SUCCESS STORY

Contact:
tech.sales@coherent.com
www.coherent.com

Astrella Enables CARS Spectroscopy Targeting Greener Energy and Propulsion

The Challenge

From power generation to mobility applications, a better understanding of combustion processes can help increase efficiency and lead to reduced emissions. A key step in achieving this understanding is to perform highly detailed mapping of combustion flame temperature and chemistry. State-of-the-art laser diagnostics for precise scalar determination are required to resolve pollutant formation and to reveal insight into energy transformation mechanisms that can help to make propulsion systems or other combustion technology more "green" and sustainable. Currently, the best method for remotely probing high flame temperatures is Coherent Anti-Stokes Raman Spectroscopy (CARS). But this is a highly complex technique, which must be performed in a laboratory by a well-trained laser operator. A team led by Dr. Alexis Bohlin at Delft University of Technology (the Netherlands) set out to develop a simpler method that could be more widely deployed. The Coherent Astrella one-box ultrafast regenerative amplifier laser system turned out to be a key enabler in their work.

The Solution

Dr. Bohlin explains, "The challenge is that the best pure-rotational CARS technique requires both femtosecond pulses for impulsive excitation of the gaseous molecules in the sample, and picosecond pulses for probing them. And, because of the high temperature of the flame, the molecules are present at low number densities. This requires laser pulses of very high power, which should ultimately be near "transform limited" in pulse length, and essentially be perfectly synchronized in terms of phase. Doing this with multiple laser sources is less practical, but with the impressive output from the Astrella, we saw another solution and that was to use it as a single laser source." In their experimental setup, the Astrella output is split, with 35% of the output compressed to 35 fs pulses used for impulsive excitation (with constructive two-photon pairs provided within the bandwidth), while the remaining 65% is used to create ps probe pulses efficiently with second harmonic bandwidth compression (SHBC). Here the use of a home-built 4f pulse shaper in transmission enables smooth tuning of the probe pulse duration from about 2 ps up to about 15 ps, as needed for optimum spectral resolution of different chemical species and flame conditions. Since the pulses originate from a single ultrafast source, these are automatically synchronized at the measurement location in the flame, and their high energy content permits 1D-imaging by forming the focused beams as light sheets.

The Result

Using their pure-rotational CARS imaging method, the Bohlin group successfully obtained high spatial and temporal resolution data on the temperature of an unstable premixed methane/air flame-front. Specifically, they demonstrated 1 kHz cinematographic 1D-CARS quantitative thermometry obtained with a single-shot precision of <1% and an accuracy <3%. [1] Dr. Bohlin summarizes, "There are many diagnostic challenges for precision thermometry in the world, including 'exotic' examples like aerodynamic heating in shock tubes and reactive engines for launching into space. In the past, you had to somehow bring these applications to the lab, but with our streamlined system based on a single Astrella ultrafast source, it should be possible to take the instrument to the applications, with potentially game-changing implications."

"I love the turnkey aspect of the Astrella. We spend less time optimizing laser pulses and more time using laser pulses. It's that simple."

—Dr. Alexis Bohlin
Delft University of Technology, the Netherlands