

A Widely Tunable Vernier Filter on a Ge-on-SOI Platform for Sensing Applications

Sanja Radosavljevic, Nuria Teigell Beneitez, Andrew Katumba, Muhammad Muneeb, Michael Vanslebrouck, Bart Kuyken and Gunther Roelkens

Photonics Research Group, Ghent University - imec, Technologiepark 15, 9052 Ghent
Center for Nano- and Biophotonics, Technologiepark 15, 9052 Ghent, Belgium
sanja.radosavljevic@ugent.be

Abstract: We present a Vernier tunable racetrack resonator filter on Ge-on-SOI, with 110 nm FSR at 5 μm . The racetrack has a Q-factor of 20000 and side-peak suppression >20 dB, sufficient for wavelength selection in an external cavity laser. © 2018 The Author(s)

OCIS codes: (130.7408) Wavelength filtering devices; (130.3120) Integrated optics devices; (130.3060) Infrared; (160.6840) Thermo-optical materials; (220.4241) Nanostructure fabrication;

1. Introduction

The silicon photonics has a wide range of applications, including spectroscopic sensing, which plays an important role in environmental monitoring, chemical process control, security and medical applications [1,2]. Lately, the research is shifting towards mid-infrared due to the orders of magnitude higher optical absorption cross-section in this range as compared to the telecom and visible wavelength range [3]. Germanium-on-Silicon-on-Insulator (Ge-on-SOI) emerged as a promising solution for mid-infrared sensing platform in wavelength range 4-12 μm [4,5].

Currently available tuning mechanisms for broadband gain mid-infrared lasers hinder their application in sensing, as wavelength tuning often relies on an external diffraction grating. An interesting implementation of widely tunable mid-IR lasers on this Ge-on-SOI platform is to butt couple a midIR III-V gain chip to the silicon photonic integrated circuit (PIC) that comprises a widely thermally tunable Vernier filter for the laser wavelength selection (Figure 1 a). One of gain materials of interest in the mid-infrared are quantum cascade (QC) structures, which have already been demonstrated with watt-level output power operating at room temperature in the mid-infrared region [6]. A PIC design that can be used to test the Vernier functionality on Ge-on-SOI platform is shown in Figure 1 b).

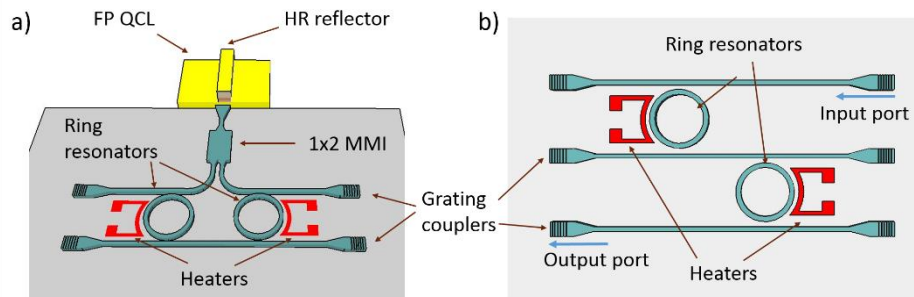


Figure 1 A widely tunable external cavity QCL without any moving parts: the rotating grating is replaced by a tunable reflector on a chip. The tunable filter consists of a beam combiner/splitter and a Vernier ring resonator filter in a loop configuration (a), a tunable Vernier filter based on ring resonators (b).

2. Simulation Results

The free spectral range (FSR) of the Vernier filter FSR_V , realized by cascading the individual resonators, depends on the individual FSRs of the racetrack resonators, FSR_1 and FSR_2 , and reads:

$$FSR_V = \left| \frac{FSR_1 FSR_2}{FSR_2 - FSR_1} \right| \quad (1)$$

In our design, FSR_1 and FSR_2 are 9.3 nm and 8.6 nm respectively in the 5 μm wavelength range, leading to a combined FSR_V of 114 nm and the side-peak suppression of >15 dB. The transmission of the Vernier filter is shown in Figure 2 a).

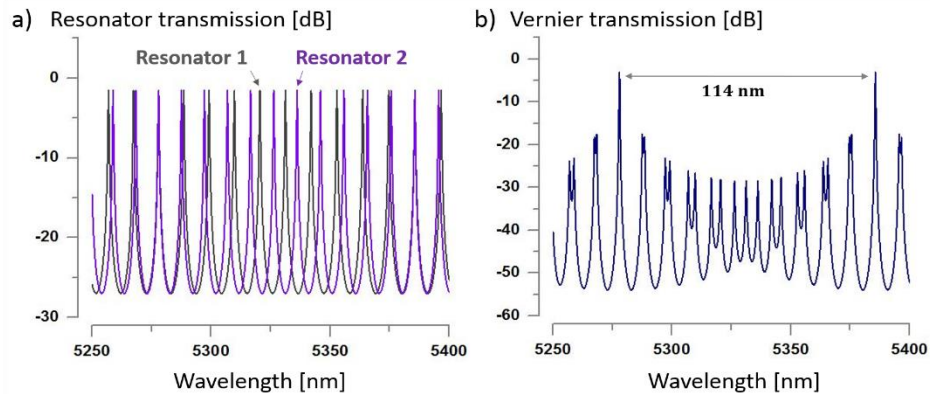


Figure 2 The simulated transmission spectra of individual racetrack resonators (a) and the transmission of the Vernier filter built with these racetracks (b).

