Widely-Tunable Polymer Waveguide Grating Laser

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***Abstract*—A tunable laser structure integrated in a hybrid polymer waveguiding platform consisting of a InP-based curved-stripe gain chip and a thermo-optically tunable waveguide grating is presented. A sophisticated heater design allows tuning ranges above 50 nm with a peak power degradation lower than 2 dB. Lasing linewidths of 500 KHz have been achieved and 2.5 Gb/s back-to-back transmission experiments have also been successfully proven showing clean and open eye diagrams.**

Keywords-polymer waveguide platform; tunable polymer waveguide grating laser.

I. INTRODUCTION

In recent years, wavelength-division-multiplexing passive optical networks (WDM-PON) as well as coherent detection schemes have attracted a great deal of attention. These applications demand cost-effective and yet high-performance tunable laser sources to be used in colorless transceivers and as tunable local oscillator, respectively. To this end, hybrid-integrated tunable waveguide grating lasers comprised of an active gain element and a thermo-optically (TO) tuned polymer Bragg reflector have been proposed [1-3]. With such structures, wavelength tuning over 26 nm has been achieved [1].

In the present work, a tunable polymer waveguide grating laser (PWGL) consisting of a curved-stripe (CS) InP-based gain chip and an integrated thermo-optically tunable polymer waveguide Bragg grating has been developed using HHI's PolyBoard hybrid integration platform [4]. A tuning range of more than 50 nm has been achieved by using a sophisticated heating structure. Laser linewidths of even below 500 KHz have been obtained for some devices. Direct modulation at 2.5 Gb/s has been also successfully performed.

II. PRINCIPLE OF OPERATION AND STRUCTURE

A schematic of the structure of the proposed PWGL is shown in Fig.1. A curved-stripe gain chip with a high-reflection (HR) coating at the rear facet acts as the optical gain medium while the waveguide grating in the PolyBoard platform is used as a wavelength selective feedback mirror. Wavelength tuning is accomplished by using a heater electrode in the vicinity of the polymer grating, which induces a change in the effective refractive index of the waveguide due to the TO effect, which again produces a shift in the Bragg wavelength of the grating. The buried-heterostructure-type InP based CS gain chip comprises a MOVPE grown InGaAsP multi-quantum well active region with a PL wavelength of 1570 nm. The gain chip is butt-coupled to the polymer waveguiding platform using a 9° angled facet to avoid undesired back-reflections. In order to obtain high mode overlap between the gain chip and the polymer waveguide, the gain chip waveguide has been laterally tapered from 2.4 µm to 0.9 µm in width. Further information on the coupling technique of the InP active device to the PolyBoard can be found in [4].

The PolyBoard waveguide platform consists of a buried waveguide structure with an index contrast of $\Delta n=0.02$ made of commercially available polymer material. For such an index contrast, a waveguide cross-section of 3.5 µm x 3.5 µm has been used to ensure monomode behavior. For implementing the selective mirror, 3^{rd}- or 5^{th}-order sidewall-corrugated Bragg gratings are formed in the waveguide core layer without the need for an extra lithographic and etching step. The reflectivity and bandwidth can be well-controlled by modifying the amplitude of the corrugation and the length of the grating, respectively [2]. For the tuning feature, a metal heater has been deposited in the surroundings of the corrugated waveguide. Along the waveguide grating, air trenches have been etched on both sides in order to achieve higher heat confinement. The fairly high TO coefficient ($dn/dT \sim 10^{-4}/°K$) of the polymer material, together with its low thermal conductivity and the proposed heating structure, provided an appreciably large tuning range at low heating power. An additional phase control heater has been added for fine wavelength tuning and adjustment of the side-mode suppression ratio (SMSR).

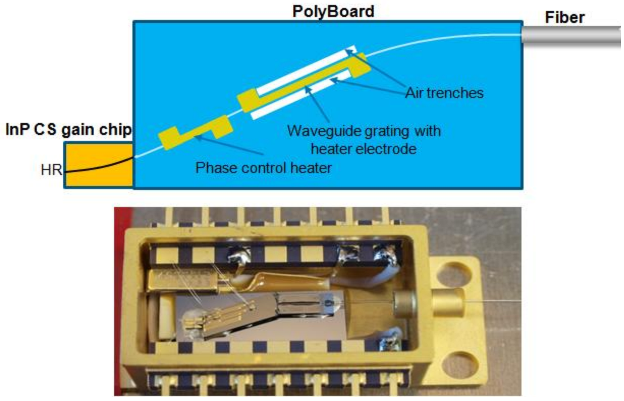


Figure 1. Schematic structure of the tunable PWGL based on HHI´s PolyBoard (up) and a picture of an assembled device (bottom).

