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On-Chip Multiple Colliding Pulse Mode-Locked Laser for Millimeter and Terahertz Wave Generation

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We report a novel on-chip multiple colliding pulse mode-locked (ocMCPM) semiconductor laser source for the generation of an optical pulse train at millimeter wave frequency repetition rate, generating a repetition rate at a higher harmonic of the fundamental laser round-trip frequency. We demonstrate a repetition rate at 100 GHz (within the millimeter wave frequency range), using a resonator cavity length with fundamental repetition rate at 25 GHz. As the optical pulse train output is generated within the chip, thanks to integrated mirrors, further increases of the repetition rate are possible, through an optical clock multiplier (OCM) scheme, in order to reach 300 GHz, for terahertz wave generation.

Recent technology roadmaps point to the need of increasing the data rates used in wireless communication systems into the multi-gigabit-per-second to cope with the future needs based in current trends of the demand [1]. A current cost effective solution is to increase the carrier wave frequency into the millimetre (30 to 300 GHz) and terahertz (300 GHz to 3 THz) wave regions [2]. The difficulties to generate, amplify and modulate signals at these frequencies have been overcome by combining electronic with photonic techniques. Currently, most if not all of the reported wireless communication links operating above 100 GHz employ photonic generation of the carrier frequency, demonstrating different available techniques.

There are various photonic techniques to generate MMW and THz frequencies, among which optical heterodyning and pulsed techniques are commonly used. Pulsed sources are usually based on mode locked laser structures [3], having recently reported that it can increase the radiated emitted power about 7 dBm above heterodyning schemes [4]. Mode locked sources can either be passive or hybrid, depending on weather the pulse train is locked to an electronic reference. Passive mode locking requires only fixed direct current and reverse voltage to generate the pulsed signal, which lacks stability. The stability can be addressed through hybrid mode locking, in which the reverse voltage is combined with a continuous wave (CW) signal at the fundamental frequency. The stability is inherited from the electronic source, but is limited by the electrical modulation bandwidth, usually below 30 GHz. The aim of this work is to present the on-chip multiple colliding pulse mode-locked laser diode structure (ocMCPM) using multimode interference reflectors (MIRs). Thanks to active-passive integration technology, we realized these structures as a photonic integrated circuit (PIC).

The structure of the on-chip multiple colliding pulse mode-locked laser diode is sketched in Fig. 1(a). The ocMCPM´s assembly includes three semiconductor optical amplifiers (Lengths, LSOA 1 = 182 um, LSOA 2 = 348 um and LSOA 3 = 350 um), two saturable absorbers (Lengths, LSA 1/2 = LSA 1/4 = 20 um) with four electrical isolators (Lengths, LISO = 20 um each) located on each side of the SAs as well as passive waveguides (LPW = 451.4 um) and two multimode interference reflectors on each end in order to build the resonator cavity. The total length of the cavity is L_cav = 1632 um which offers a fundamental repetition rate of 25 GHz. Besides, the microscope photograph of the fabricated sample is shown in Fig. 1(b). Similarly, we present the block diagram of the future approach in order to multiply by four the repetition rate of an ocMCPM in Fig. 1(c) and the schematic of the OCM-x4 in Fig. 1(d) respectively.

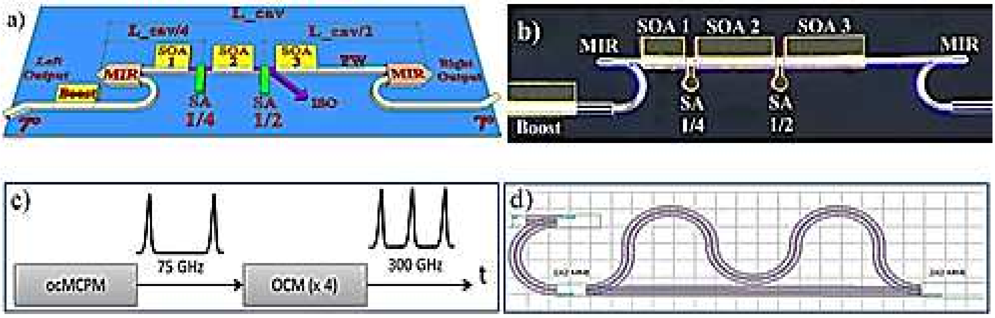

Fig. 16. (a) Schematic of the ocMCPM structure. (b) Microscope photograph of the ocMCPM. (c) Block diagram of the future approach. (d) Schematic of the OCM-x4.

The ocMCPM was characterized by choosing a bias condition, which exhibits this behaviour. The recorded optical spectrum for ocMCPM is depicted in Fig. 2(a). Moreover, the electrical characterization was carried out at the same bias condition. The electrical mode beating tone at 405 MHz is delivered by the Rohde & Schwarz FS-Z110 external mixer head working with the tenth harmonic which down converts the 100 GHz repetition rate of the ocMCPM. Fig. 2(b) shows the recorded electrical spectrum of the mode beating provided by the ocMCPM.

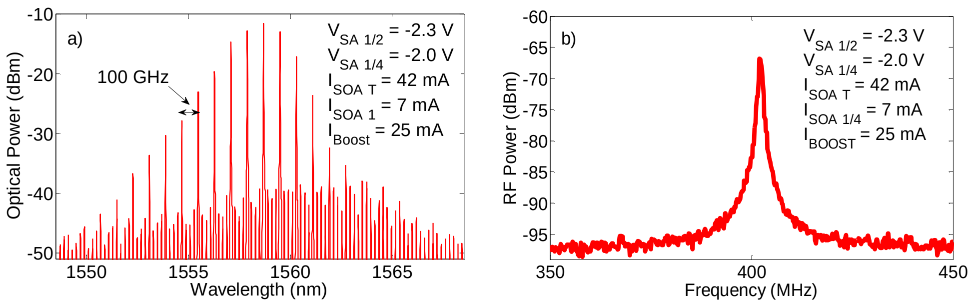

Fig. 2. ocMCPM characterization. (a) Optical spectrum. (b) Electrical spectrum.

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