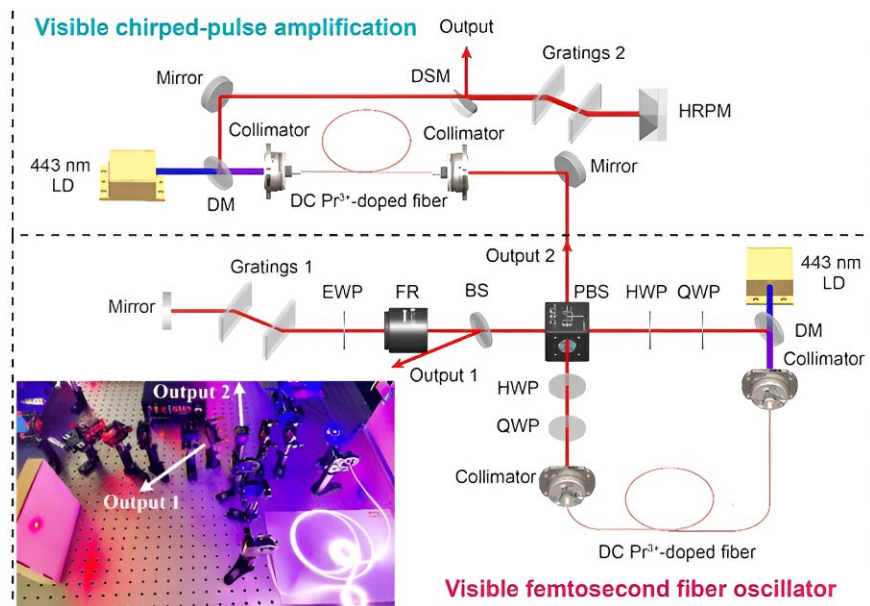


Unlocking visible femtosecond fiber oscillators: An advance in laser science

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Visible-light femtosecond fiber oscillator and amplifier (schematic; inset, photograph). Credit: J. Zou, Q. Ruan, et al.

The emergence of ultrafast laser pulse generation, marking a significant milestone in laser science, has triggered incredible progress across a wide array of disciplines, encompassing industrial applications, energy technologies, life sciences, and beyond. Among the various laser platforms that have been developed, fiber femtosecond oscillators, esteemed for their compact design, outstanding performance and cost-

effectiveness have become one of the mainstream technologies for femtosecond pulse generation.

However, their operating wavelengths are predominantly limited to the infrared region, spanning from of 0.9-3.5 μm , which has, in turn, restricted their applicability in numerous applications that require light sources at [visible wavelengths](#) (390-780 nm). Expanding compact femtosecond fiber oscillators into new visible wavelengths has long been a challenging yet fervently pursued goal in laser science.

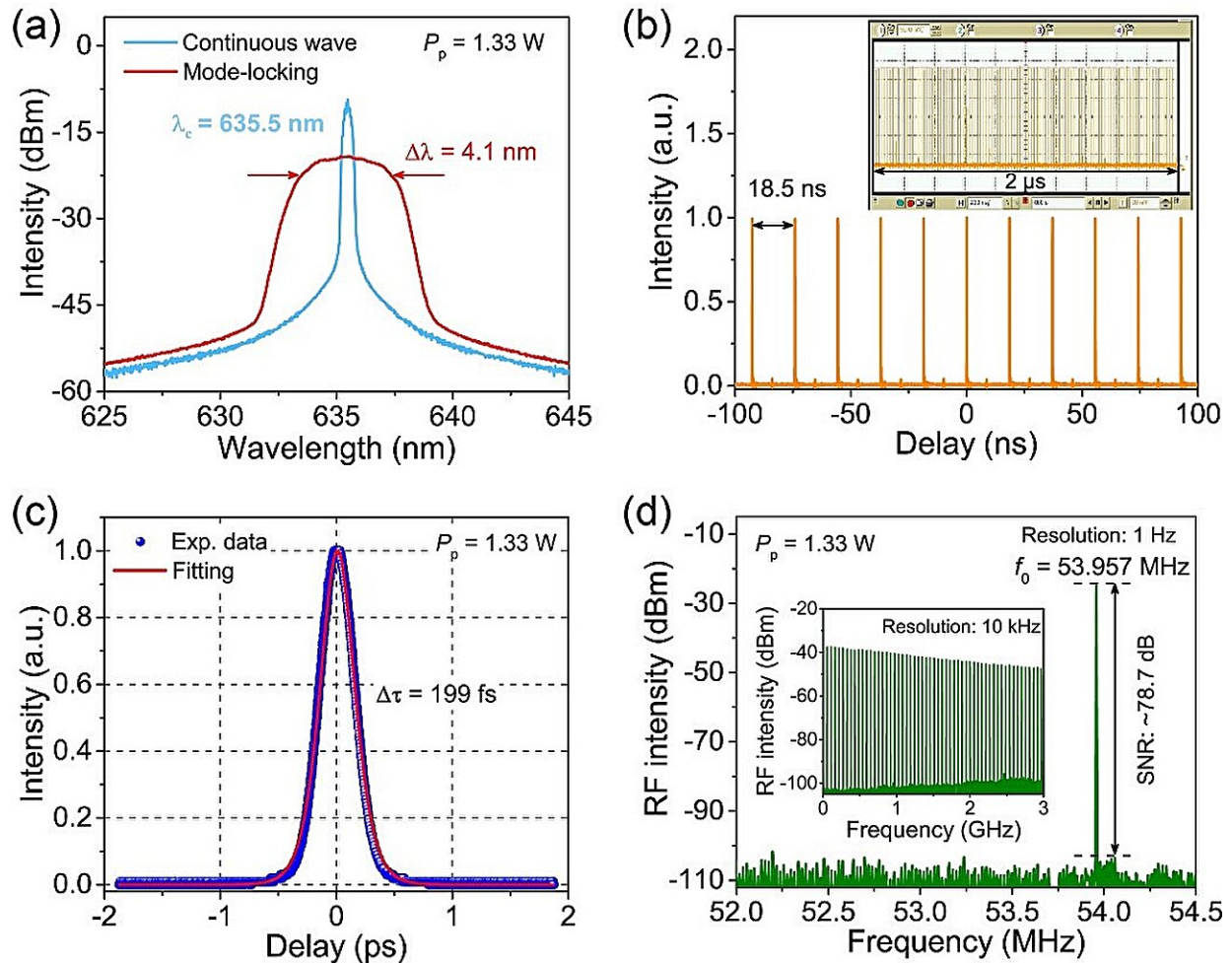
Currently, the majority of visible fiber lasers use rare-earth-doped fluoride fibers, such as Pr^{3+} , as the effective gain medium. Over the years, remarkable advancements have been made in developing wavelength-tunable, high-power, Q-switched and mode-locked visible fiber lasers.

