Session ID, 2-14: Optical Frequency Comb Generator based on a Monolithically Integrated Ring Laser

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Abstract: We report the demonstration of an optical-frequency comb generator based on a monolithically integrated ring laser. We have designed a device fabricated in a Multi-Project Wafer (MPW) run in an active/passive integration process from a generic building blocks. Chip fabrication has been carried out on the JePPIX technology platform, within the InP technology MPW run. A passive modelocked ring laser architecture is chosen, due to its ease of integration with other components to achieve photonic integrated circuits (PICs). The -10 dB span of the optical comb obtained is 8.75 nm (1.09 THz) with lines spaced by 10.1 GHz.

1. Introduction

Optical frequency comb generator (OFCG) has many applications including, among others, sources for dense wavelength multiplexing division transmitters to exploit the high bandwidth of single mode optical fiber [1,2]. Another utilization is the direct injection of an optical frequency comb signal to two monolithically laser diodes to generate the phase-stabilized carrier signal for the real-time error-free coherent wireless transmission link [3]

Some key requirements for a comb generator are a good spectral flatness, an equal frequency spacing, spectra width and a narrow linewidth for each comb-lines, to use in coherent systems. [4]

One type of optical comb aims to produce multiple optical lines with the frequency intervals defined by an external synthesizer. In this case, comb generation is achieved by successive phase modulation of the external laser reference line in an amplified recirculating loop. This modulation frequency is important as it determines the resulting optical comb spacing. The loop configuration is chosen for its proven performances in term of flat comb generation as demonstrated by published fiber ring implementations [5].

Also, it is possible to generate a flat top optical comb using a Mach Zehnder modulator [6]. In [7] it was proposed an InP based comb generator for optical OFDM transmission using a Mach Zehnder interferometer inside an amplified ring. But they demonstrate only 6-line frequency comb. In [8] it was obtained a 2.06 THz broadband comb that it had 70 lasing lines and was generated using a hybrid modelocked laser with gain flattening filter, but it was not completely flat.

Another type of optical comb is when using modelocked ring lasers that are integrated on a single chip. In [9] it was presented an optical coherent comb centered around 1542 nm with a 3 dB bandwidth of 11.5 nm.

2. Device

We have designed a device fabricated in a Multi-Project Wafer run in an active/passive integration process from a generic building blocks, including semiconductor optical amplifier (SOA), Saturable absorber (SA), passive waveguides (PWs), multimode interference (MMI) and phase modulators (EOMs). Chip fabrication has been carried out on the JePPIX technology platform, within the InP technology multi-project wafer run. A modelocked ring laser architecture is chosen, due to its ease of integration with other components to achieve photonic integrated circuits (PICs). So there is no need of facet mirrors.

The block diagram and photograph of photonic integrated circuit is presented in figure 1. The fully fabricated device has a round-trip cavity length of 8062 µm, corresponding to a frequency spacing of 10 GHz. The Mach Zehnder Interferometer (MZI) uses two 1000 µm phase modulator (EOM) to generate the frequency comb, one in each arm. Also, it uses two 370 µm semiconductor optical amplifier (SOA) with intermediate 20 µm saturable absorber (SA).

3. Measurements

To make the optical frequency comb the two semiconductor optical amplifier (SOAs) are biased at 62 mA drive current each one, -2,0 V bias on the saturable absorber; the phase modulators are biased at $V_1 = V_2 = -1{,}3$ V. The average ouput optical power is 2 mW. The -10 dB span of the comb is 8,75 nm (1,09 THz) with lines spaced by 10,1 GHz as determined by the cavity length. The optical spectrum of the comb is shown in figure 1c).

. The RF spectrum was recorded with an electrical spectrum analyzer (ANRITSU MS2668C) and it is shown in figure 2a) where the fundamental frequency is 40,86 dB over the noise floor. The fundamental frequency is found at 10,16 GHz which corresponds with the frequency spacing determined by the cavity length.

An autocorrelation trace of a picosecond pulse generated at 10.1 GHz are shown in figure 2b). Picosecond pulses with a pulse width of 21,2 ps (assuming a hyperbolic sech waveform) were obtained. Here we have employed an erbium doped fiber amplifier (EDFA, Nortel telecom FA14UFAC) to amplify the output signal prior to autocorrelation. The dotted curve is the experimental trace, and the solid curve is the theoretical fit. The FWHM of the intensity autocorrelation is 32,8 ps, which corresponds to a pulse width of 21,2 ps, in agreement with the theory.

