Efficient generation of relativistic near-single-cycle mid-infrared pulses in plasmas

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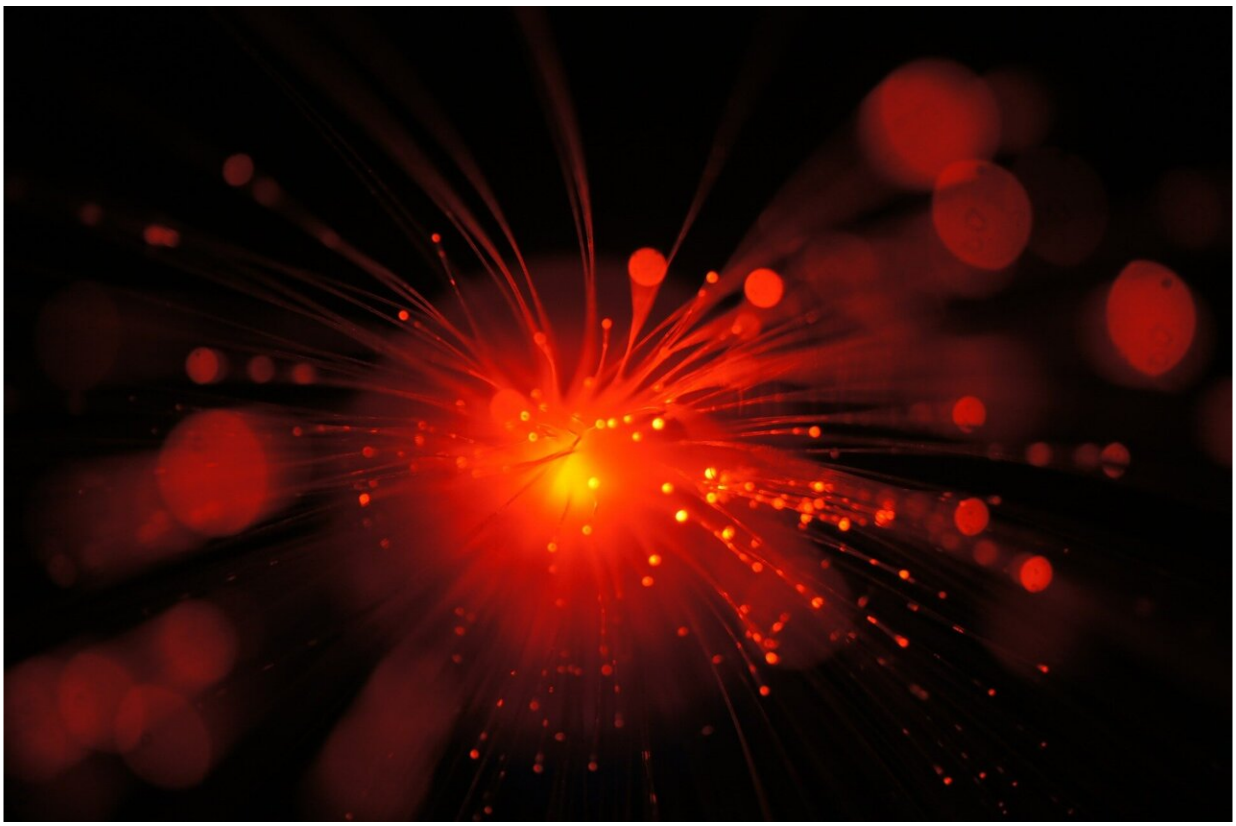

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The invention of the chirped pulse amplification technique by Strickland and Mourou in 1985 has boosted the peak power of ultrashort laser pulses to an unprecedented level, which have found broad applications in fundamental science, industry and medicine. However, such high power lasers are usually obtained at the near-infrared wavelength of about 0.8 micron. The extension to the mid-infrared band (2-20 microns) is of great interest to broader applications. At present, the generation of mid-infrared laser pulses based on conventional optical technologies is limited by the frequency bandwidth, energy gain, and damage threshold of the optical crystals, which make it challenging to achieve high-intensity low-cycle mid-infrared laser pulses.

In a new paper published in *Light: Science & Application*, scientists from the Shanghai Jiao Tong University, China and University of Strathclyde, UK proposed a new scheme to efficiently generate mid-infrared light pulses of near-single-cycle with a few millijoules in energy by use of a plasma medium. This scheme adopts two terawatt-level short-pulse lasers initially with wavelength of ~0.8 micrometers, which are incident into an underdense plasma channel with a certain time delay. One of them is used as a driving laser to excite a laser wakefield in the plasma, which appears as a few moving plasma density bubbles behind the driving pulse. Another laser pulse as the signal pulse co-propagates with the driving pulse with a certain time delay, so that it is loaded at the head position of the second plasma bubble. This signal pulse is modulated by the plasma bubble and its frequency will be down-shifted rapidly. After a propagation distance of about 2 millimeters, it is effectively converted into a near-single-cycle mid-infrared light pulse with a center wavelength of about 5 microns, and its conversion efficiency is as high as about 30%.

"An interesting aspect of our scheme is that the obtained mid-infrared pulse parameters, including pulse energy, central wavelength, pulse duration, carrier phase, and even polarization state, are tunable by changing the parameters of the incident laser pulse and plasma," said Zheng-Ming Sheng, one of the lead authors of the paper.

"Compared with traditional optical crystal materials, plasma-based optical methods can sustain extremely high power and intensity laser pulses," added Su-Ming Weng, another lead author of the paper. "This makes the plasma-based optical method unique in the manipulation of ultrashort high power lasers."

"Our scheme can be realized on a laser system with a kilohertz repetition rate, thereby providing a stable and efficient method to generate mid-infrared light pulses with millijoules, relativistic intensity, and near single cycle for wide applications," said Jie Zhang, one of the coauthors, the laser plasma program leader in Shanghai Jiao Tong University.

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