Hybrid external cavity laser with a 160-nm tuning range

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Abstract: We present a hybrid laser by using an InP reflective semiconductor optical amplifier chip butt-coupled with a SiN tunable reflector chip. The laser wavelength tuning range is 160 nm and the linewidth is 30 kHz.

OCIS codes: 140.5960 Semiconductor lasers; 140.3600 Lasers, tunable; 130.0130 Integrated optics.

1. Introduction

Chip-scale lasers with a wide wavelength-tunable range and a narrow linewidth have attracted wide attention in the areas of telecommunications, sensing, and light detection and ranging (LiDAR), etc. As the gain part is separated from the wavelength-tunable part and the photon lifetime is relatively long, it is easier for an external cavity laser (ECL) to achieve a wide tuning range and a narrow linewidth. In the past decade, there is extensive research on hybrid ECLs that combine III-V gain material with a passive optical circuit made of silica, SiN, or silicon-on-insulator (SOI) [1-5]. The reported ECLs have a wide wavelength tuning range of 80-110 nm [2-5].

In this paper, we demonstrate an ECL composed of an InP gain chip butt-coupled to a SiN wavelength-selective tunable reflector. It has an ultra-wide wavelength tuning range up to 160 nm and the linewidth at the 1559 nm wavelength is measured to be approximately 30 kHz.

2. Device description

Fig. 1(a) shows the schematic structure of the device. An InP reflective semiconductor optical amplifier (RSOA) is butt-coupled to a SiN chip. The rear side of the RSOA gain chip is high-reflection (HR) coated with a reflectivity of 95%. The InP waveguide on the front side is slanted by 8° and anti-reflection (AR) coated (reflectivity of 0.5%), resulting in a very low reflectivity. The SiN chip consists of a spot size converter (SSC), a thermo-optic (TO) phase shifter, a two-ring based Vernier filter, and a tunable Sagnac loop reflector. The SiN waveguide has a propagation loss of 0.5 dB/cm at the 1550 nm wavelength. The circumferences of the Vernier ring resonators are 726 μm and 740 μm, generating a common resonance free spectral range (FSR) of around 100 nm. The power coupling coefficient ($|\kappa|^2$) between the bus waveguide and the ring resonator is designed to be 0.1 at the 1550 nm wavelength. The total single-pass length of the SiN passive cavity (exclude two rings) is about 14.4 mm. Fig. 1(b) shows the simulated reflective spectrum of the Vernier filter with the resonances from two rings aligned to the 1550 nm wavelength. Fig. 1(c) shows the amplified spontaneous emission (ASE) spectra of the RSOA under six current injection levels. As the current increases, the spectrum becomes wider and red-shifted. The gain reduces at a high current because of the raised temperature. Thus, the ASE covers short wavelengths at a low current level and long wavelengths at a high current level. The ROSA exhibits a comb spectrum at high gain due to the residual reflection from the front side.

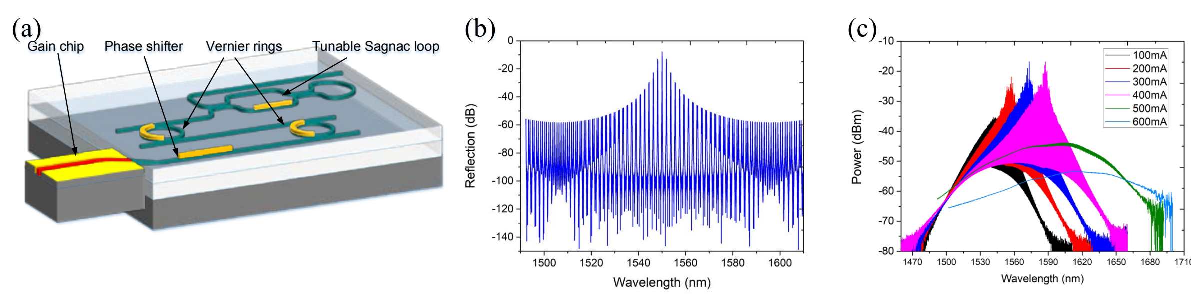

Fig. 1. (a) Schematic structure of the ECL. (b) Simulated reflective spectrum of the Vernier filter. (c) Measured ASE spectra of the RSOA.