III. DEVICE PERFORMANCE

The output power of a tunable PWGL at different heating powers has been measured on a device containing a waveguide grating with a length of 700 µm. The drive current of the gain chip was chosen to amount to 50 mA. The phase control heater was not used with these measurements. Results are shown in Fig. 2, where it can be seen that a tuning range in excess of 50 nm across the C-band has been obtained using less than 170 mW of heating power. The decay of the peak power degradation of the laser over this wide tuning range was found to be lower than 2 dB, while the SMSR could be maintained at values well below -26 dB. By using the phase heater, however, to optimally adjust the phase inside the laser cavity, will further reduce the SMSR values significantly.

Linewidth measurements have been performed using a self-homodyne method. For this investigation, a device with a 2500 µm long grating and a distance between the back-facet of the gain chip and the polymer grating of 1220 µm was used. Obtained values are shown in Fig. 3, where the lineshapes and the 3-dB linewidth values for different heating currents are depicted. Linewidths below 750 KHz have been obtained for the heater powers indicated, and in some cases values even below 500 KHz were measured.

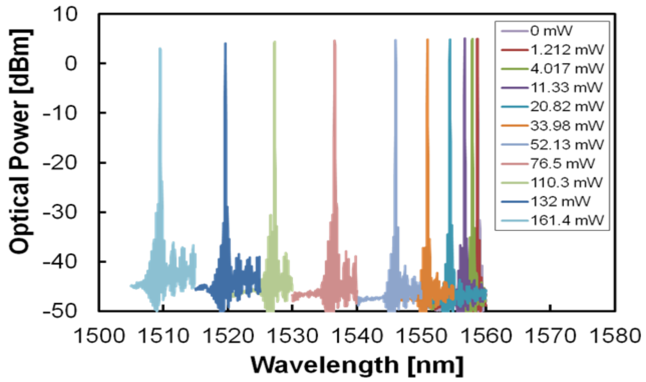


Figure 2. Optical spectrum for different electrical powers applied to the heater electrode.

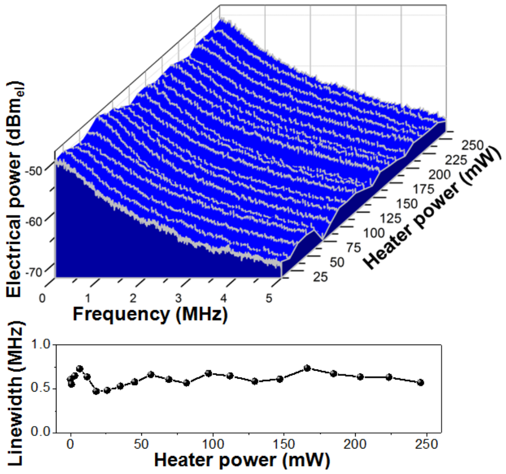
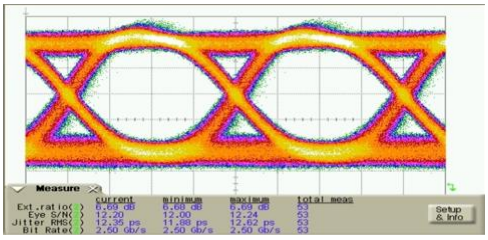


Figure 3 Lineshapes measured using a self-homodyne method (top) and 3-dB linewidth values (bottom) obtained for different heating powers.



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             current     minimum     maximum     total meas
  Ext.ratio( ) 6.69 dB     6.68 dB     6.69 dB     53
    Eye S/N( ) 12.20       12.00       12.24       53
 Jitter RMS( ) 12.35 ps    11.88 ps    12.62 ps    53
   Bit Rate( ) 2.50 Gb/s   2.50 Gb/s   2.50 Gb/s   53
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Figure 4. Back-to-back eye diagram of the NRZ modulation at 2.5 Gb/s.

Furthermore, a back-to-back transmission test was carried out by directly modulating the gain chip using pseudo-random non-return-to-zero (NRZ) data (2^{31}-1) at a rate of 2.5 Gb/s. The laser structure used in this experiment exhibited the same dimensions as the one used for the linewidth evaluation. A result is shown in Fig. 4 proving the achievement of open and clear eye diagrams with extinction ratios of 6.7 dB.

As a further development, this tunable PWGL structure can be modified aiming at higher speed modulation by reducing the total cavity length. It shall also be mentioned that - in the framework of the EC funded project POLYSYS - the investigated tunable laser structure has also been implemented on the basis of an electro-optically (EO) active polymer to eventually form the feed laser of polymer EO modulators. First results will be presented at the conference.

IV. CONCLUSIONS

In this paper a tunable PWGL based on HHI's PolyBoard hybrid integration platform has been presented. Due to an optimized electrode design for efficient heat confinement and thus low power consumption, a tuning range higher than 50 nm with a heating power of less than 170 mW has been achieved. Peak power degradation in this tuning range is lower than 2 dB, and linewidths below 500 KHz have been measured. Direct modulation capability of at least 2.5 Gb/s was successfully proven.

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