High power wavelength tunable external cavity laser for optical transmission

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ABSTRACT

We report a novel hybrid integrated photonic wavelength-tunable laser for transmitter applications. The device combines two photonic integrated circuit (PIC) technologies, Indium Phosphide (InP) and TriPleX® silicon nitride (Si_3N_4), to realize a high-power laser. The laser comprises one semiconductor optical amplifier (SOA), integrated on InP, coupling into a Si_3N_4 external cavity. The cavity includes a Vernier filter of two micro-ring resonators (MRRs) for highly precise wavelength selection. By tuning the MRRs, an ultra-narrow wavelength band is selected from the C-band for single-mode lasing. The laser provides over 21 mW output power, with a linewidth 126 Hz, over 60 dB side-mode suppression ratio (SMSR), and relative intensity noise (RIN) ≤ -170 dB/Hz. The MRRs are tuned via stress-optic actuation using lead zirconate titanate (PZT) films, which use < 1 µW per tuning element in quasi-static operation, resulting on a total of 0.5 W for the device.

Keywords: Integrated photonics, external cavity laser, high power laser, ring resonator, optical transmitter, silicon nitride (Si_3N_4)

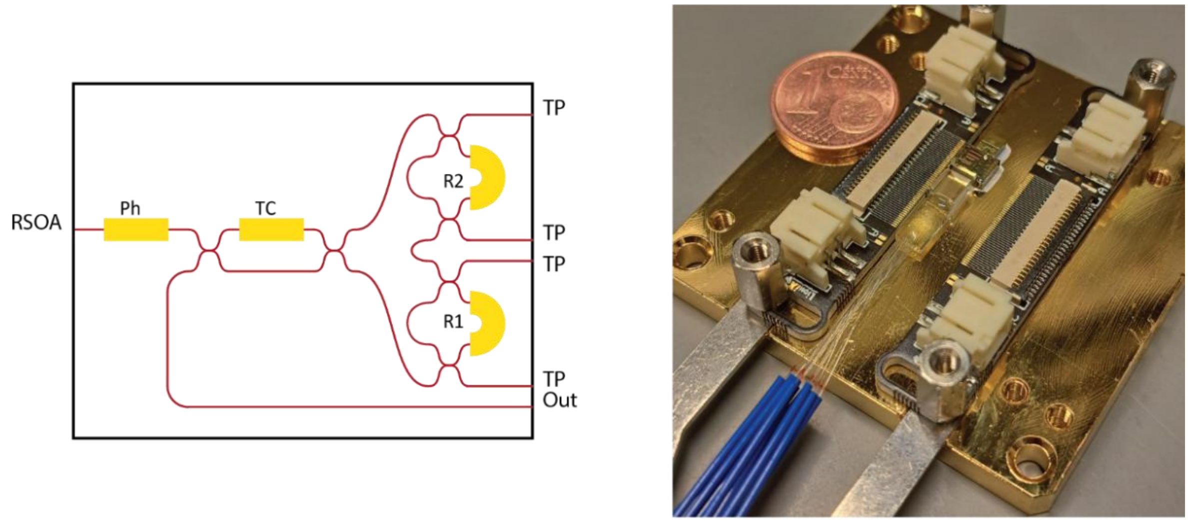
1. INTRODUCTION

Hybrid photonic integration of single-material platforms overcomes many existing limitations of photonic integrated circuits (PICs), leading to unique, compact, and robust photonic devices. The combination of Indium Phosphide (InP) and Silicon Nitride (Si_3N_4) waveguides [1] is of particular interest to data transmission applications within the telecommunications and data communications fields. The distinct advantages of light generation and modulation in the first materials and the ultra-low loss propagation and coupling of the second provide, in synthesis, functionalities that are otherwise unachievable in separation.

Within this frame, we report the design and measurements of a novel lead zirconate titanate (PZT) based hybrid integrated photonic wavelength-tunable optical laser. The laser comprises one reflective semiconductor optical amplifier (RSOA), integrated on InP, coupling into a Si_3N_4 external cavity. The cavity includes a Vernier filter made up of two PZT actuated micro-ring resonators (MRRs) for highly precise wavelength selection. The MRRs are tuned via stress-optic actuation by PZT films, which use less than 1 µW per tuning element in quasi-static operation [2]. The total power consumption of the laser is coming from the RSOA, compared to state-of-the-art hybrid lasers where the power consumption comprises of the heater actuator and the RSOA [3].

