

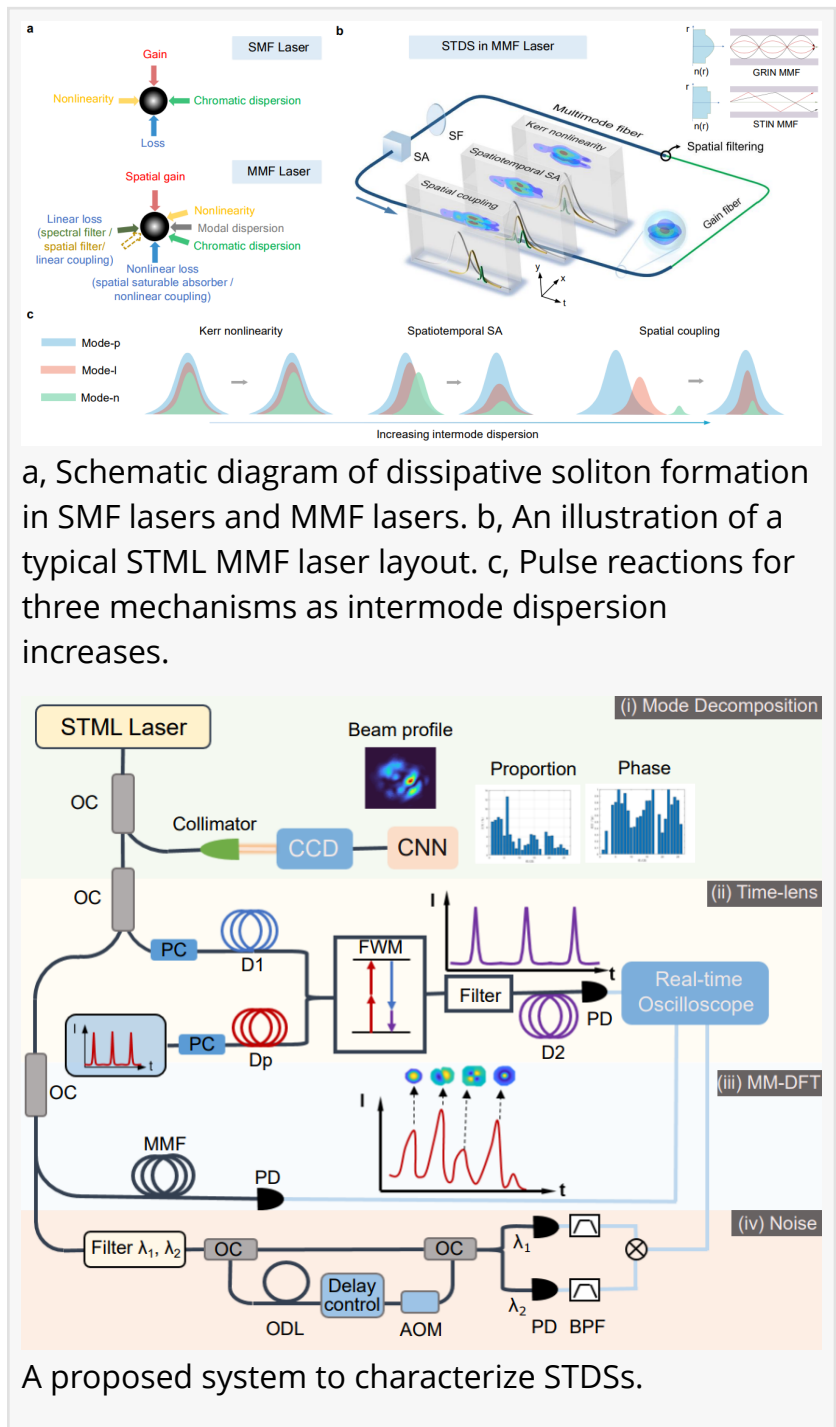
Spatiotemporal mode-locking and dissipative solitons in multimode fiber lasers

CHINA, November 1, 2023

/EINPresswire.com/ -- [Multimode fiber](#)

(MMF) lasers can be invaluable for various applications, including high-energy pulse generation, precision measurement, and nonlinear microscopy. They also serve as an outstanding testbed for nonlinear spatiotemporal physics. The generation of ultrashort pulses in nonlinear multimode resonators relies upon spatiotemporal mode-locking (STML), which involves synchronization in both spatial and temporal dimensions. This review focuses on the fundamentals of STML, with a particular emphasis on the dynamics under large intermode dispersion. Recent progresses in spatiotemporal measurement techniques, exotic nonlinear dynamics of spatiotemporal dissipative solitons (STDS), and spatial mode engineering in MMF lasers are covered. We also provide an outlook on future perspectives for STML.

The birth of spatiotemporal mode-locking (STML) can date back to the report of Wright et al., in 2017. Following this breakthrough, research on STML has thrived. However, our comprehension and control of spatiotemporal dissipative solitons (STDSs) and STML in multi-mode fiber (MMF) lasers are not as mature as those in single-mode



