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Progress in Real-Time Measurements of Ultrafast Instabilities in Nonlinear Fiber Optics

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Recent years have seen many dramatic advances in the real-time measurement of ultrafast non-repetitive optical signals, which have brought many new insights into the underlying physics (1,2). Studies to date, however, have been based on using either real-time spectral characterisation using the dispersive Fourier transform (DFT), or real-time temporal characterisation using a time lens approach with sub-picosecond resolution. In the particular field of nonlinear fibre optics, these results have been applied to studies of modulation instability, supercontinuum generation and optical turbulence, and real-time techniques are now becoming a standard tool to understand how noise effects influence a range of nonlinear propagation scenarios (3-8).

In this paper, we will review our work in this area, and we will also report the first simultaneous use of real-time DFT and time lens techniques to characterise instabilities observed during the build-up of dissipative soliton structures in a mode-locked fibre laser. Dissipative solitons are localized states of a physical system that are characteristic of far-from-equilibrium systems in many fields of science including chemistry, biology, and physics. There has been much recent interest in studying their behaviour in laser systems, but experimental studies have been limited by the fact that it has not been possible to follow the dynamical soliton evolution in real-time. In our work, we have overcome this problem by using simultaneous DFT and time lens measurements to completely characterize the spectral and temporal evolution of dissipative solitons in a transient unstable laser start-up regime showing complex break-up and collision behaviour before stabilization. Moreover, being able to measure both the temporal and spectral properties simultaneously allows us to use phase retrieval for reconstruction of the full field (i.e. the pulse in intensity and phase) and calculation of the corresponding complex nonlinear eigenvalue spectrum. These results provide a unique picture of the internal evolution of dissipative solitons in a mode-locked laser system, and we anticipate further application of this approach in the optimization of lasers with improved performance and stability.

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