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Ytterbium thin-disk lasers pave the way for sensitive detection of atmospheric pollutants

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Alongside carbon dioxide, methane is a key driver of global warming. To detect and monitor the climate pollutants in the atmosphere precisely, scientists at the Max Planck Institute for the Science of Light (MPL) have developed an advanced laser technology. A high-power ytterbium thin-disk laser drives an optical parametric oscillator (OPO) to generate high-power, stable pulses in the short-wave infrared (SWIR) spectral range. This allows researchers to detect and analyze a wide variety of atmospheric compounds. This novel method can play a crucial role in tracking greenhouse gas cycles and the effects of climate change and was recently published in the journal APL Photonics.

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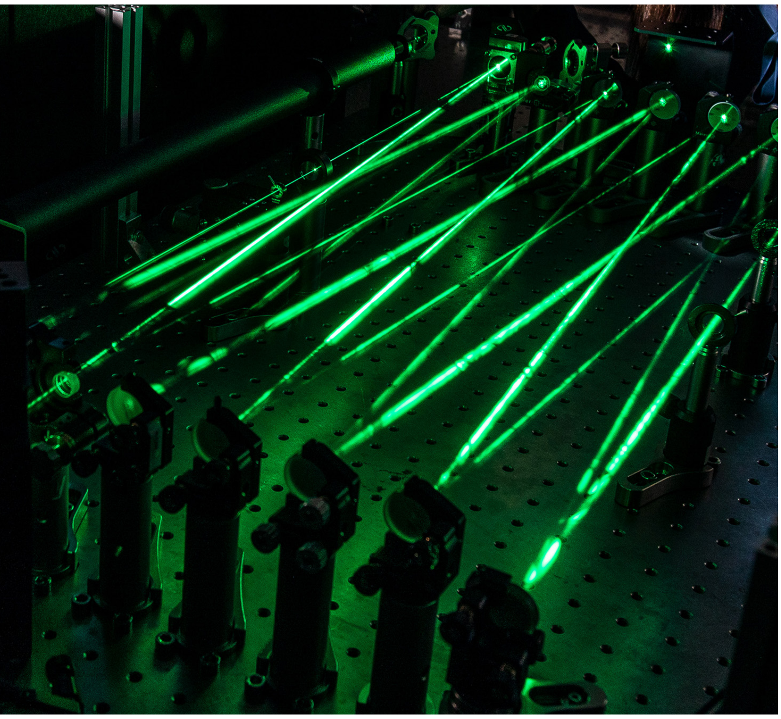
The optical parametric oscillator pump by ytterbium thin disk laser.



Short-lived pollutants play a critical role in global warming. For example, methane is of particular relevance to the global greenhouse effect because its warming potential is 25 times higher than that of carbon dioxide. However, detecting and monitoring these pollutants is challenging for two reasons. Firstly, water vapor interferes and overlaps with the absorption spectra of many gases in the standard infrared ranges normally used for detection. Secondly, these pollutants are difficult to detect due to their volatile presence in the atmosphere. By targeting the SWIR range, where pollutants such as methane absorb strongly while water absorption remains minimal, the new laser system offers unprecedented detection sensitivity and accuracy.

Central to this innovation is the ytterbium thin-disk laser, which produces high-power, femtosecond pulses at megahertz repetition rates. This allows the system to pump an OPO, converting laser pulses to the SWIR range with remarkable power and intensity. Operating at twice the repetition rate of the pump laser, the OPO delivers stable, tunable SWIR pulses optimized for high-sensitivity spectroscopic applications. The team's pioneering approach also integrates broadband, high-frequency modulation of the OPO output, which allows the enhancement of the signal-to-noise ratio, providing even greater detection precision.

"The output of our laser system can be scaled to higher average and peak power, due to the power scalability of ytterbium thin-disk lasers. Employing the system for the accurate detection of pollutants in real time allows deeper insights into greenhouse gas dynamics. This could help address some of the challenges we face in understanding climate change." said Anni Li, PhD student at the MPL.

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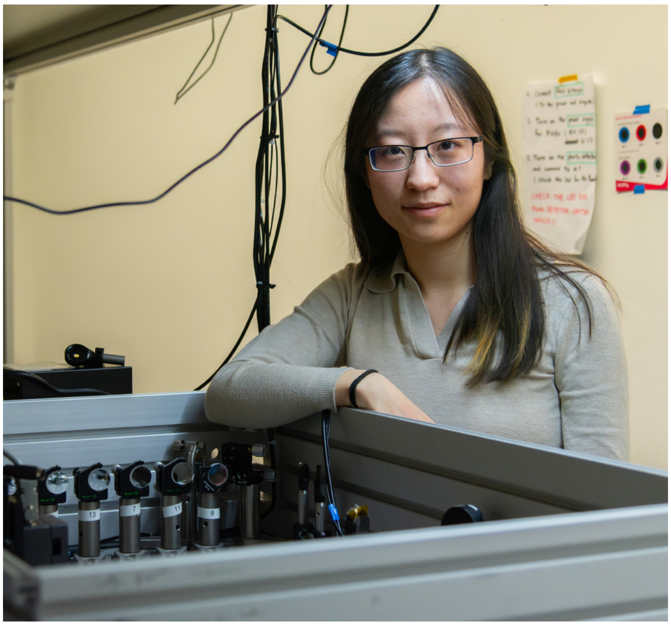
The laser's capacity to generate high-power, stable pulses in the SWIR range is a game-changer for field-resolved spectroscopy and femtosecond fieldoscopy, methods which enable researchers to detect and analyze a wide range of atmospheric compounds with minimal interference.

"This new technology is not only applicable to atmospheric monitoring and gas sensing, but also holds potential for other scientific fields such as earth-orbit communication, where high bandwidth modulated lasers are required." said Dr. Hanieh Fattahi, the lead researcher on the project. The researchers plan to develop the system further with the goal of creating a versatile platform for real-time pollutant monitoring and earth-space optical communications.



Anni Li, Doctoral Student in the research group ›Femtosecond Fieldoscopy‹ led by Dr. Hanieh Fattahi

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