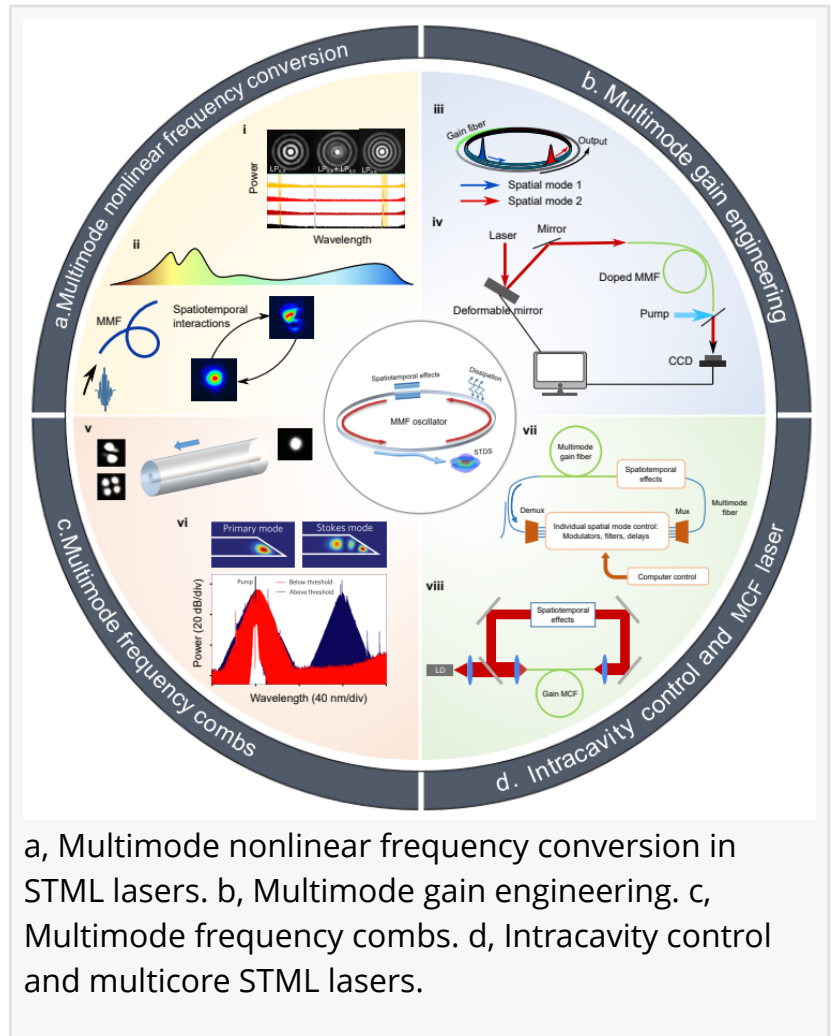
fiber lasers. Some of the key challenges include achieving ultrahigh pulse energy and arbitrary mode profiles in MMF lasers and refining spatiotemporal characterization techniques. Tackling these challenges would unlock diverse applications for MMF lasers.

Recently, a review article entitled "Spatiotemporal mode-locking and dissipative solitons in multimode fiber lasers" was published in "Light: Science & Applications" by the team led by Changxi Yang and Chengying Bao from Tsinghua University, China. This review summarizes the research progress on STML and STDS in MMF lasers and outlines several perspectives that may bring breakthroughs for STML lasers.

Balancing intermode dispersion and synchronizing mode-resolved pulses are a prerequisite for STML. Depending on the magnitude of intermodal dispersion, three dominant mechanisms contributing to balancing intermode dispersion and govern STML: Kerr nonlinear dominant regime, spatiotemporal saturable absorber dominant regime, and spatial coupling dominant regime (Fig. 1b). Each regime exhibits distinct dynamics for the three-dimensional pulses. These STDSs differ from conventional ones with fixed pulse shapes due to the complex spatiotemporal coupling nature affecting their temporal, spectral, and spatial characteristics (Fig. 1c).

Multi-dimension measurement techniques and nonlinear dynamics. - Measurement is vital for understanding STDS behaviors. Presently, spectral filtering and spatial sampling can hardly capture the full dynamics of STDSs and hinders our ability to control STML lasers. Real-time, multi-dimensional optical field measurements are crucial to grasp spatiotemporal dynamics. Combining techniques like multimode dispersion Fourier transform, time lenses, mode decomposition, and timing jitter measurements may make a powerful system to characterize spatiotemporal dynamics of STDSs (Fig. 2). With full characterization of STDSs in spatial, temporal, and spectral dimensions, more exotic nonlinear dynamics can be captured and STML dynamics can be revealed.

Mode engineering and energy scaling. - Mode field control and wavefront shaping have versatile applications. However, customizing mode components in multimode lasers remains challenging.



Beam self-cleaning, or introducing spatial light modulators may enable mode field control of STML lasers. Attaining high pulse energy with user-defined mode profile can open the door for many exciting applications including nonlinear microscopy. Moreover, spatial coherence may add new possibilities for applications (e.g., chaotic Lidar) where low coherence can be an advantage.

This section covers the applications and novel technological pathways of spatiotemporal mode-locked lasers (Fig. 3). Topics include multimode optical frequency combs, wavelength-division multiplexing for multimode lasers, generation of multimode supercontinuum, mode-locked single-cavity dual/multi-combs, and coherently-pumped multimode lasers. These advances can push our ability to control photons in loosely confined, multi-mode, nonlinear, ultrafast systems to a new level.

DOI

10.1038/s41377-023-01305-0

Original Source URL

<https://doi.org/10.1038/s41377-023-01305-0>

Funding information

This work is supported by the National Natural Science Foundation of China (NSFC) (61975090, 62175127), by the Tsinghua University Initiative Scientific Research Program (20211080080, 2022108006), and by the Tsinghua-Toyota Joint Research Fund. The authors declare no conflicts of interest.

Lucy Wang

BioDesign Research

[email us here](#)

This press release can be viewed online at: <https://www.einpresswire.com/article/665561702>

EIN Presswire's priority is source transparency. We do not allow opaque clients, and our editors try to be careful about weeding out false and misleading content. As a user, if you see something we have missed, please do bring it to our attention. Your help is welcome. EIN Presswire, Everyone's Internet News Presswire™, tries to define some of the boundaries that are reasonable in today's world. Please see our Editorial Guidelines for more information.

© 1995-2023 Newsmatics Inc. All Right Reserved.