Here we summarize the most high-impact work in the project, which refers to an ultra-short pulse fibre laser in which three different types of pulses can be chosen to be emitted. To make the work be more easily understood, we start from some basic knowledge background.

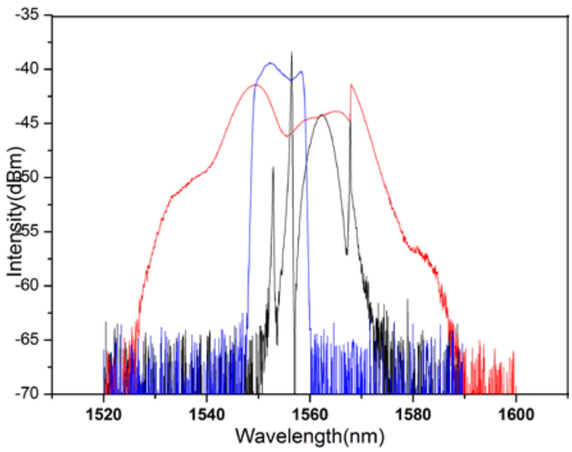
Optical fibre is a transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair. Optical fibers are used most often as a means to transmit light in fiber-optic communications, where they permit transmission over longer distances and at higher bandwidths (data rates) than wire cables. Besides, optical fibers can be used to construct lasers [1].

A laser is a device that emits light. A laser differs from other sources of light in that it emits light coherently. Spatial coherence allows a laser to be focused to a tight spot, to stay narrow over great distances (collimation). Lasers can also have high temporal coherence, which allows them to emit light with a very narrow spectrum, i.e., they can emit a single color of light. Temporal coherence can be used to produce pulses of light as short as a femtosecond through mode locking technology. Mode-locking is a technique by which a laser can be made to produce pulses of light of extremely short duration, on the order of picoseconds (10^{-12} s) or femtoseconds (10^{-15} s). The basis of the technique is to induce a fixed-phase relationship between the longitudinal modes of the laser's resonant cavity. The laser is then said to be 'phase-locked' or 'mode-locked'. Depending on the properties of the laser, these pulses may be of extremely short duration, as short as a few femtoseconds [2].

In a mode-locked fibre laser, the interplay among the effects of gain/loss, dispersion (the dependence of wave velocity on frequency) and nonlinearity can be used to shape the pulses and manipulate the light dynamics and, hence, lead to different regimes of mode locking. When the group-velocity dispersion (GVD) of the laser is anomalous, the balance between nonlinearity and dispersion results in soliton formation in a laser [3]. Generally speaking, a soliton is static inside a laser cavity, namely, the soliton propagates in a cavity without any changes. In a laser with segments of nearly equal magnitudes of GVD but with opposite signs, a pulse will stretch and compress experiencing lower nonlinearity. This dispersion-managed (DM) soliton [4] operation exists for net anomalous or small normal GVD and allows femtoseconds pulses with up to nanojoule energies. Recent work [5] has shown that much higher pulse energies can be reached in fibre lasers that operate at all-normal or strong net normal dispersion regime. In the normal-dispersion regime, dissipation (loss) is required and plays a key role in the pulse shaping, and dissipative solitons (DSs) [5] can be found in this regime. DSs features rectangular pulse spectrum.

Techniques for generating specialized waveforms have become increasingly important in many scientific areas, including, amongst others, ultrahigh-speed optical communications, and optical signal processing. Versatile ultrafast laser sources, which can selectively emit different types of pulses, are highly desirable in this context. The key to access different pulse regimes in passively mode-locked fibre laser is in-cavity dispersion management. Commonly employed methods to achieve in-cavity dispersion tuning include grating pairs, or simply physically changing the length of the fibre in the cavity. All these techniques however, require manual tuning of some physical parameters of the cavity. Spectral pulse shaping employed in a mode-locked fibre laser has emerged as a method to achieve a potentially high degree of control over the dynamics and the output of the laser purely through software control.

In this work, we demonstrate that different pulse regimes including soliton, DM soliton, and DS mode-locking regimes can be switched and reliably targeted by programming the dispersion and bandwidth on an in-cavity programmable filter. The generation and in-cavity evolution of the different regimes are further confirmed by a numerical analysis. Each of these mode-locking regimes obviously takes on major practical importance. To our knowledge, this is the first time that these distinctly different pulse solutions are obtained in a single laser system without applying any physical changes in the laser cavity. Numerical simulations are presented which confirm the different nonlinear pulse evolutions inside the laser cavity. The proposed technique holds great potential for achieving a high degree of control over the dynamics and output of ultrafast fibre lasers, in contrast to the traditional method to control the pulse formation mechanism in a DM fibre laser, which involves manual optimization of the relative length of fibres with opposite-sign dispersion in the cavity. Our versatile ultrafast fibre laser will be attractive for applications requiring different pulse profiles such as in optical signal processing and optical communications.



The above figure shows three distinct pulse regimes including soliton (black), dispersion-managed soliton (red) and dissipative soliton (blue).

References

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