Microcombs Based on Laser Cavity Solitons

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Abstract: We summarize our results on the generation of temporal laser cavity-solitons in a system comprising an optical micro-cavity nested in a fiber laser. We will discuss their features, region of existence, potential and challenges ahead.

Dissipative solitons are self-confined pulses which appear in driven and lossy systems when the phase dispersion is balanced by the nonlinear phase-shift. Ultrashort pulses generated by passive mode-locking lasers are a very important example of temporal dissipative solitons in optics. Temporal cavity-solitons [1,2,3] also belong to this class of pulses and have been instrumental in the development of optical frequency combs in nonlinear micro-cavities, or "micro-combs" [1].

Temporal cavity-solitons have been largely studied in a 'driven' configuration, where an external pumping source is resonantly coupled in the nonlinear micro-resonator to sustain and excite the solitary pulses. More recently, we demonstrated that it is possible to generate localised pulses in a configuration where the micro-cavity is inserted in a fiber laser loop, as described in Figure 1.

In particular, we reported the observation of laser cavity-solitons [4], which have previously attracted large attention especially in spatial configurations, such as in semiconductor lasers [5]. By merging their properties with the physics of both micro-resonators and multi-mode systems, this scheme represents a fundamentally new paradigm for the generation, stabilisation and control of solitary optical pulses in micro-cavities.

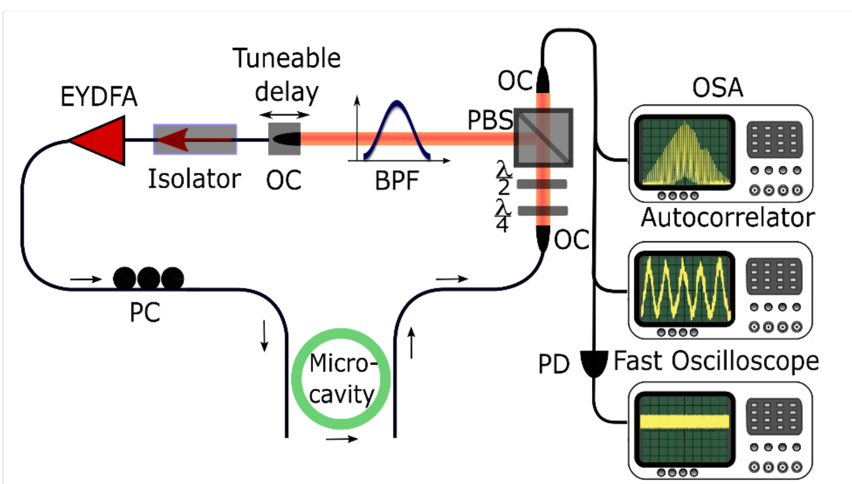

Fig. 1. Scheme of the nested, travelling-wave cavities configuration: a Kerr micro-resonator (green loop) is nested in an amplifying fibre-loop (black). The amplifying cavity comprises a gain fibre (erbium-ytterbium doped amplifier, EYDFA), a tuneable delay line with optical couplers (OC), polarising beam splitter (PBS), polarisation control and a band-pass filter (BPF). The output of the laser is monitored with an optical spectrum analyser (OSA), a second-harmonic non-collinear autocorrelator and an oscilloscope to measure the radio-frequency noise of the system.

In general, laser cavity-solitons are a highly efficient class of cavity-solitons because they are intrinsically background-free. This is in stark contrast to cavity-solitons obtained in nonlinear Kerr cavity driven by an external source and described by the well-known Lugiato-Lefever equation [2,3]. Currently, these self-localised waves form on top of a strong background of radiation, usually containing 95% of the total power for bright configurations [6].

Our laser cavity-solitons cover a spectral bandwidth exceeding 50 nm and are induced with average powers more than one order of magnitude lower than those typically used in state-of-the-art soliton micro-combs [1]. Very importantly, in stark contrast to temporal cavity-solitons based Lugiato-Lefever systems, our bright laser cavity-solitons are background-free, and we achieve a mode-efficiency [4] above 75%, compared to typical 1% - 5% for bright solitons realised with standard approaches. Moreover, we can affect the soliton repetition-rate with a simple approach. The free-spectral range of the fiber cavity can be affected by a delay line that modifies the fibre cavity length and, hence, the mode-spacing. In turn this tunes the position of the mode of the system and the repetition rate of the micro-comb.

In this presentation, we will discuss the possible type of pulses that can be observed in our system [4,7], with a particular attention to both localised and periodical solutions. We will discuss the range of existence of Turing patterns and solitons and possible approaches to their generation and control.

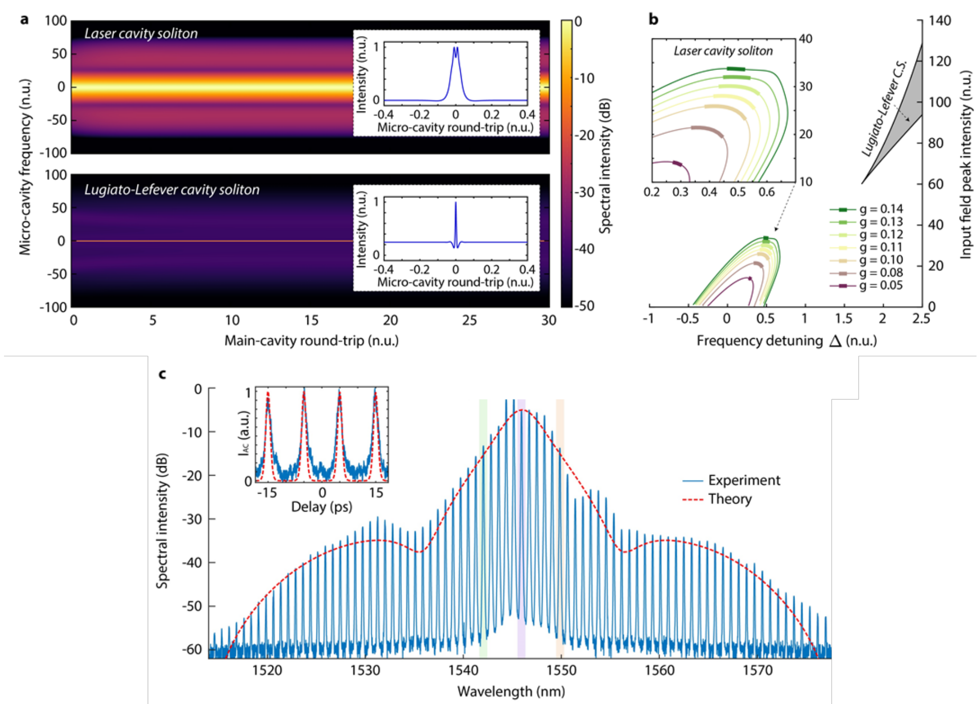

Fig. 2. a. Theoretical comparison of the propagation a laser cavity-soliton and a Lugiato-Lefever cavity-soliton in the same type of micro-resonator. b. Map of existence of the laser cavity solitons for different fiber cavity gain. The cavity gain parameter g is normalized to the total losses of the system and can vary from 0 to 1. The frequency detuning is normalized with respect to the free-spectral range of the micro-cavity, in this graph, positive values of Δ correspond to red detuned frequencies. c Experimental (blue) and theoretical (red-dashed) spectrum of a laser cavity-soliton. The inset reports the autocorrelation.

References

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