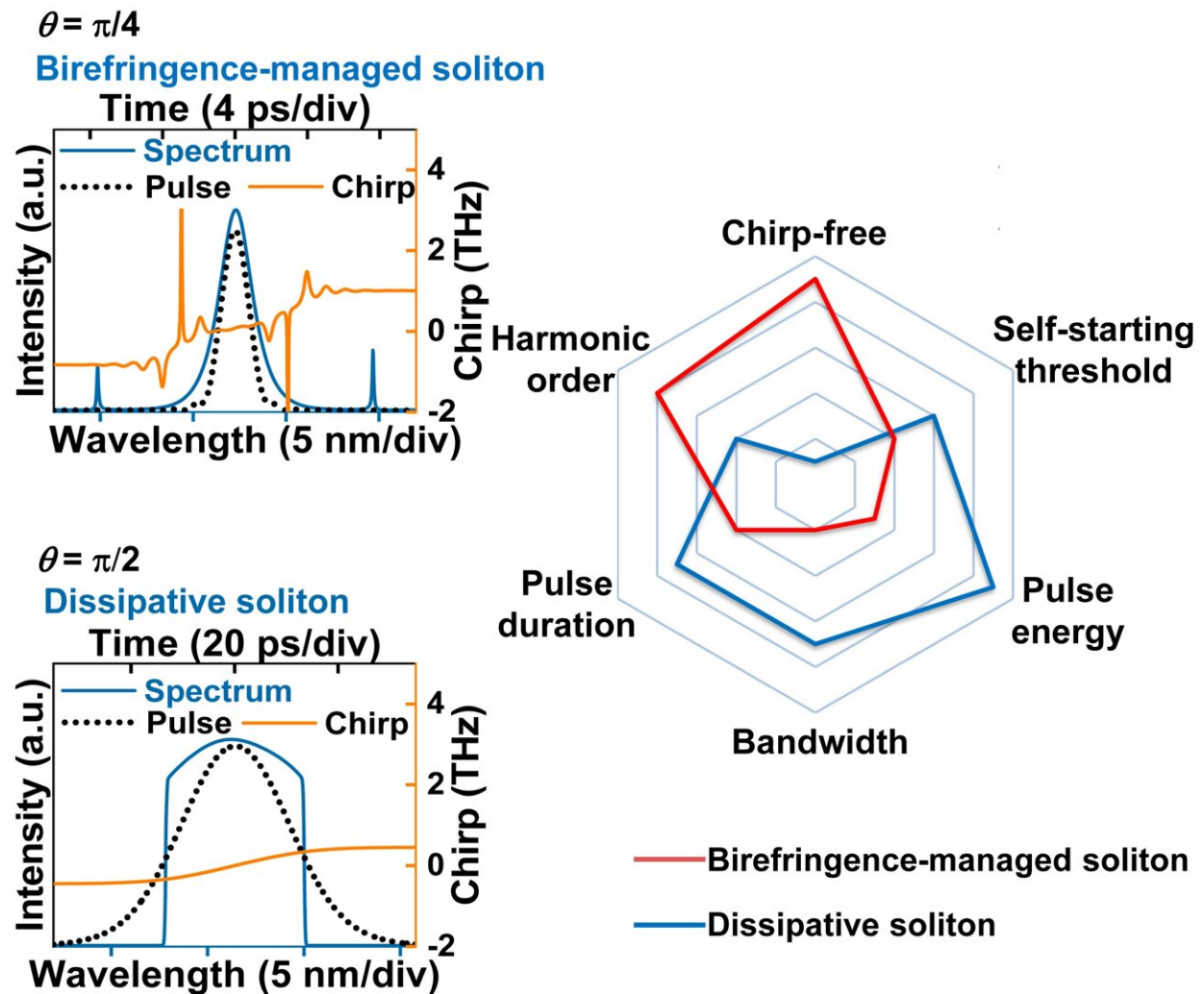


A birefringence-managed normal-dispersion fiber laser delivering energy-tunable chirp-free solitons

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Comparison of birefringence-managed soliton and dissipative soliton in the same normal-dispersion fiber laser. Credit: *Ultrafast Science* (2022). DOI: 10.34133/2022/9760631

Over the past decades, researchers have demonstrated conventional solitons, stretched pulses, self-similar pulses, and dissipative solitons by managing the dispersion and nonlinearity of fiber lasers. However, new types of robust pulses were less discovered in mode-locked fiber lasers, since dissipative solitons were reported in ~2000s. On the other hand, chirp-free solitons are only achieved with anomalous-dispersion fiber lasers in the past, and the single-pulse energy is constrained within a relatively tight bound.

Recently, a joint research team led by Prof. Dong Mao and Jianlin Zhao from Northwestern Polytechnical University, together with Prof. Zhipei Sun from Aalto University, proposed a novel class of chirp-free pulse in net-normal-dispersion erbium-doped fiber lasers. The birefringence-related phase-matching effect dominates the formation of the chirp-free [soliton](#), and hence it is termed as birefringence-managed soliton.

Controllable harmonic mode-locking from 5-order to 85-order can be achieved at the same pump level of ~10 mW with soliton energy fully tunable beyond ten folds, indicating a new birefringence-related energy law that intrinsically distinct from the energy theorem of conventional solitons.

For the normal-dispersion fiber laser containing a section of polarization-maintaining fiber, mode coupling between two orthogonal-polarized components occurs when the pulse propagates from single-mode fiber to

polarization-maintaining fiber. The laser operation mainly depends on the polarization state of the pulse in single-mode fiber.

When the θ (i.e., the angle between y-polarized component and fast axis of PMF) is ~ 0 or $\sim \pi/2$, the laser emits dissipative solitons, while birefringence-managed soliton can be realized when θ varies between $\sim \pi/10$ and $\sim 2\pi/5$. Compared with dissipative solitons, the birefringence-managed solitons possess smaller pulse duration, bandwidth, and pulse energy, as well as self-starting threshold, and are capable of assembling themselves into high-order harmonic mode-locking states.

By virtue of single-shot spectroscopy and electrically tunable polarization controller, the transition between dissipative soliton and birefringence-managed soliton can be visualized in real time. For both transition process, they exhibit degeneration of solitons, relaxation oscillation, and regeneration of solitons. These results further validate that birefringence-managed soliton is realized in normal-dispersion region.

Numerical simulations based on coupled Ginzburg-Landau equations well reproduce the experiment observations, corroborating that apart from the chromatic dispersion, nonlinearity, and saturable absorption effects, the birefringence can be exploited to manage the [energy](#) and propagation behavior of pulse, which may open new research directions in fields of optical solitons and ultrafast fiber lasers.

This work paves an avenue to directly generate chirp-free solitons in normal-dispersion cavities without external compression. Such flexible fiber [laser](#) is capable of producing tunable high-order harmonically mode-locked solitons at a relatively low pump power, providing a promising way for realizing high-repetition-rate [pulse](#) sources operating with [low power consumption](#) for optical communication and sensing.

The paper is published in the journal *Ultrafast Science*.

More information: Dong Mao et al, Birefringence-Managed Normal-Dispersion Fiber Laser Delivering Energy-Tunable Chirp-Free Solitons, *Ultrafast Science* (2022). [DOI: 10.34133/2022/9760631](https://doi.org/10.34133/2022/9760631)

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