3. Measurement results

The fabricated racetrack resonators have Q factor around 20000. By thermally tuning one of the racetrack resonators the position of the overlapping transmission peak can be tuned in steps of the FSR of the other resonator. This way, discrete tuning of the filter can be realized as shown in Figure 3 a). The heater power used for resonator 1, P_1 , and that for resonator 2, P_2 , indicated as (P_1, P_2) . To tune through the FSR_V of the filter requires 250 mW power dissipation. The side-peak suppression of the filter transmission is more than 20 dB. In order to access wavelengths in between resonances of the resonator that was not tuned, both racetrack resonators need to be tuned at the same time. This is illustrated in Figure 3 b).

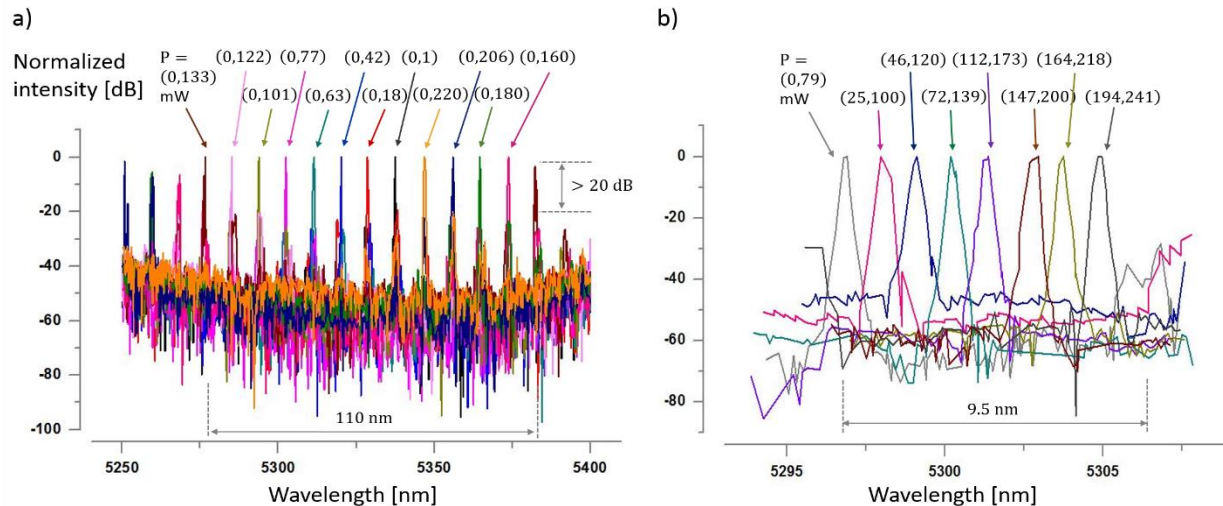


Figure 3 The measured normalized intensity spectra of discrete Vernier tuning (a) and the normalized intensity spectra of the continuous tuning of the same Vernier filter (b).

4. References

- [1] J. T. Robinson, C. Long, and M. Lipson, "On-chip gas detection in silicon optical microcavities," *Opt. Express* **16**, 4296-4301 (2008).
- [2] F. Cunin, T. A. Schmedake, J. R. Link, Y. Y. Li, J. Koh, S. N. Bhatia, and M. J. Sailor, "Biomolecular screening with encoded porous-silicon photonic crystals," *Nature materials* **1**, 39-41 (2002).
- [3] P. A. Werle, "Review of recent advances in semiconductor laser based gas monitors," *Spectrochim. Acta Mol. Biomol. Spectrosc.* **54**, 197-236 (1998).
- [4] A. Malik, S. Dwivedi, L. Van Landschoot, M. Muneeb, Y. Shimura, G. Lepage, J. Van Campenhout, W. Vanherle, T. Van Opstal, R. Loo, and G. Roelkens, "Ge-on-Si and Ge-on-SOI thermo-optic phase shifters for the mid-infrared," *Opt. Express* **22**, 28479-28488 (2014).
- [5] S. Radosavljevic, B. Kuyken, and G. Roelkens, "Efficient 5.2 μm wavelength fiber-to-chip grating couplers for the Ge-on-Si and Ge-on-SOI mid-infrared waveguide platform," *Opt. Express* **25**, 19034-19042 (2017).
- [6] Q. Y. Lu, Y. Bai, N. Bandyopadhyay, S. Slivken, and M. Razeghi, "Room-temperature continuous wave operation of distributed feedback quantum cascade lasers with watt-level power output," *App. Phys. Lett.* **97**, 231119 (2010).