Monolithic Integration of a High Power Semiconductor Master Oscillator Power Amplifier

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***Abstract*— We present a high power semiconductor Master Oscillator Power Amplifier monolithically integrated on InP, which includes a modulation section. This device can be used for random-modulation-continuous wave lidar systems or free-space communications.**

***Index Terms* — Distributed feedback lasers, semiconductor optical amplifier, integrated optics devices, multi-section laser, master oscillator power amplifier.**

I. INTRODUCTION

High power, single-mode semiconductor emitters at 1.55 µm are very promising devices for lidar systems and free-space communications thanks to their low weight, compactness, high wall-plug efficiency and radiation hardness. To compete with fiber and solid-state lasers, they must exhibit output power > 0.5 W with a stable wavelength.

II. DESIGN OF THE STRUCTURE

We have investigated the Master Oscillator Power Amplifier (MOPA) architecture which usually consists of two sections, a distributed Bragg reflector (DBR) or distributed feedback (DFB) laser acting as a master oscillator and a power semiconductor optical amplifier (SOA). The MOPA architecture seems the more convenient solution to obtain both high power and single-mode operation [1], [2]. In that case, the SOA is often flared to increase its saturation power.

Instabilities in MOPA devices mainly comes from 2 factors: the disturbance of the DFB laser due to the light which returns into it, the mode competition between the whole cavity defined by the 2 chip facets and the DFB laser (Fig. 1). To mitigate these 2 effects, one key parameter is the reduction of the reflections at the SOA facet. To decrease as much as possible the reflections coupled to the waveguide mode, we have tilted the SOA waveguide and we have included a bent between the DFB laser and the flared SOA (Fig. 2). One advantage of the bent MOPA architecture is that we can both control the reflectivity of the DFB laser back facet (waveguide perpendicular with the facet) and have a tilt for the SOA waveguide. The bent section can be used as a pre-amplifier SOA or as a modulation section (forward-biased).

The MOPA chips were High Reflectivity (HR) / Anti Reflectivity (AR) coated. Then individual chips were mounted p-side up on Aluminum Nitride submounts (Fig. 3).

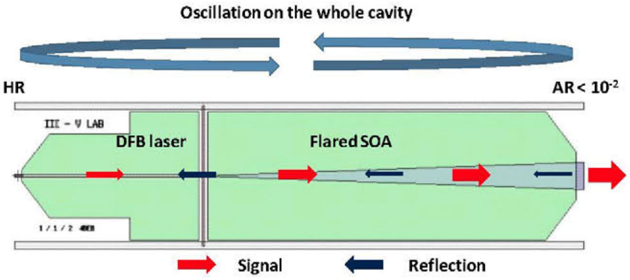

Fig. 1. Schematic of a straight MOPA.

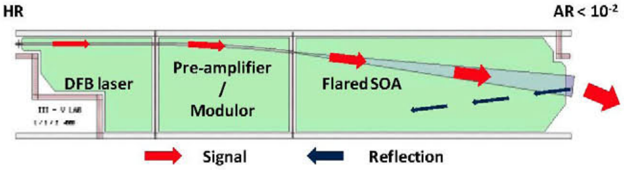

Fig. 2. Schematic of a bent MOPA.

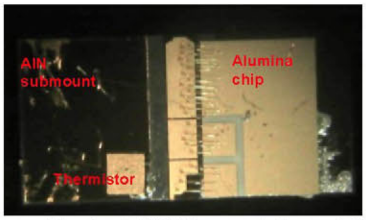

Fig. 3. Picture of the bent MOPA mounted on a AlN submount.

III. RESULTS

For all the devices shown in the letter, the DFB laser, the modulator and the flared SOA lengths are respectively 1, 1 and 3 mm. Fig. 4 is a plot of the output power as a function of the flared SOA bias current at 10° C ($I_{DFB} = 400$ mA, $I_{mod} = 300$ mA). The maximum output power is 620 mW for 5.7 A. With shorter device (same DFB laser and modulator length but only 2 mm long flared SOA), we have obtained a maximum output power of 430, 510 and 600 mW respectively at 18, 12 and 6° C ($I_{SOA} = 3$ A).

The optical spectrum is plotted Fig. 5 for $I_{DFB} = 400$ mA, $I_{mod} = 300$ mA and $I_{SOA} = 3$ A. The device is single-mode with a side mode suppression ratio (SMSR) superior to 45 dB. The peak is blue-shifted (17 nm) compared with the amplified spontaneous emission. Be closer or slightly red-shifted from the maximum of the ASE will be better to get a higher output power. For an application point of view, the stability of the peak wavelength is very important. Fig. 6 shows the evolution of the optical spectra as a function of the DFB laser bias current for $I_{mod} = 300$ mA and $I_{SOA} = 3$ A. Because the DFB laser is not λ/4 phase-shifted there are 2 peaks close to the threshold (each side of the stop-band). From $I_{DFB} = 200$ mA, the laser remains purely single-mode without any mode-hopping. The parabolic evolution of the wavelength is due to heating effects (standard for DFB laser).

