High power, tunable, narrow linewidth dual gain hybrid laser

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Abstract: We present the first hybrid integrated laser with two gain sections coupled to one tunable cavity. The resulting laser has a output power of up to 85 mW and an intrinsic linewidth of 320 Hz.

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Tunable semiconductor lasers with a narrow linewidth have found a wide range of important applications, reaching from coherent communications, optical sensing to arising applications such as microwave photonics. Especially integrated microwave photonics [1] aims to achieve RF-to-RF signal processing in the optical domain with a small footprint while offering wide bandwidths. Recently, we developed a hybrid integrated photonic platform [2] based active InP components such as gain sections, modulators, and detectors with passive silicon nitride-based TriPleX offering low propagation losses of < 0.1 dB/cm. However, so far current hybrid as well as heterogeneously integrated lasers lack sufficient power for some application such as microwave photonics.

Here, we present, to the best of our knowledge, the first hybrid integrated laser consisting of more than one InP gain sections sharing a common laser mirror. The resulting 85 mW at a pump current of twice 250 mA is the highest output power of a hybrid laser to date. Furthermore, the laser shows a low intrinsic linewidth of 320 Hz as well as a low relative intensity noise (<-160 dBc/Hz).

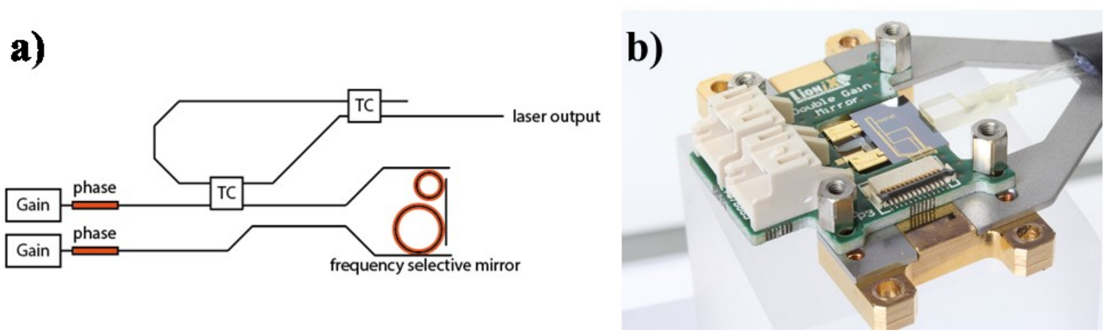

Figure 1 a) Conceptual design of the dual gain laser cavity consisting of a tunable dual-ring cavity, two gain section with phase tuners and two tunable Mach-Zehnder couplers (TC) to control the output coupling and output power. b) Photograph of the assembled dual gain laser.

The scheme and a photograph of the two gain section hybrid integrated laser is shown in Fig. 1 (a) and (b), respectively. The cavity is based on a well-known principle of Vernier mirror with two micro-resonators of slightly different length and, hence, free-spectral ranges of 208 GHz and 215 GHz. To achieve a higher optical output power the cavity is coupled to two individual InP reflective semiconductor optical amplifiers (RSOA) with a length of 700 µm instead of one [3]. The coupling losses from the InP RSOAs to TriPleX laser cavity are estimated to be 1 dB. Each of the RSOAs has an individual electrical connection. On the TriPleX chip, two thermo-optic tuners are used to control the phases of the RSOAs within the cavity and two tunable Mach-Zehnder couplers are used to combine both output coupling of the cavity and the power in the output waveguide. The output waveguides are coupled to a fiber array with standard polarization maintaining fibers with a coupling loss of 0.5 dB.