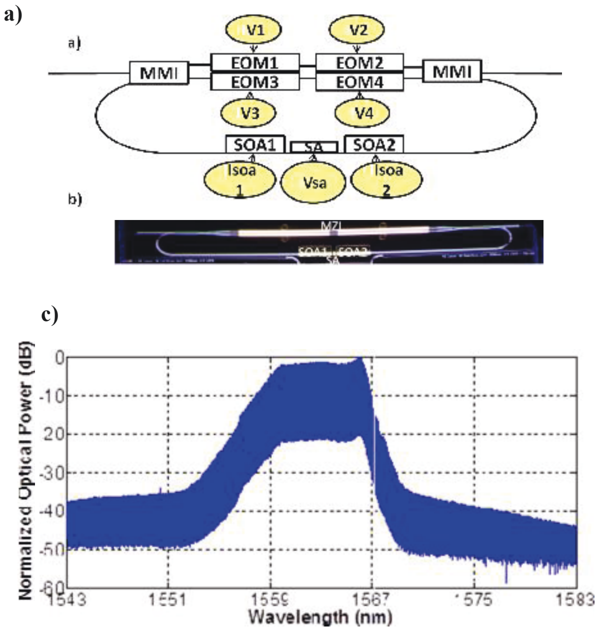

Figure 1 : **a)** Block diagram of the integrated ring laser. SOA: Semiconductor optical amplifier, SA: Saturable absorber, MMI: Multimode interference, EOM: electro-optic modulator. **b)** Photograph of the integrated ring laser, indicating the two SOA and the Mach Zehnder Interferometer (MZI) that include two phase modulator (EOM) in each arm. MZI uses multimode interference (MMI) couplers to form two arms. **c)** Measured comb spectrum on optical spectrum analyzer. Isoa1=Isoa2= 62 mA; V1= V2= -1.3V, Vsa= -2.0 V. The average optical power is 2 mW. The -10 dB span of the comb is 8.75 nm (1.09 THz) with lines spaced by 10.1 GHz

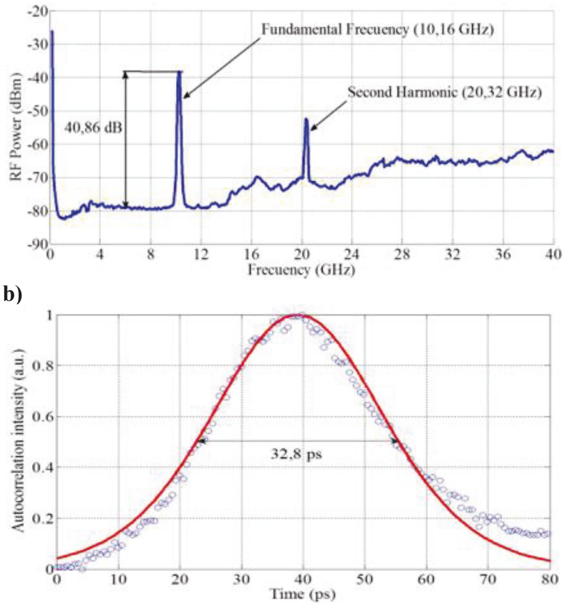

Figure 2 : **a)** Measured RF power from a 40 GHz photodiode with electrical signal analyzer, where the fundamental frequency is 40,86 dB over the noise floor. Fundamental frequency = 10,16 GHz, Span = 40GHz, RBW=VBW=3MHz, Sweep time (ST) = 1s, Isoa1=Isoa2= 62 mA, Veom1= Veom2= -1.3V, Vsa=-2.0 V. **b)** Intensity autocorrelation measurement from APE (Applied Physics and Electronics) Pulse-Check background-free auto-correlator. The dotted curve is the experimental autocorrelation trace, and the solid curve is the fit for a sech2 shape. Span = 80 ps, Isoa1=Isoa2= 62 mA, V1= -2 V, V2= -3V, Vsa=-2.0 V.

4. Conclusion

In conclusion, we have demonstrated an optical frequency comb generator using an integrated ring laser with Mach Zehnder Interferometer, fabricated in a Multi-Project Wafer run. 10,1 GHz spaced lines over a spectral width of 8,75 nm (at -10 dB) were achieved, at output optical power of 2 mW. It is not necessary to use a RF signal or an external laser to generate the comb. The device exhibits a remarkable flatness, a RF linewidth of 15,41 KHz and picosecond pulses with a pulse width of 21,2 ps (assuming a hyperbolic sech waveform). The spectral flatness it is important in order to have optical sources in DWDM systems.

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