However, despite the significant progress in the near-infrared region, achieving femtosecond mode-locking in visible fiber lasers remains an exceptionally challenging task. This challenge is attributed to the underdevelopment of ultrafast optics components at visible wavelengths, limited availability of high-performance visible modulators, and the extremely normal dispersion encountered in visible fiber laser cavities.

Recent attention has focused on femtosecond mode-locked fiber oscillators in near-infrared using a phase-biased nonlinear amplifying loop mirror (PB-NALM). PB-NALM eliminates the need for long intracavity fibers to accumulate phase shifts.

This innovation not only facilitates tuning flexibility and long-life operation but also provides an opportunity to manage the intracavity dispersion in a larger parameter space from normal to anomalous dispersion regimes. Consequently, it is anticipated to catalyze a breakthrough in direct femtosecond mode-locking of visible fiber laser

and propel fiber femtosecond oscillators into the visible band.



Typical characteristics of the visible-light femtosecond fiber oscillator. (a) Optical spectra of mode-locking and continuous wave operations. (b) Oscilloscope trace of the pulse train (inset: a screenshot of oscilloscope trace). (c) Autocorrelation trace of the output pulses. (d) RF spectrum at the fundamental frequency (inset: a broadband RF spectrum; 3 GHz span). Credit: J. Zou, Q. Ruan, et al.

Researchers from the Fujian Key Laboratory of Ultrafast Laser

Technology and Applications at Xiamen University recently developed a visible-light mode-locked femtosecond fiber oscillator and amplifier, [as reported](#) in *Advanced Photonics Nexus*.

The fiber femtosecond oscillator, which emits red light at 635 nm, employs a figure-nine cavity configuration. It applies a double-clad Pr³⁺-doped fluoride fiber as the visible gain medium, incorporates a visible-wavelength PB-NALM for mode-locking, and utilizes a pair of customized high-efficiency and high-groove-density diffraction gratings for dispersion management. A visible self-starting mode-locking established by the PB-NALM directly yields red laser pulses with a pulse duration of 199 fs and a repetition rate of 53.957 MHz from the oscillator.

Precise control of the grating pair spacing can switch the pulse state from a dissipative or stretched-pulse soliton to a conventional soliton. Additionally, a chirped-pulse amplification system built alongside the [oscillator](#) boosts the laser performance immensely, resulting in an average output power over 1 W, a pulse energy of 19.55 nJ, and a dechirped pulse duration of 230 fs.

Prof. Zhengqian Luo, head of the Electronic Engineering Department of Xiamen University, says, "Our result represents a concrete step toward high-power femtosecond fiber lasers covering the visible spectral region and could have important applications in industrial processing, biomedicine, and scientific research."

The authors anticipate that their new scheme for high-performance visible-light femtosecond fiber laser generation will lay the foundations for visible-light [femtosecond](#) fiber lasers to serve in applications such as special material precision processing, biomedicine, underwater detection, and optical atomic clocks.

More information: Jinhai Zou et al, 635 nm femtosecond fiber laser oscillator and amplifier, *Advanced Photonics Nexus* (2024). [DOI: 10.1117/1.APN.3.2.026004](https://doi.org/10.1117/1.APN.3.2.026004)

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