2. DESIGN AND ASSEMBLY

Figure 1 a) and b) present the conceptual layout design and a photograph of the fabricated and assembled PZT-based hybrid laser. The assembled module consists of a InP RSOA, a Si_3N_4 TriPleX® vernier filter, a fiber array and interconnect standard printed circuit boards (PCBs) to control the PZT actuators and apply pump current for the RSOA. The frequency selective mirror is based on a well-known principle of Vernier mirror (90 nm FSR) with two micro-resonators of slightly different length. On the TriPleX® chip, stress-optic PZT tuners are used to set the frequency of the selective mirror rings (R1 and R2), a phase shifter (Ph) is employed to control the phase of the modes in the cavity and a Mach-Zehnder tunable coupler (TC) to control the power coupled out of the cavity. A fiber array with standard polarization maintaining fibers is attached to the TriPleX® chip. The conceptual layout in Figure 1 a) indicates the test ports (TP) and output port (Out) of the assembled device shown in Figure 1 b). This chip was assembled on a LioniX standard characterization package (CPS) sub-mount including standard PCBs. The TriPleX® to fiber coupling loss is equal to 1.5 dB and the coupling loss from the InP RSOA to TriPleX® is estimated to be about 1 dB.

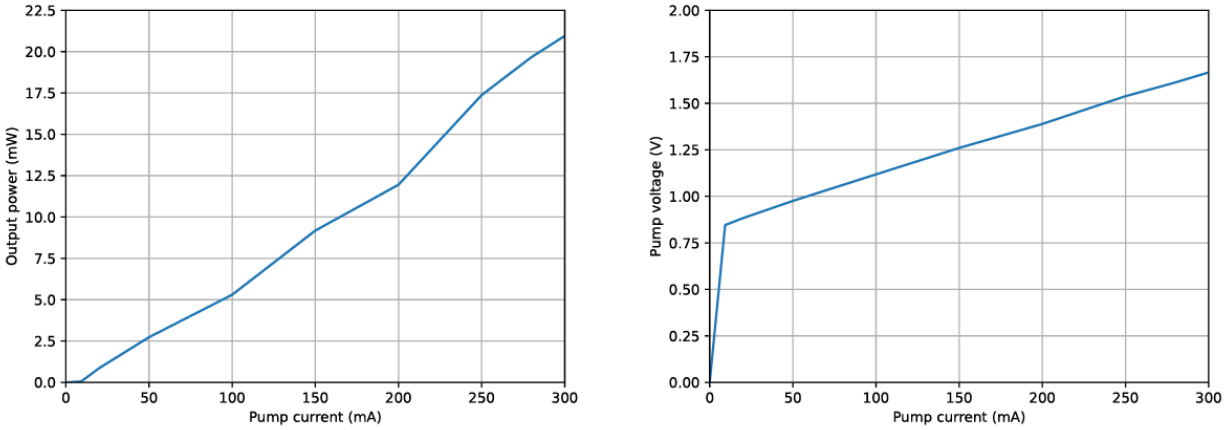


a) b)

Figure 1. a) Conceptual design of a single gain laser cavity consisting of a tunable dual-ring vernier filter, one RSOA with a phase tuner (Ph) in the cavity, two phase tuners in both micro rings (R1 and R2), and tunable coupler (TC) to control the output coupling power. b) Photograph of the assembled PZT based single gain laser TriPleX® chip (5x5 mm).

3. MEASUREMENTS

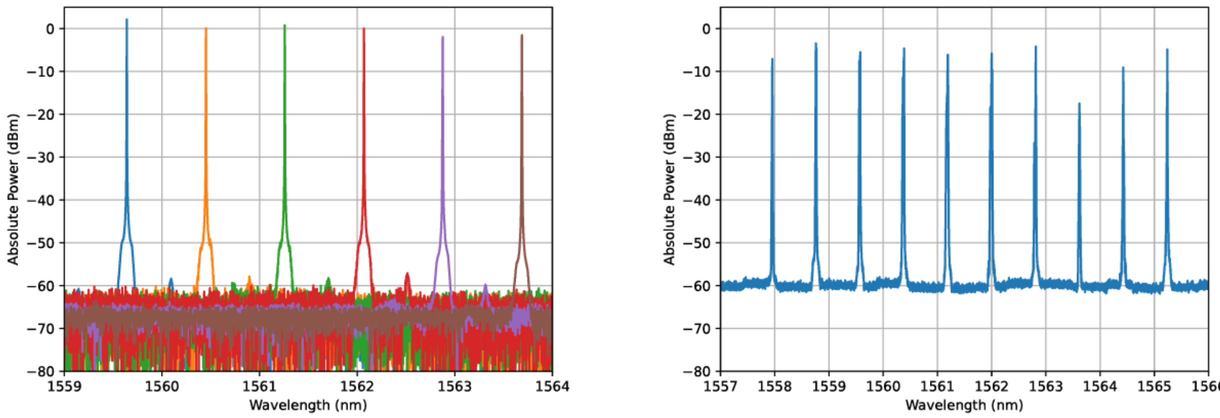
With this novel PZT-based laser we show a record fiber output power of 21 mW with a pump current of 300 mA, which is comparable to the typical output power of the same type of cavity design with heaters. This output power is the highest achieved output power with a fully PZT tunable laser. Figure 2 a) shows the fiber-output power as a function of pump current without saturation from which it can be concluded that this laser does not saturate due to insufficient cooling as earlier shown devices [3]. Figure 2 b) presents the measured VI-curve of the RSOA, which shows a power consumption of 0.48 W for a pump current of 300 mA, resulting in a wall plug efficiency of 4.5 %.



