Monolithically Integrated 1GHz Extended Cavity Linear Mode-Locked Laser

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We report a monolithically integrated 42 mm long cavity linear mode-locked laser at 1541 nm, with a low repetition rate at 1 GHz. The device uses InP-based active-passive integration technology and integrated multimode interference reflectors. Passive (PML) and hybrid mode-locked (HML) regime operation are experimentally demonstrated. The device exhibits a very narrow RF linewidth of the beat note of few KHz and Hz for both regimes.

Nowadays, several photonic or electronics techniques for generating of microwave signals used for short-range high data rate communication systems, frequency combs generators, metrology among other applications, are available to satisfy the needs of the customer. However, the use of optic fibre to carry signal long distances with a very low propagation loss, is one of the advantages that photonic techniques have over electronic. Moreover, photonic techniques have other additional advantages such as the quality of the signal generated (low phase noise), the tuning range of the generated frequency and bandwidth modulation [1]. Two of the most common photonic signal generation techniques used for the microwave carrier signals generation are based on optical heterodyning (Dual Wavelength Laser Source), or pulsed lasers (Mode-Locked Laser Source). Each of the techniques has its own quality features and tuning range [2]. The main advantage of the solution provided by the pulsed lasers is that they offer stable signal generation, directly yielding a frequency comb. There are extensive references on integrated mode-locked lasers [3]. However, few solutions operating within the frequency range of our interest (10 MHz to 14 GHz). One of the easiest ways to decrease the repetition rate is increasing the length of the resonator cavity. However, due to the propagation loss in the InP platform, they must be performed by hybrid integration. The most recent reference is an on-chip III-V-on-silicon mode locked laser with a repetition rate of 1 GHz. The length cavity is 37.4 mm [4].One of the characteristics in the use of photonic integration technologies circuits is to reduce system size. We aim to develop photonic integrated circuits (PICs) for the generation and distribution of frequency standards and calibration signals of very high quality by photonic techniques.

The PIC was designed using standardized building blocks and fabricated within a commercial MPW run through an InP active-passive integration foundry service. The mask manufacturing carried shown in figure 1 (a), where we have the linear laser structure. A photograph of the extended cavity made in a spiral-shaped structure is shown in figure 1 (b).

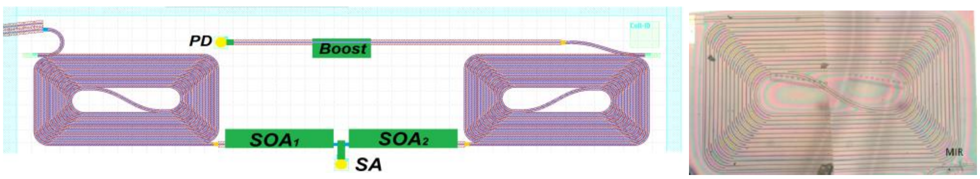
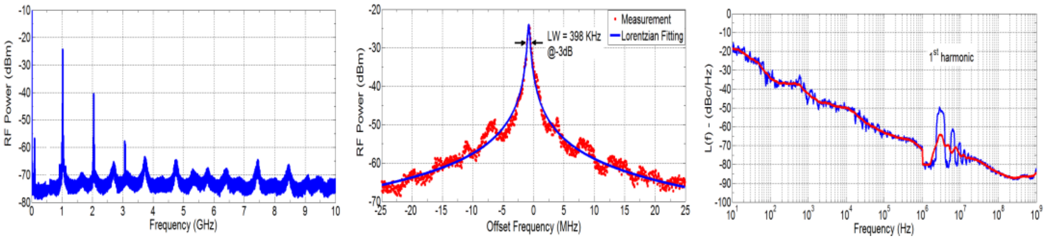


Fig. 1. (a) Layout of the photonic integrated circuit. (b) Microscope photograph of the extended cavity made in a spiral-shaped structure

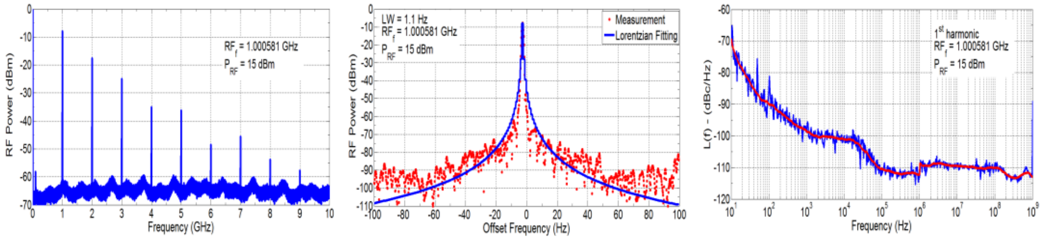
The linear laser structure has a cavity length of 42 mm, corresponding to a frequency spacing of 1 GHz. It has two 750 µm semiconductor optical amplifiers (SOA) with a 50 µm saturable absorber (SA) placed between them. The saturable absorber is located in the middle of the whole linear laser structure. At both ends of the SOA, we designed a waveguide passive, whose length is generated by a spiral-shaped structure. Both spiral-shaped structures on each side of the amplifiers are connected to individual multimode interference reflector (MIR) mirrors to form the Fabry-Perot cavity. At one of the linear laser structure outputs, we placed another SOA (booster) in order to amplify the optical signal launched into the photodiode (PD). Regarding the other output, a 7º angled waveguide to carry light out of the chip is used. An antireflective (AR) coating to avoid light back-reflections is used on the chip facets.

The extended cavity linear mode-locked laser was characterized by choosing the bias conditions which exhibit both passive and hybrid regime of the mode-locked laser. The chosen bias condition to get both regimes is setting a total forward bias current of 110 mA and a reverse bias voltage of -2.8 V for the gain sections and saturable absorber, respectively. These results are presented in figure 2 and figure 3. Electrical spectrums generate an electrical frequency comb, where the fundamental frequency tone appears at the repetition frequency (1 GHz) of the device, with higher harmonics. The fundamental frequency tone appears in detail being clearly hybrid mode in which the device is more stable. The device yields a very narrow RF linewidth of the beat note, 398 KHz and 1.1 Hz @-3dB, both for PML and HML, respectively.



(a) (b) (c)

Fig. 2. Mode-locked laser characterization in passive regime. (a) Electrical spectrum response. (b) Linewidth measurement of the fundamental frequency tone. The achieved beat note was about 398 KHz at -3dB using a Lorentzian shape fitting (blue line). (c) Phase noise measurement of the fundamental frequency tone.



(a) (b) (c)

Fig. 2. Mode-locked laser characterization in hybrid regime. (a) Electrical spectrum response. (b) Linewidth measurement of the fundamental frequency tone. The achieved beat note was about 1.1 Hz at -3dB using a Lorentzian shape fitting (blue line). (c) Phase noise measurement of the fundamental frequency tone.

References

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