Using this novel design, we achieved a record maximum output power of 85 mW at the fiber output and consequently an on-chip power of 95 mW at a pump current of 250 mA at both RSOAs. At pump currents above 250 mA the RSOA saturated due to insufficient cooling. Note that the output power by using two RSOAs is indeed twice as much when compared to devices with only one RSOAs and a similar cavity design. This is, to the best of our knowledge, the highest power achieved with any hybrid integrated laser to date. Furthermore, this increased output power is achieved while maintaining its tuning range typical for such lasers from 1520nm to 1580 nm and a high side mode-suppression ratio (SMSR) of more than 50 dB.

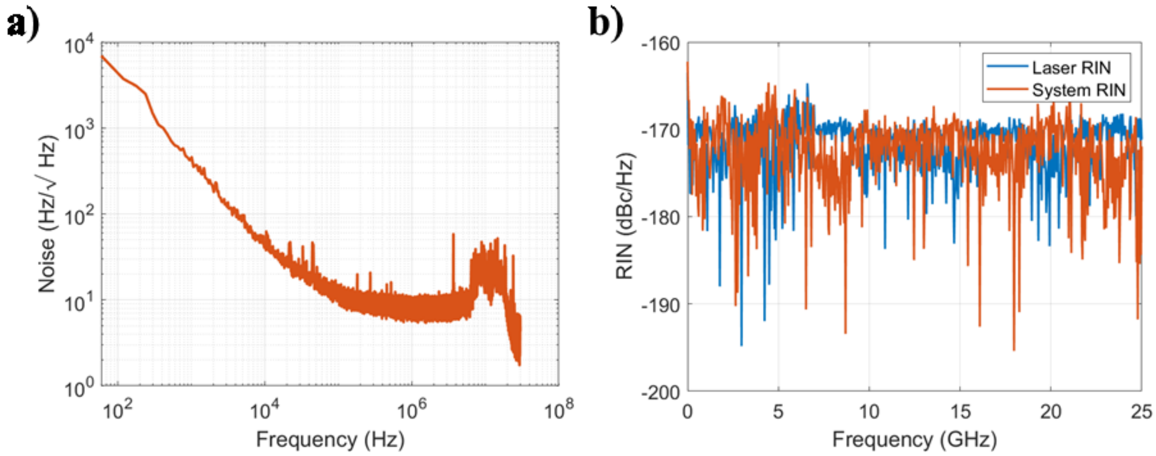

Figure 2 a) Frequency noise measurement of the dual-gain laser showing a intrinsic linewidth of 300 Hz. b) Measured relative intensity noise (RIN) of the laser and the system for frequencies up to 25 GHz.

The frequency noise of the laser shown in Fig 2 (a) was measured using a linewidth analyzer (HighFinesse LWA-1k) up to a frequency of 20 MHz. Note that for this measurement the heaters were inactive due to noise induced by the heater drivers, while both gain sections were driven with a pump current of 100 mA. It can be seen that the white noise floor reaches a level of 10 $Hz/Hz^{1/2}$ corresponding to an intrinsic Lorentzian linewidth of the laser of around 320 Hz, which is comparable to low intrinsic linewidths reported earlier using hybrid integration [4]. To show that the laser will contribute little noise a system such as in microwave photonics, we measured its relative intensity noise (RIN) using a high-speed detector and an electrical spectrum analyzer up to a frequency of 25 GHz. The RIN measurement is shown in Fig 2 (b) and it can be seen that the RIN (shown in blue) is well below -160 dBc/Hz over the whole measurement range and for most of the frequencies at a level as low as -170 dBc/Hz. Additionally, we show the relative system noise (RIN and shot noise) shown in red as a comparison to the RIN.

In conclusion, we demonstrated for the first time a hybrid integrated laser with two gain sections coupled to a single cavity. The laser shows a record high optical power of 85 mW at the fiber output and 95 mW on-chip, while still being tunable and showing a high SMSR of more than 50 dB. Due to the low-loss of the cavity waveguides the laser shows an intrinsic Lorentzian linewidth of 320 Hz and a low RIN of less than -160 dBc/Hz. In future devices the output power can be improved by a better thermal management of the RSOA or simply by adding more ROSA units to the device.

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