Unveiling the Key Role of Ultrafast Shock Formation During Fibre-Based Extreme Self-Compression in the Mid-Infrared

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The ultimate time resolution in many fields such as spectroscopy or lightwave electronics crucially depends on the availability of phase-stable ultrafast light sources whose frequency content spans across multiple spectral domains. Most solutions to this challenge are based on spectral broadening of standard ultrafast lasers in different nonlinear media, and few if any offer ultraviolet to terahertz spectral coverage along with synchrotron-level brightness in a compact platform. One route to achieving this goal relies on ultrafast self-compression in gas-filled hollow anti-resonant fibres, which are excellent platforms offering reconfigurable optical properties, ultrabroad guidance windows and high damage threshold.

The physics of extreme pulse self-compression in fibres relies on the dynamic interplay of multiple linear and nonlinear effects, some of which such as pulse self-steepening and subsequent optical shock formation become increasingly important as the duration of the incoming pulses shortens. The formation of catastrophic shock events is ubiquitous in nature, which somewhat seems to dislike it since the associated discontinuities are quickly regularized by action of various dispersive phenomena, making observation of shock events and their effects very difficult in general.

In this talk we will discuss how ultrafast shock formation uniquely enables the generation of few-cycle pulses with a bandwidth spanning from the UV to the THz via extreme self-compression of mid-infrared pulses in gas-filled anti-resonant fibres. In particular, the onset of optical shocks permits overcoming the dramatic dispersive effects of structural fibre resonances, resulting in multi-octave-spanning coherent spectra that may boost progress in the next generation of ultrafast exploratory science.