Frequency agile Si_3N_4-MEMS photonic integrated external cavity laser

Student paper

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We demonstrate a Vernier ring laser at 1550 nm with 6 mW output power, 400 GHz intrinsic laser linewidth, linear frequency tuning of 1.5 GHz at 100 kHz chirp rate and wavelength switching with 7 ns rise time and 75 nW power consumption using silicon nitride photonic chip with integrated PZT actuators. We perform FMCW LiDAR for a target scene 10 m away with a 8.5 cm distance resolution.
Keywords: *FMCW LiDAR, hybrid integrated laser, silicon nitride, Vernier laser*

INTRODUCTION

External cavity lasers (ECL) with feedback circuits implemented in photonic integrated circuits demonstrated significant progress in recent years[1]. Frequency selective reflection can be achieved with Vernier filters in an integrated photonic circuit. Vernier filter based lasers have significantly matured with the realization of filters in silicon[2], silicon nitride[3] or other material platforms[4] and reached sub-kHz intrinsic laser linewidths[5]. High frequency modulation speed (exahertz/s) and switching speed of up to 50 MHz have only been demonstrated recently in Vernier based intgerated lasers based on lithium niobate[6]. Several application areas would benefit from such low noise, frequency agile and RSOA based external cavity integrated laser. Examples are fast wavelength switching for data centers, which has been studied in digital supermode distributed Bragg reflector (DS-DBR), Vernier-tuned distributed Bragg reflector (VT-DBR) and DFB configurations with mode-hop-free wavelength tuning and wavelength switching[7] demonstrated using integrated heaters with speeds up to 10 kHz. Another application is FMCW LiDAR, where high laser frequency tuning linearity and low frequency noise of the laser are crucial to measuring distance and velocity at mid to long ranges[8]. Despite significant progress, the fast and linearly tunable integrated laser requires either a DFB laser with e-beam lithography fabrication steps or MEMS-VCSELs with additional linearization.

Here, we report a hybrid integrated ECL based on RSOA and Vernier filters in low loss Si_3N_4 PIC enhanced with integrated piezoelectric actuator, which constitute a low cost solution, alleviating the use of DFB, while enabling high coherence and fast (MHz bandwidth), linear and low power frequency tuning.

RESULTS

Fig. 1(a) shows the schematic of the laser. An InP reflective semiconductor optical amplifier (RSOA) with 90% back facet reflectivity is edge coupled to the SiN PIC with a directional coupler and two cascaded microrings in a Vernier filter configuration. The SiN microrings R1 and R2 with FSR_1=96.7 GHz, FSR_2=97.9 GHz have intrinsic linewidths of 43.5 MHz and 64.4 MHz with symmetric input/drop-port coupling of 96.0 MHz correspondingly. The laser frequency in our device is controlled with a structure fabricated on top of SiN chip, which comprises a PZT actuator for fast actuation and microheaters for Vernier filter alignment. Figure 1(b) presents a laser frequency tuning scheme. First, we align a resonance pair of the two rings to achieve CW lasing by applying DC voltage to the microheater. Then, a triangular voltage signal applied simultaneously to both piezoactuators, resulting in a linear laser frequency sweep. Applying a square signal to a single piezoactuator allows for fast wavelength switching. Frequency noise measurements of the hybrid packaged laser by heterodyne beatnote spectroscopy show that the laser frequency noise reaches a value (white noise floor) of 127 Hz^2/Hz at a 6 MHz offset, corresponding to an intrinsic laser linewidth of 400 Hz. We next characterize the frequency agility of the laser (Fig. 1(c,e,g). We apply a triangular signal with 11 V_{PP} amplitude from an arbitrary frequency generator simultaneously to both PZT actuators at a frequency of 100 kHz. The laser output frequency is measured by a heterodyne beatnote with a reference ECDL on a fast photodetector. Figure 1(c,e,g) present the processed laser frequency spectrograms with the corresponding nonlinearities at 100 kHz ramping frequency. Frequency excursion of 1516 MHz with 1% nonlinearity at 100 kHz is observed using the PZT actuators without any additional linearization (the maximum tuning range of the laser in a single mode regime is limited by 3 GHz). To reach lower tuning nonlinearities we implemented a predistortion compensation routine. After 10 iterations, at 100 kHz modulation frequency, the achieved RMS nonlinearity reaches as low as 3.85 MHz (0.25%). Results on the fast wavelength switching are presented in Fig. 1(d,f,k). To switch the wavelength of the laser we align the Vernier filter with a microheater and then actuate only one ring with the PZT actuator, applying a square signal from 0 V to 8 V at a 100 kHz rate. Fig. 1(d) depicts the transmission power in both channels, showing wavelength switching of 97 GHz at 100 kHz rate. To determine switching speed we fit the rise and fall transmission curves with hyperbolic tangent function. Fitting yields 10–90% rise time of 7 ns and fall time of 6 ns (see Fig. 1(f,k)). Such fast wavelength switching and low measured actuator power consumption per switching of only 75 nW demonstrate an advantage of Vernier ring lasers with integrated PZT actuators over microheaters with typical switching times of hundreds of nanoseconds.

