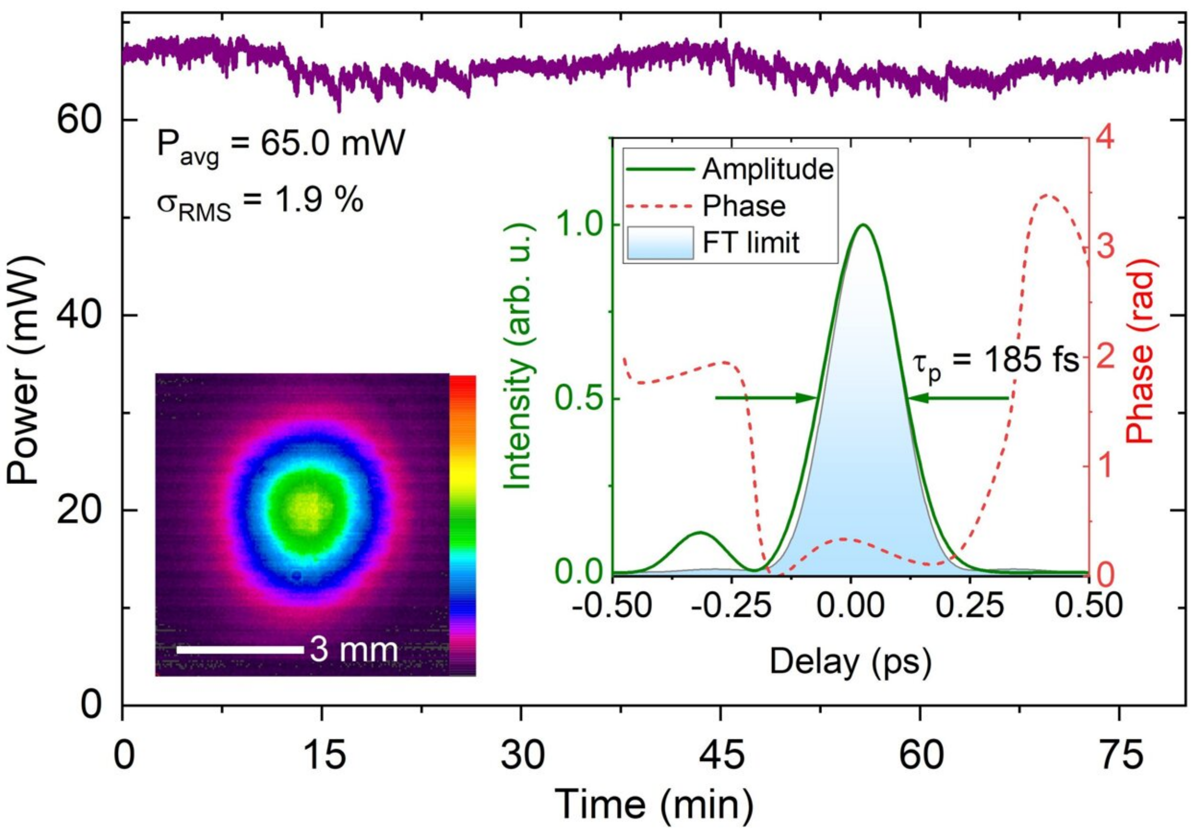
Intense femtosecond light pulses in the mid-infrared for spectroscopic and technical applications

