at the MHz level [5]. These limitations can be largely removed in hybrid lasers, where the gain from a semiconductor optical amplifier chip is receiving spectrally filtered feedback from a second chip fabricated from dielectric material. The dielectric chip carries an integrated-optical waveguide circuit with which highly selective filtering and a long photon lifetime can be realized beyond what is typically possible in semiconductor platforms.

Here we report on the properties of wavelength-tunable hybrid diode lasers with extended cavities based on silicon nitride waveguide circuits (Si_3N_4 in SiO_2), the latter chosen for its ideal combination of high index contrast and low propagation loss. We have recently shown [6] that the low loss in this platform allows to extend the optical length of the integrated cavity substantially to about 0.5 m. At the same time low loss enables sharp intracavity spectral filtering by cascading micro-ring resonators (MMRs) with various different roundtrip lengths and high quality factors. With such a hybrid laser, we observed single-frequency oscillation with sub-kHz (290 Hz) intrinsic linewidth, which is the lowest value that has ever been demonstrated with a chip-based diode laser.

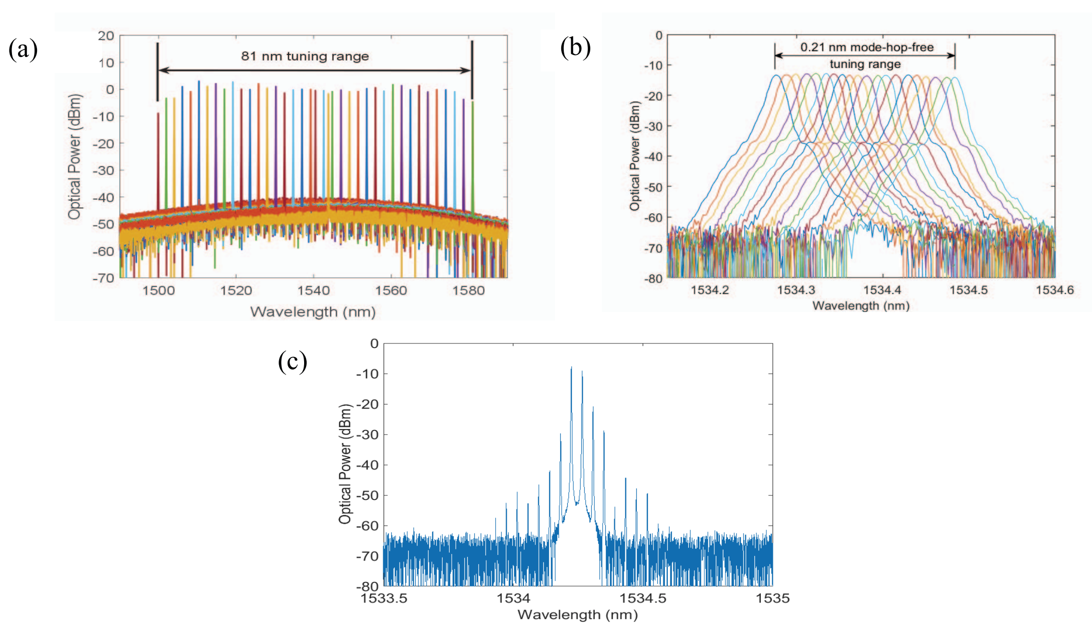

Fig.1 a) superimposed laser spectra in the 1.55 µm range obtained with stepwise tuning across an 81 nm wide range, b) series of optical spectra recorded during mode-hop free tuning over a 26 GHz (or 0.21 nm) range, c) generation of multiple frequencies.

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With various different configurations and making use of phase actuators, these lasers can be optimized towards wide wavelength tuning across the entire gain bandwidth (see Fig. 1 a) and also for mode-hop free (continuous) tuning. Fig. 1 b) shows mode-hop free tuning over 26 GHz, which is about 5-times the free spectral range of the respective laser cavity. Multi-wavelength operation with equidistant frequency spacing can be achieved as well (Fig. 1 c).

The presentation will give an update about current laser performance and future options.

References

[1]. S. Zhang, P. Y. Kam, C. Yu, and J. Chen, "Laser linewidth tolerance of decision-aided maximum likelihood phase estimation in coherent optical M-ary PSK and QAM systems," IEEE Photon. Technol. Lett. **21**, 1075–1077 (2009).

[2]. L. He, S. Özdemir, J. Zhu, W. Kim, and L. Yang, "Detecting single viruses and nanoparticles using whispering gallery microlasers," Nat. Nanotechnol. **6**, 428–432 (2011).

[3]. Y. Jiang, A. Ludlow, N. Lemke, R. Fox, J. Sherman, L.-S. Ma, and C. Oates, "Making optical atomic clocks more stable with 10^{-16}-level laser stabilization," Nat. Photon. **5**, 158–161 (2011).

[4]. M. Faugeron, M. Tran, O. Parillaud, and M. Chtioui, "High-power tunable dilute mode DFB laser with low RIN and narrow linewidth," IEEE Photon. Technol. Lett. **25**, 7–10 (2013).

[5]. Y. A. Akulova, G. A. Fish, P.-C. Koh, C. L. Schow, P. Kozodoy, A. P. Dahl, S. Nakagawa, M. C. Larson, M. P. Mack, T. A. Strand, C. W. Coldren, E. Hegblom, S. K. Penniman, T. Wipiejewski, and L. A. Coldren, "Widely tunable electroabsorption-modulated sampled-grating DBR laser transmitter," IEEE J. Sel. Topics Quantum Electron. **8**, 1349–1357 (2002).

[6]. Y. Fan, R.M. Oldenbeuving, C.G. Roeloffzen, M. Hoekman, D. Geskus, R.G. Heideman, and K.-J. Boller, "290 Hz intrinsic linewidth from an integrated optical chip-based widely tunable InP-Si_3N_4 hybrid laser", Conference on Lasers and Electro-Optics, San Jose, CA, US, 14-19 May 2017, post-deadline paper, DOI: 10.1364/CLEO_AT.2017.JTh5C.9