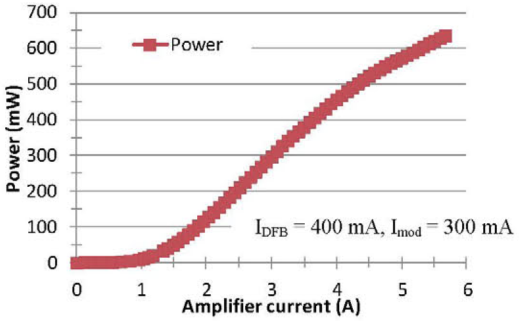

Fig. 4. P-I measurement for a 5 mm long MOPA (T = 10° C).

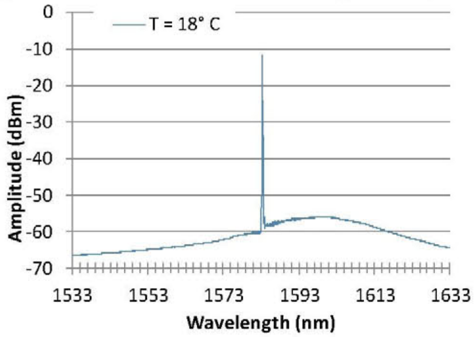

Fig. 5. Optical spectrum (T = 18° C).

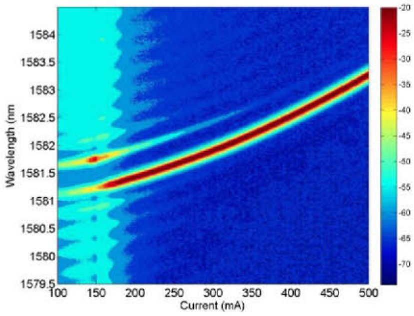

Fig. 6. Optical spectra (variation of I_{DFB}, I_{mod} = 300 mA and I_{SOA} = 3 A).

The optical linewidth measured using the delayed self-heterodyne method (1 km SMF fiber) was in the 2 to 5 MHz range for high DFB bias currents. We have observed an increase of the linewidth with the increase of the flared SOA current (Fig. 7). We think this is due to an increase of the current source noise.

Fig. 8 shows preliminary modulation results of a similar device with different grating pitch leading to a slightly different emission wavelength and a lower maximum output power (~ 180 mW). The CW bias conditions of this device are: $I_{DFB} = 300$ mA and $I_{PA} = 2.5$ A. The response to the superimposition of a dc bias current $I_{mod} = 100$ mA and a 12.5 MHz square signal (peak-to-peak voltage Vpp = 18 V) applied to the modulation section (bent section) is shown in Fig. 8a. Fig. 8b shows the optical modulation amplitude (OMA) and the Extinction Ratio (ER) as a function of the modulation amplitude Vpp. At 12.5 MHz a maximum OMA of ~ 170 mW with an ER of ~ 42 dB is obtained for Vpp = 20 V. This modulation results are encouraging for the application of the device as laser source for the detection of atmospheric CO_2 by random modulation-continuous wave differential absorption lidar (RMCW DIAL) [3].

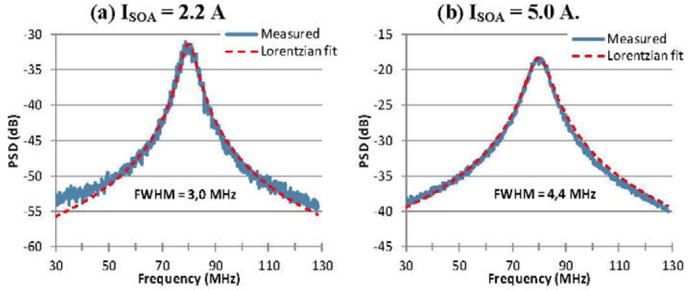

Fig. 7. Optical linewidth for I_{SOA} = 2.2 (a) and I_{SOA} = 5.0 (b).

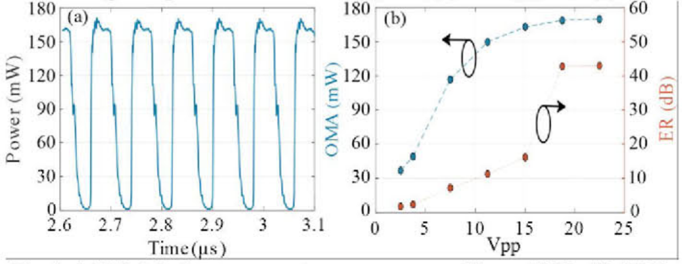

Fig. 8. (a) Modulation response to a square wave (Vpp = 18 V). (b) OMA and ER. f = 12.5 MHz, I_{DFB} = 300 mA, I_{mod} = 100 mA and I_{SOA} = 2.5 A.

IV. CONCLUSION

We have fabricated a 3-section monothically integrated MOPA. The output power is in the 400-600 mW range and the wavelength emission peak is single-mode (SMSR > 45 dB) and stable. The optical linewidth is below 5 MHz. Preliminary modulation results indicate the suitability of these devices for RMCW lidar applications.

V. ACKNOWLEDGMENT

The authors acknowledge the European Commission Directorate-General for Research and Innovation within the framework of the European Space Project BRITESPACE under Grant 313200, the Communidad de Madrid within the Program SINFOTON-CM under Grant S2013/MIT-2790 and the Ministerio de Economia y Competitividad of Spain through the RANGER Project under Grant TEC2012-38864-C03-02.

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