November 21 2022



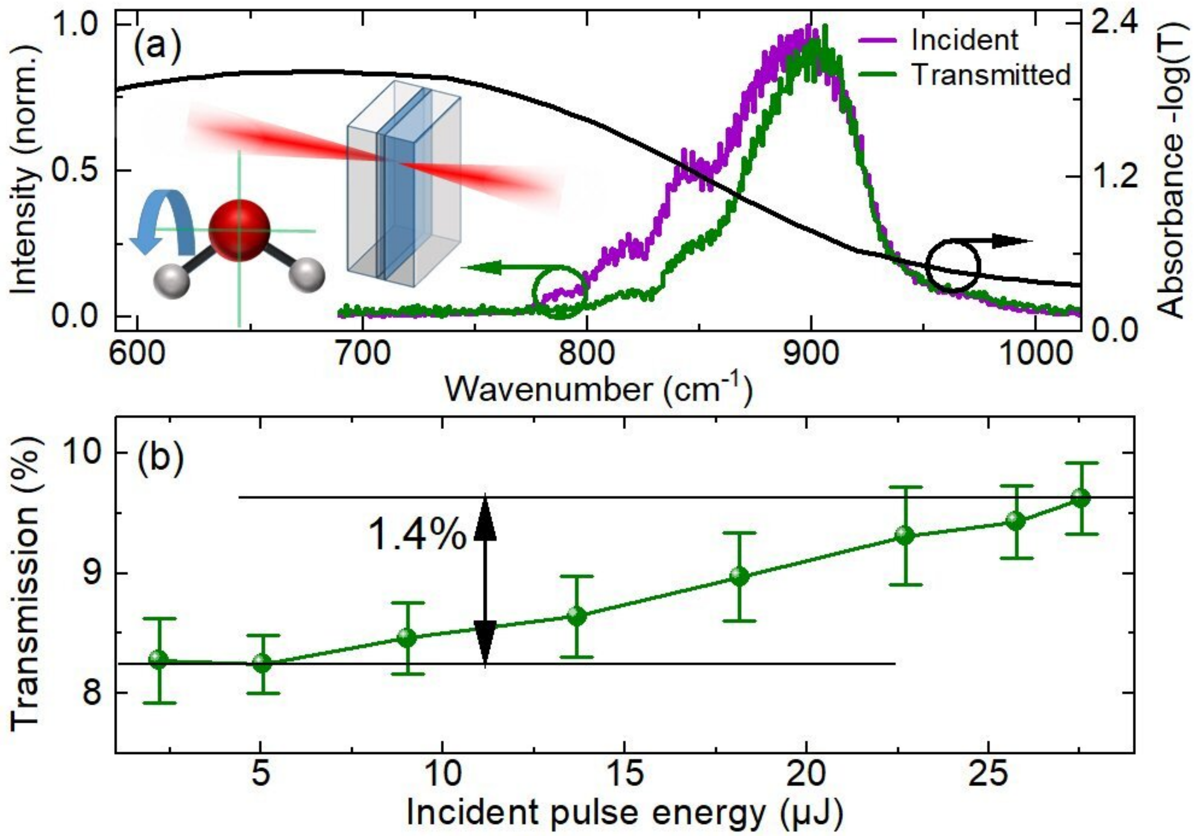
Characterization of the OPCPA pulse performance at 11.4 μm. Long-term pulse stability measurement. The average power is 65 mW, the standard deviation 6_RMS=1.9%. Left inset: Far-field intensity distribution. Right inset: Retrieved temporal pulse shape of the few-cycle pulse. Credit: *Optica* (2022). DOI: 10.1364/OPTICA.472650

A new light source generates ultrashort infrared pulses at wavelengths around 12µm with previously unattained peak intensity and stability. First experiments in vibrational spectroscopy on water demonstrate the high potential of the system for applications.

Ultrashort light pulses represent an important tool in basic research and have also found their way into numerous optical technologies. The infrared spectral range with wavelengths longer than 1µm plays a key role in optical communication, while pulses with wavelengths of up to 300 µm are required in optical measurement and analysis technology and in imaging techniques.

Extremely short pulses with only a few oscillation cycles of the light wave ("few cycle" pulse) are a particular technical challenge. Their generation requires precise control of the optical phase and their propagation conditions. Few-cycle pulses at wavelengths longer than 10 µm are important for fundamental studies of the non-equilibrium properties of condensed matter, i.e., solids and liquids, and exhibit a high application potential, for example in optical materials processing. As a result, the generation of such pulses is a cutting-edge research topic.

In the journal *Optica*, researchers from the Max Born Institute in Berlin report on a new light source that delivers ultrashort infrared pulses beyond 10µm wavelength with record parameters. The extremely compact system is based on the concept of optical parametric chirped pulse amplification (OPCPA), in which a weak ultrashort infrared pulse is amplified by interaction with an intense pump pulse of shorter wavelength in a nonlinear crystal.



Nonlinear transmission of liquid water (12 μm thick film held between two transparent windows) at the librational (L2) band (vibration indicated by the circular arrow). (a) L2 absorption of water (black line) and incident (magenta line) and transmitted (green line) spectra of the 11.4 μm pulses (energy: 25 μJ). (b) Transmission of the water sample as a function of incident pulse energy, showing a nonlinear transmission increase. Credit: *Optica* (2022). DOI: 10.1364/OPTICA.472650

In the novel light source, pump pulses of about 3ps duration at a wavelength of 2μm drive a three-stage parametric amplifier with a pump energy of 6mJ. The amplified pulses at a wavelength around 12μm have an energy of 65μJ and a duration of 185fs, corresponding to a peak power around 0.4 gigawatts (1 GW = 10^9 W) within about 5 optical cycles of the light wave. In the 1kHz train the pulses are highly stable and of excellent optical beam quality. Output power and repetition rate of the system are scalable.

The potential of this unique source was demonstrated in experiments on liquid water. For the first time, hindered rotations, so-called librations, of water molecules were excited to such an extent that their optical absorption decreased significantly. From the analysis of this absorption saturation, a lifetime of the librational excitation of 20 to 30fs is estimated.

More information: Pia Fuertjes et al, Few-cycle 65-µJ pulses at 11.4 µm for ultrafast nonlinear longwave-infrared spectroscopy, *Optica* (2022). DOI: 10.1364/OPTICA.472650

Provided by Forschungsverbund Berlin e.V. (FVB)