Characterization of an AWG-based dual-wavelength ring laser

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Abstract: In this paper we present characterization results of a monolithically integrated InP-based dual-wavelength laser. The device has been fabricated using active/passive integration technology on a standardized photonic integration platform. In this laser an Array Waveguide Grating (AWG) is used as intra-cavity filter to obtain lasing on two wavelengths using a common optical amplifier in the cavity. A Mach-Zehnder construction allows for controlling the power balance between the two wavelengths. The impact of the crosstalk between AWG channels on the control of the device and the characterization method used to calibrate the Mach-Zender interferometers inside the laser cavity are reported.

Two wavelengths, one common SOA

In this paper we present results on the control and characterization of a photonic integrated dual-wavelength laser for optical-mixed based sub-Terahertz wave generation [1, 2]. Both wavelengths are generated and amplified by one common semiconductor optical amplifier (SOA). As a consequence, λ_1 and λ_2 share the same variations caused by changes in refractive index due to changes in temperature and variations in carrier concentration. This should help in reducing noise in the frequency difference between the two modes.

Design of ring dual-wavelength laser

The schematic representation of the ring dual-wavelength laser is depicted in Fig. 1. An AWG is used as intra-cavity filter to combine the two channels and consequently λ_1 and λ_2. The advantages of using an AWG for this purpose and more details about the design parameters are presented in [3]. In order to achieve lasing action simultaneously on two different wavelengths supported by a single SOA, accurate control of the roundtrip loss in the cavity is required to balance the power of λ_1 and λ_2. This can be obtained through balanced Mach-Zehnder interferometers (MZIs) with voltage controlled electro-optic phase modulators (PHMs) placed in each individual channel. As a drawback, the circuit becomes more complex and the control more difficult compared to two separate lasers.

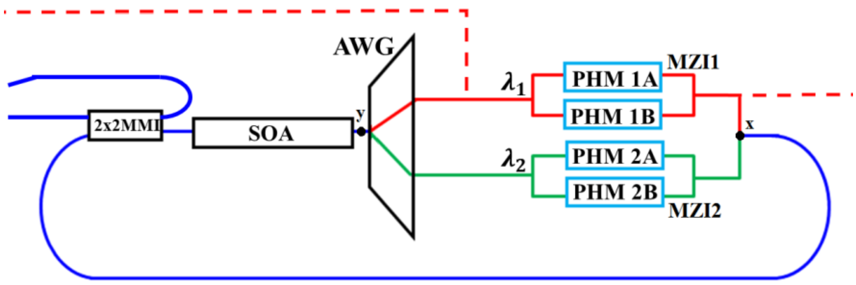

Fig. 1: Schematic of the ring dual-wavelength laser. An SOA provides gain for both wavelengths. An AWG is used as intra-cavity filter to combine λ_1 and λ_2. MZIs are used to compensate losses in the individual channels. A 2x2 multimode interferometer (MMI) couples the light out of the ring cavity.

Preliminary results

All the results reported in this section have been obtained at a temperature of 12°C of the actively cooled aluminum chuck on which the chip is mounted. The SOA and the PHMs on the chip are wire bonded to a simple circuit board from which connections to the current and voltage suppliers are made. As expected, while biasing the common SOA without balancing the losses in the different channels using the MZIs, the device lases in a single mode; the modes in the other channel are suppressed. The frequency spacing to the side modes matches the expected value of 5.5 GHz related to the cavity length of 15 mm.

Fig. 2 shows that by adjusting the voltage values applied to the PHMs, the losses in the two channels can be balanced and dual-mode operation can be achieved. The SMSR is higher than 25 dB. However, a power difference of 4 dB is still present between λ_1 and λ_2 meaning that the settings are not optimized. The requirement on the power ratio between the two wavelengths is not particularly strict though. A power ratio of 2 for $P\lambda_1$ / $P\lambda_2$ leads to a reduction in difference frequency modulation depth to 0.94 compared the ideal power ratio of 1.

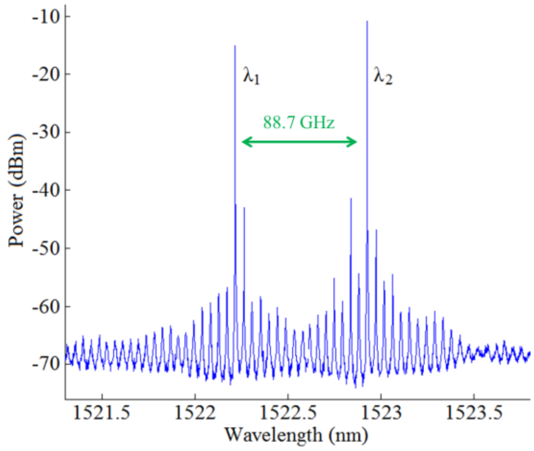

Fig. 2: Output spectra of the ring laser while operating in dual-mode.

The operating point of Fig. 2 has been identified adjusting the settings manually, whereas a more systematic method is desired. Furthermore, the frequency difference between the two lasing wavelengths is 88.7 GHz, considerably smaller than the measured channel spacing of the AWG (120 GHz). This is shown to be due to crosstalk between the two channels in the AWG.

Crosstalk effect and indirect calibration method for PHMs in the MZIs

The crosstalk also complicates the control of the laser because the two channels are not independent from each other. As a consequence, while adjusting losses and tuning of Channel 1, not only λ_1, but also λ_2 is affected. Simulations of the transmission of the filter composed of the AWG and the MZI construction (from point *x* to point *y* in counterclockwise direction in Fig. 1) show that, due to the crosstalk, the settings applied to the PHMs affect in particular the difference in frequency between the maxima of the two channels. As a result, to obtain the desired frequency difference between λ_1 and λ_2 is difficult.

In order to be able to control the device, a precise characterization of the MZIs is needed. Compared to previous devices [4], two additional input/output waveguides (dash lines in Fig. 1) have been placed in the design in order to characterize separately MZI1 using an external laser source (V_π= 6 V, extinction ratio = 15 dB). However, MZI2 must be characterized indirectly since it is placed in the inner part of the ring. The method consists on setting MZ1 to destructive interference configuration forcing the device to lase through Channel 2. Scanning the voltage applied to the PHMs of Channel 2, the threshold current (I_{th}) of the laser changes due to the change of the losses in the cavity. As a result, the transmission function of MZI2 can be extracted. Fig. 3 shows the value of I_{th} while scanning the voltage of PHM2A. When both channels are set to maximum extinction, lasing action takes place through Channel 2: this suggests that the extinction ration is lower in MZI2 than in MZI1. The graph in Fig. 3 shows a value of V_π equal to 6.4 V, consistent with the one measured directly on MZI1, validating the method.

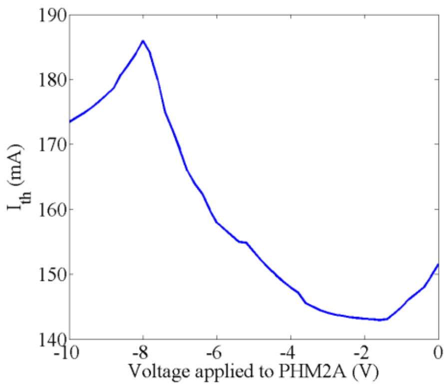

Fig. 3: Values of threshold current as a function of the voltage applied to PHM2A while Channel 1 is set to maximum extinction and PHM2B is grounded. The transmission function of MZI2 can be extracted.

References

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