Resolving the teeth of optical frequency comb with a multimode fiber spectrometer

M. Cassinerio[1], N. Coluccelli[1], B. Redding[2], H. Cao[2], P. Laporta[1], G. Galzerano[1]

1. Dipartimento di Fisica - Politecnico di Milano and Istituto di Fotonica e Nanotecnologie - CNR, Piazza Leonardo da Vinci 32, 20133 Milano, Italy

2. Department of Applied Physics, Yale University, New Haven, Connecticut 06520, USA

Optical frequency combs are versatile spectroscopic tool providing excellent accuracy, high spectral purity, and broad spectral coverage at the same time. Direct frequency comb spectroscopy (DFCS)techniques exploits the large number of frequency comb components (comb teeth) to provide a massive set of parallel detection channels and acquire spectroscopic informations. In particular, a lot of interest has been focused on resolving the single comb tooth in DFCS measurements, and two main techniques have been reported so far: the first, based on virtually-imaged phased arrays (VIPA), and the second so-called "dual-comb" spectroscopy [1,2]. We present a new DFCS technique with comb-tooth level resolution, based on the frequency dependence of the speckle pattern generated at the output of a multi-mode fiber [3].

Figure 1 shows the setup used for spectroscopy. The laser source is an Er:fiber frequency comb with an output power of 0.5 W, a repetition rate of 250 MHz, and pulse durations of 40 fs. The comb is fully stabilized, both the repetition and offset frequency are referenced to a GPS-assisted Rb standard; in particular, the offset frequency is measured using an f-2f interferometer after spectral broadening by a highly non-linear fiber. The output of the comb passes through a 10-cm cell filled with acetylene and then a tunable fiber filter having a bandwidth of 0.3 nm around 1535.7 nm (not shown in the picture). The comb is coupled into a Fabry-Perot cavity with a filtering factor of 4, which increase the comb teeth frequency spacings to 1 GHz. After pre-filtering, the comb is coupled into a PM single-mode fiber and then into a 100-m long multimode (MM) fiber with a core diameter of 100 µm, placed inside a vacuum chamber. The speckle pattern generated at the output of the MM fiber is finally imaged onto an InGaAs camera.

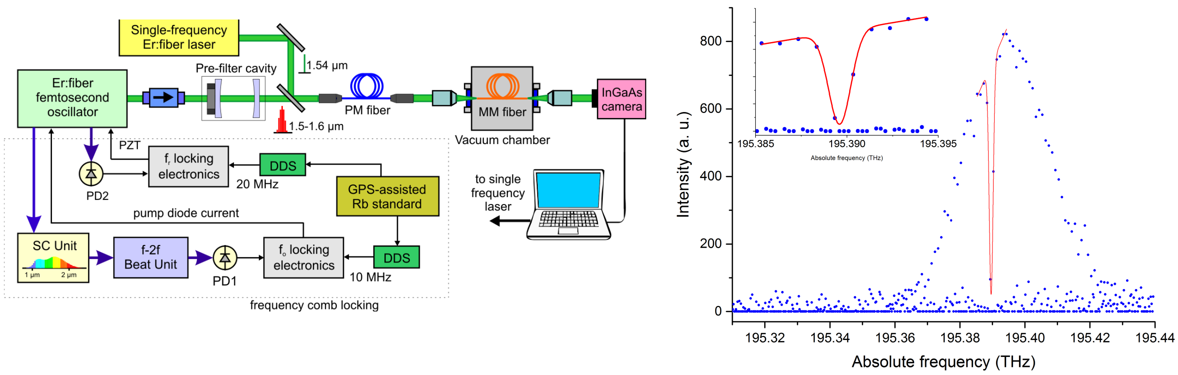

Fig. 1 Schematic employed for the DFCS based on multimode-fiber spectrometer (left). Transmission spectrum of an acetylene cell retrieved by processing the speckle pattern at the output of the multimode fiber; the inset shows the Voigt fit to non-zero points of the transmission spectrum (right).

The fiber spectrometer needs to be calibrated before DFCS measurement. The calibration is performed by acquiring the speckle pattern generated by a single-frequency tunable laser: the frequency is scanned from 1535 to 1536 nm at steps of ~0.2 pm (250 MHz) and a speckle-pattern is stored at each frequency. The transmission spectrum of the comb is retrieved by correlating the comb speckle pattern with each single-frequency pattern to calculate the separate spectral components. The result is shown in Fig. 1, where an absorption line of acetylene can be clearly seen together with the envelope of the comb spectrum due to the tunable fiber filter. The inset shows that the comb modes are resolved, specifically it can be noted a recursive sequence of three null points and one non-zero point, corresponding to the three comb mode rejected by the FP cavity and the one transmitted. The frequency axis is absolute, as the calibration is performed by referencing the single-frequency laser to the Rb-stabilized comb. Further progress will be presented during the conference.

References

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