3. Experimental results

Fig. 2(a) shows the overlapped lasing spectra with the laser wavelength tuned from 1500 nm to 1660 nm. In the experiment, a small injection current was applied when the laser wavelength was in the short end. In the long wavelength end, we increased the current to 500 mA to purposely redshift the gain spectrum. Due to the wavelength sensitivity of the directional coupler, the reflectivity of the Sagnac loop varies with wavelength. Therefore, during laser wavelength tuning, the TO phase shifter in the Sagnac reflector was also tuned accordingly to ensure a constant reflectivity. The lasing spectra in Fig. 2(b) reveals that the laser has a high side mode suppression ratio (SMSR) of 45 to 55 dB. Fig. 2(c) shows the light-current (L-I) curve at the wavelength of 1559 nm. The on-chip output optical power reaches 17.5 mW at the current level of 400 mA. We also measured the laser linewidth using the heterodyne method. Fig. 2(d) presents the RF spectrum resulted from beating our laser with a reference laser. After Lorentzian fitting and subtracting the linewidth of the reference laser, we obtained the linewidth of our hybrid laser to be around 26 kHz.

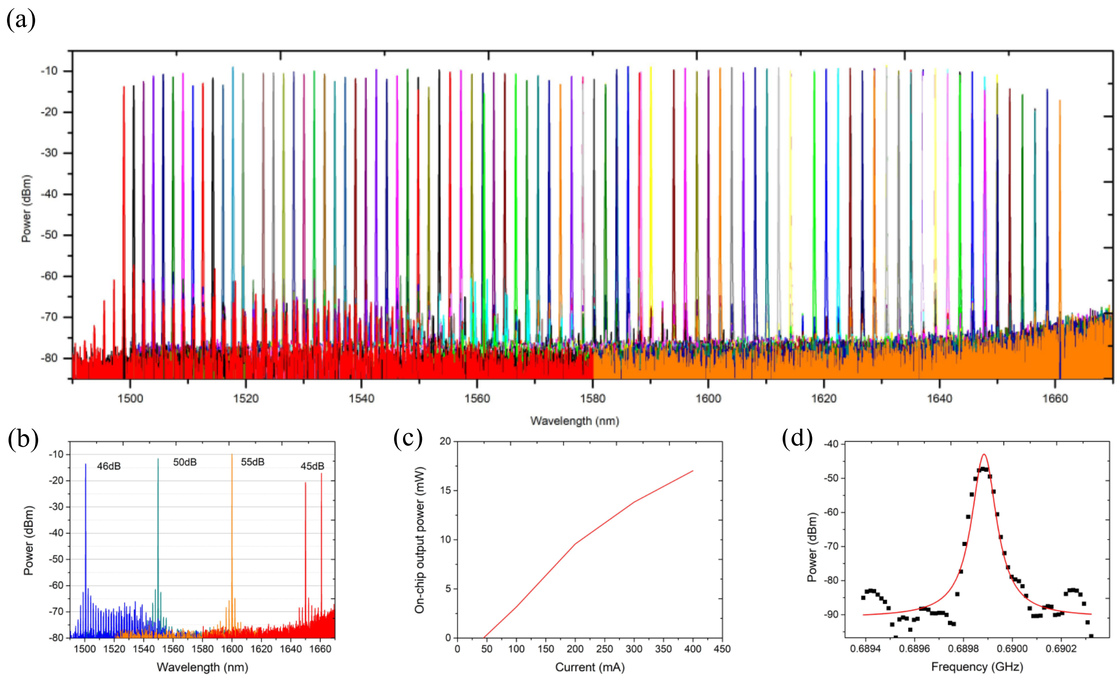

Fig. 2. (a) Measured lasing spectra when the laser wavelength is tuned by 160 nm. (b) SMSR measurement at several typical lasing wavelengths. (c) L-I curve at the wavelength of 1559 nm. (d) Beating spectrum obtained by the heterodyne method and the corresponding Lorentzian fitting.

4. Conclusions

In summary, we have demonstrated an InP-SiN hybrid ECL that gives an ultra-wide wavelength tuning range of 160 nm and a narrow linewidth of 26 kHz. The performance can be further improved by conducting thermal management and modifying the design to have a tunable coupling coefficient for ring resonators and improved coupling between the two chips.

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5. References

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