World Academy of Science, Engineering and Technology
International Journal of Aerospace and Mechanical Engineering
Vol:17, No:02, 2023

Photonic Dual-Microcomb Ranging with Extreme Speed Resolution

Authors : R. R. Galiev, I. I. Lykov, A. E. Shitikov, I. A. Bilenko

Abstract : Dual-comb interferometry is based on the mixing of two optical frequency combs with slightly different lines spacing which results in the mapping of the optical spectrum into the radio-frequency domain for future digitizing and numerical processing. The dual-comb approach enables diverse applications, including metrology, fast high-precision spectroscopy, and distance range. Ordinary frequency-modulated continuous-wave (FMCW) laser-based Light Identification Detection and Ranging systems (LIDARs) suffer from two main disadvantages: slow and unreliable mechanical, spatial scan and a rather wide linewidth of conventional lasers, which limits speed measurement resolution. Dual-comb distance measurements with Allan deviations down to 12 nanometers at averaging times of 13 microseconds, along with ultrafast ranging at acquisition rates of 100 megahertz, allowing for an in-flight sampling of gun projectiles moving at 150 meters per second, was previously demonstrated. Nevertheless, pump lasers with EDFA amplifiers made the device bulky and expensive. An alternative approach is a direct coupling of the laser to a reference microring cavity. Backscattering can tune the laser to the eigenfrequency of the cavity via the so-called self-injection locked (SIL) effect. Moreover, the nonlinearity of the cavity allows a solitonic frequency comb generation in the very same cavity. In this work, we developed a fully integrated, power-efficient, electrically driven dual-micro comb source based on the semiconductor lasers SIL to high-quality integrated Si_3N_4 microresonators. We managed to obtain robust 1400-1700 nm combs generation with a 150 GHz or 1 THz lines spacing and measure less than a 1 kHz Lorentzian withs of stable, MHz spaced beat notes in a GHz band using two separated chips, each pumped by its own, self-injection locked laser. A deep investigation of the SIL dynamic allows us to find out the turn-key operation regime even for affordable Fabry-Perot multifrequency lasers used as a pump. It is important that such lasers are usually more powerful than DFB ones, which were also tested in our experiments. In order to test the advantages of the proposed techniques, we experimentally measured a minimum detectable speed of a reflective object. It has been shown that the narrow line of the laser locked to the microresonator provides markedly better velocity accuracy, showing velocity resolution down to 16 nm/s, while the no-SIL diode laser only allowed 160 nm/s with good accuracy. The results obtained are in agreement with the estimations and open up ways to develop LIDARs based on compact and cheap lasers. Our implementation uses affordable components, including semiconductor laser diodes and commercially available silicon nitride photonic circuits with microresonators.

Keywords : dual-comb spectroscopy, LIDAR, optical microresonator, self-injection locking
Conference Title : ICAPVFO 2023 : International Conference on Avionics, Photonics and Vehicle Fiber-Optics
Conference Location : Buenos Aires, Argentina
Conference Dates : February 20-21, 2023