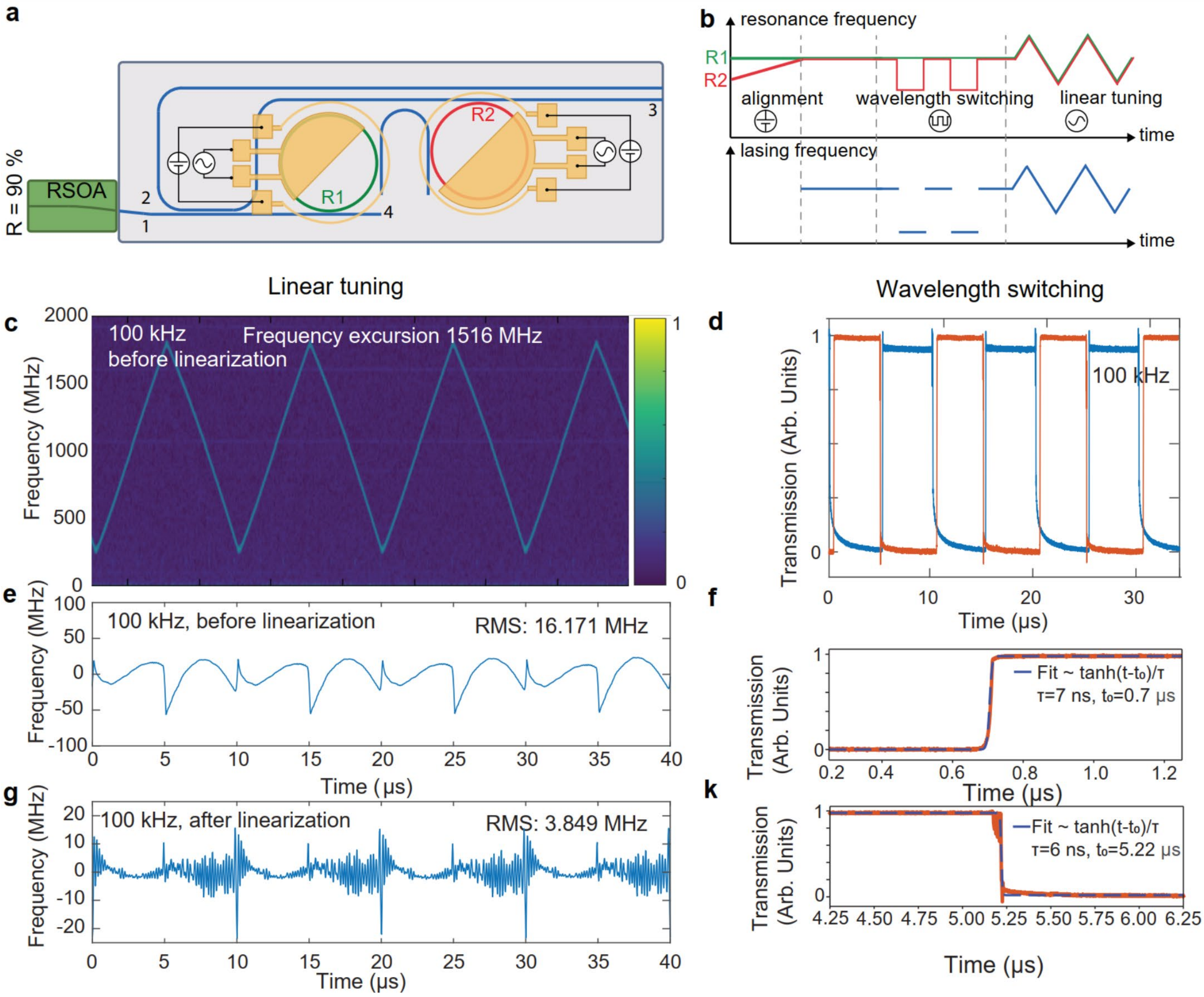

Fig. 1. Integrated external cavity laser. (a) Schematics of the laser. (b) Laser frequency tuning schematic. Coarse alignment of resonances of 2 microrings to observe lasing is done with integrated microheaters. Triangular voltage signal applied simultaneously to both piezoactuators results in linear laser frequency sweep. Applying square signal to a single piezoactuator allows to perform fast wavelength switching. (c) Laser frequency spectrogram with the corresponding nonlinearities (e,g) at 100 kHz chirp frequency upon applying 11 Vpp non-corrected ramp signal (e) and after 10 iterations of predistortion compensation (g). (d) Measured transmission at 2 different wavelength channels, demonstrating wavelength switching at 100 kHz rate. (e,f) Transmission curve (red) and its fit (blue) reveal the rise time of 7 ns and the fall time of 6 ns.

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