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Real-Time Study of Coexisting States in Laser Cavity Solitons

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1. Introduction

Laser cavity-solitons microcombs have recently been introduced by our team at the University of Sussex [1]. To gain insight into their dynamics, they need to be studied with an extremely high temporal resolution, as they are ultrashort pulses of hundreds of femtoseconds and at the same time, on a long temporal span, to observe their formation dynamics and subsequent interactions. These challenging temporal features require the development of ad-hoc metrological tools such as Dispersive Fourier Transform, which has opened the research field of so-called ‘non-repetitive’ events [2]. In nonlinear optics, this includes the study of optical rogue waves [3] and solitons collision-induced explosion in mode-locked lasers [4].

2. Experimental results and discussions

The Dispersive Fourier Transform (DFT) technique is a powerful tool for characterizing the spectrum of optical pulses in real-time. However, this technique relies on temporally stretching optical pulses in a fibre, which can result in pulse overlapping and thus information losses. This problem is solved by optically sampling our laser emission rate at a reduced repetition rate using amplitude modulation (Fig. 1(a)). By lowering the repetition rate to 33MHz, we manage to reduce the signal duty cycle thus allowing pulses temporal stretching without overlap.

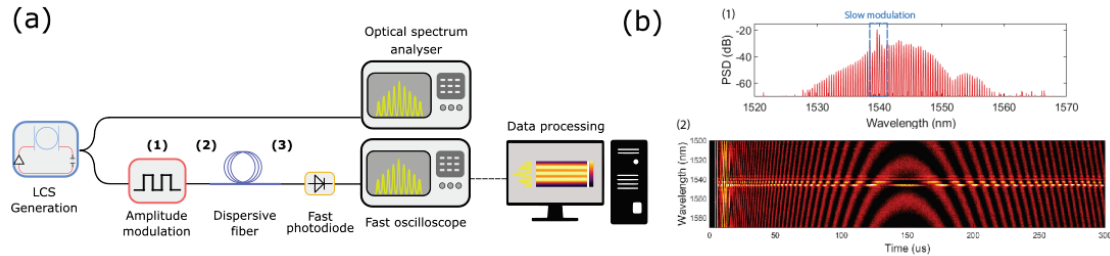


Figure 1. (a) LCS are generated using a micro-resonator nested in a fibre cavity. Real-time diagnostic setup. Amplitude modulation is first used to reduce LCS repetition rate, allowing them to temporally stretch in a dispersion compensation fibre. The pulses are then recorded using a fast detection setup comprising a fast photodetector and oscilloscope. (b)-1 Optical spectrum of the LCS. The spectral lines responsible for the slow modulation are circled in blue. (b)-2 Start-up of the LCS regime (0-20 μ s). The radio-frequency beating can be observed over hundreds of microseconds.

A typical DFT measurement demonstrating the coexistence of a LCS with a continuous wave state is reported in Fig. 1(b). In particular, we observe the temporal buildup of the LCS, with the DFT showing the formation of the comb-like optical spectrum visible after 20 μ s – and centred at 1540 nm. Superimposed to this spectrum, it is possible to observe a slow modulation with a frequency of approximately 80 MHz, matching the free-spectral range of our laser cavity. This modulation is due to the presence of a continuous wave state at 1540 nm which appears simultaneously with the pulsed regime. The evolution of the modulation in time indicates that the relative position of the laser lines within the microcavity is changing. The coexistence of these two states, once a stationary regime is reached, can be confirmed by a laser-scanning spectroscopy measurement.

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