a) b)

Figure 2. a) Output power vs. pump current and b) pump voltage vs. pump current.

Figures 3 a) and b) show measurements performed with a FINISAR Optical Spectrum Analyzer (OSA). Figure 3 a) shows single mode operation with fine tuned settings of the actuators for six different wavelengths on the ITU-grid with a spacing of 0.8 nm, having a side-mode suppression ratio of more than 60 dB. An additional max hold scan was performed to find the maximum tuning range with the available electronic equipment, demonstrating at least 10 different wavelengths with a tuning range between 1557.8–1565.3 nm.



a) b)

Figure 3. a) Optimized relative laser power and SMSR of >60 dB for six wavelengths and b) max hold scan for 7.8 nm range.

Additional measurements for a single wavelength of 1560.2 nm were performed with the EXFO OSA20 wavelength scan, measuring an OSNR of 77 dB for a resolution bandwidth of 0.1 nm resulting in a RIN of -170 dBc/Hz.
The frequency noise power spectral density (PSD) in Hz^2/Hz as function of Fourier frequencies in MHz is presented in Figure 4, using a HighFinesse LWA-1k linewidth analyzer. A comparison of the frequency noise measurement of the PZT laser with actuators turned on and off is shown where a slightly higher suppression of the noise appears when actuators are on. The average white noise level at the highest Fourier frequency leads to an intrinsic linewidth of the PZT laser of 126 Hz.

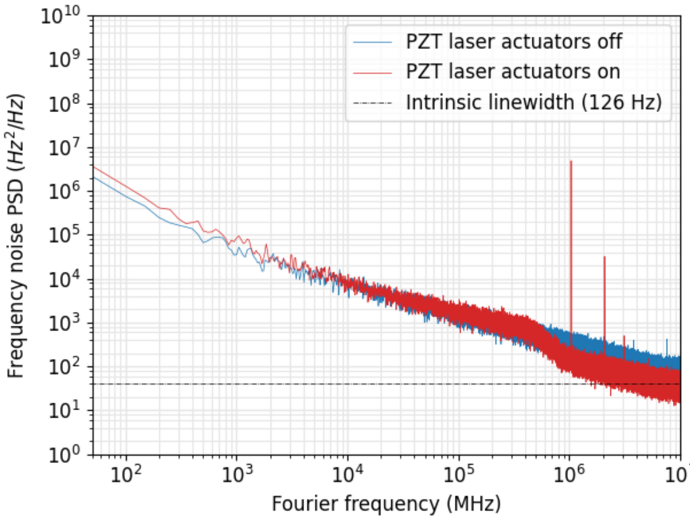


Figure 4. Measured power spectral density (PSD) as a function of Fourier frequency with the actuators of the PZT laser turned off (blue), turned on (red), and additional indication of the intrinsic linewidth of 126 Hz (dashed).

4. CONCLUSION

We demonstrated the first PZT-based hybrid integrated tunable External Cavity Laser (ECL) with comparable output power to state of the art single gain heater-based ECLs. The power dissipation of this module only comes from the pump current of the RSOA which was 0.48 W, while the PZT actuators do not add any power consumption in steady state. The updated coupling coefficients and micro ring resonators lead to high side-mode suppression of more than 60 dB. A very low intrinsic linewidth of 126 Hz was presented next to the RIN which is measured to be -170 dBc/Hz. The near ITU-grid tunablity is the first of its kind of a Si_3N_4 TriPleX® based ECL laser.

ACKNOWLEDGEMENTS

This work has been supported by European Union within the Horizon project "SPRINTER", Contract no. 01070581. Special thanks to Albert van Rees and the Chilas team for the using part of their equipment and the technical support.

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