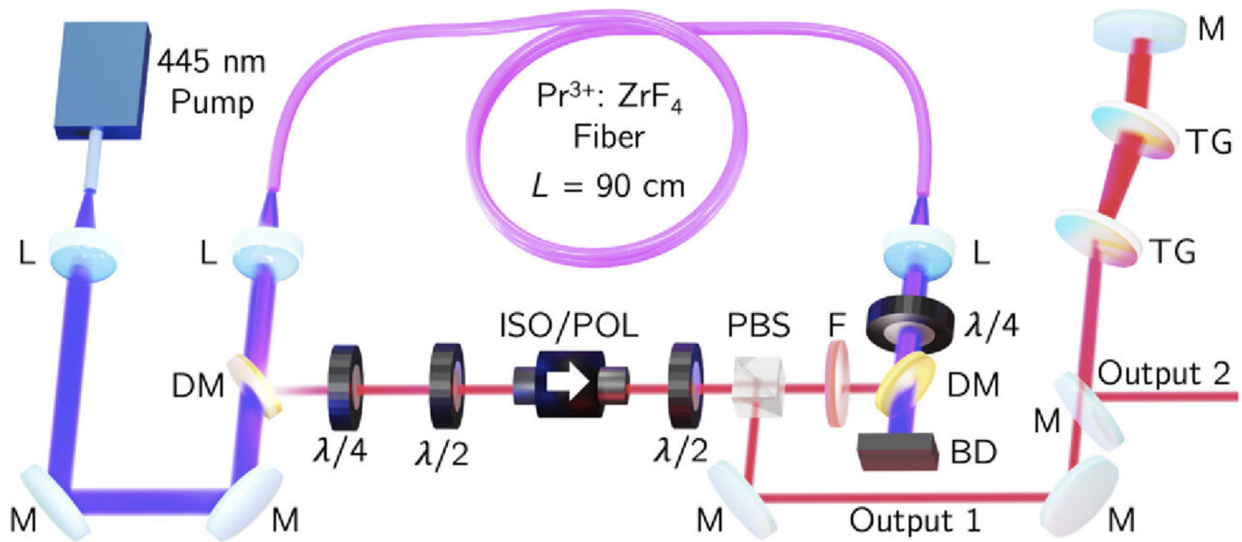
# Researchers demonstrate first visible wavelength femtosecond fiber laser

July 6 2023




Experimental setup of the fiber laser. BD, beam dump; DM, dichroic mirror; ISO/POL, polarizing optical isolator; L, lens; M, mirror; PBS, polarizing beam splitter; TG, transmission grating; ?/2, half-wave plate; ?/4, quarter-wave plate. Credit: *Optics Letters* (2023). DOI: 10.1364/OL.492671

Researchers have developed the first fiber laser that can produce femtosecond pulses in the visible range of the electromagnetic spectrum. Fiber lasers producing ultrashort, bright visible-wavelength pulses could be useful for a variety of biomedical applications as well as other areas such as material processing.

Visible femtosecond pulses are usually obtained using complex and inherently inefficient setups. Although fiber lasers represent a very promising alternative due to their ruggedness/reliability, small footprint, efficiency, lower cost and high brightness, it hasn't been possible, until now, to produce visible pulses with durations in the femtosecond ($10^{-15}$ s) range directly with such lasers.

"Our demonstration of a femtosecond fiber laser operating in the visible spectrum paves the way for a new class of reliable, efficient and compact ultrafast lasers," said research team leader Réal Vallée from Université Laval in Canada.

In *Optics Letters*, the researchers describe their new laser, which is based on a lanthanide-doped fluoride fiber. Emitting red light at 635 nm, the laser achieves compressed pulses with a duration of 168 fs, a peak power of 0.73 kW and a repetition rate of 137 MHz. Using a commercial blue laser diode as the optical source of energy, or pump source, helped make the overall design rugged, compact and cost-efficient.

"Provided higher energies and powers can be achieved in the near future, many applications could benefit from this type of laser," said Marie-Pier Lord a doctoral student involved in the project. "Potential applications include high-precision, high-quality ablation of biological tissues and two-photon excitation microscopy. Femtosecond laser pulses also allow cold ablation during material processing, a process that can make much cleaner cuts [than longer pulses] because it doesn't produce thermal effects."

## Getting visible light from fiber lasers

In a fiber laser, an optical fiber doped with rare-earth elements acts as the lasing medium. Although fiber lasers are among the most simple, rugged and reliable high-brightness laser systems, the use of silica fibers tends to limit them to near-infrared spectral region. Vallée's group has been working to extend the spectral range of these laser sources by using fibers made from fluoride instead of silica.

"We previously focused on developing mid-infrared fiber lasers, but recently gained interest in visible fiber lasers," said Lord. "Although the lack of compact and efficient pump sources for such lasers hindered their development for a long time, the recent advent of semiconductor-based laser sources operating in the blue spectrum has provided a key technology for the development of efficient visible fiber lasers."

After demonstrating fiber lasers that emit visible wavelengths continuously, the researchers wanted to extend the advance to ultrafast pulsed sources. Thanks to the refinement in the fabrication process of fluoride fibers, it is now possible to obtain lanthanide-doped fibers with properties that are essential for the development of efficient visible fiber lasers.

## Integrating technologies into a new laser

The new pulsed fiber laser developed by Vallée's team combines a lanthanide-doped fluoride fiber with a commercially available blue diode pump laser. To create and maintain a pulsed output, the researchers also had to figure out how to carefully manage the light polarization in the fiber.

"The development of a laser at a new wavelength, where the material properties of the optical components are different than those used previously, can sometimes be tricky," said co-author Michel Olivier.

"However, our experiments showed that the performance of our laser was in excellent agreement with our simulations. This confirmed that the system was well-behaved and understood, and that the important parameters of the system were characterized properly and well-adapted for pulsed lasers, especially the properties of the optical fiber that we used."

Next, the researchers would like to improve the technology by making the setup completely monolithic, meaning that the individual fiber-pigtailed optical components would all be directly bonded to each other. This would reduce the setup's optical losses, improve efficiency and make the laser more reliable, compact and robust. They are also investigating different avenues to improve the laser's pulse energy, pulse duration and average power.

**More information:** Marie-Pier Lord et al, Visible femtosecond fiber laser, *Optics Letters* (2023). DOI: 10.1364/OL.492671

Provided by Optica