Multi-Photon Multi-Chemical-Species Imaging Using Femtosecond Laser Pulses

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Abstract:
Reactive atomic species such as hydrogen (H), oxygen (O), and nitrogen (N) play a crucial role in chemical reactions in combustion and plasma systems. However, quantitative imaging diagnostics of these species are incredibly challenging because of their low number densities and associated complexities in laser-based excitation/detection schemes. In this talk, we discuss novel approaches for utilizing ultrashort, femtosecond (fs) duration laser pulses for kilohertz (kHz)-rate imaging of key atomic as well as selected molecular species in flames and plasmas. Femtosecond, two-photon laser-induced fluorescence (fs-TPLIF) of H, O, and N are facilitated by excitation using deep-UV fs pulses followed by fluorescence detection in the visible or near-infrared wavelengths. Some recent advances of fs-TPLIF for photolytic-interference-free, kHz-rate, two-dimensional imaging of H and O in flames and plasmas are presented. Subsequently, fs-TPLIF of carbon monoxide (CO) imaging diagnostics are discussed by using 230.1-nm excitation of the $B^1\Sigma^+ \leftarrow X^1\Sigma^+$ electronic transition of CO. Specific temporal and spectral filtering approaches are implemented for minimizing interferences in challenging flame conditions involving soot and liquid fuel sprays. Furthermore, we have recently extended fs-duration laser pulses for kHz-rate imaging of key flame radical, hydroxyl (OH). Broadband, 283-nm wavelength, 80-fs-duration laser pulses are used for excitation of a large number of rovibrational transitions in the OH $A^2\Sigma^+ \leftarrow X^2\Pi$ (1, 0) band, followed by LIF imaging from (0,0) and (1,1) vibrational manifolds. Following initial spectral characterization, single-laser-shot, 1-kHz, OH-PLIF imaging in turbulent flames is reported. Also outlined are the future opportunities and challenges of broadband fs pulses for multi-species, multi-photon imaging diagnostics in realistic reacting flows.

Short Bio:

Dr. Waruna Kulatilaka is an Associate Professor and Morris E. Foster Faculty Fellow I in the Department of Mechanical Engineering at Texas A&M with a joint courtesy appointment in the Department of Aerospace Engineering. His primary research activities are focused on the development and application of advanced optical and laser-based diagnostics for combustion, propulsion, plasma, and remote sensing applications. In recent years, he has pioneered the development of ultrashort-pulse multi-photon imaging techniques for highly reactive atomic species such as H, O, and N in flames and plasmas. He and the associated research teams have made significant contributions to laser diagnostics including, LIF, CARS, polarization spectroscopy, LIBS, and wave-mixing techniques, using nanosecond, picosecond, and femtosecond pulsed lasers, that are reported in over 60 peer-reviewed journal publications and numerous conference papers. Prior to the current appointment, Dr. Kulatilaka was a Senior Research Scientist/On-Site Contractor at the Air Force Research Laboratory at the Wright-Patterson Air Force Base, OH (AFRL/RQTC) for over five years, and also completed a two-year postdoctoral research term at the Combustion Research Facility (CRF) at the Sandia National Laboratories, Livermore, CA. He is active in numerous professional organizations, including ASME (Fellow), AIAA (Associate Fellow), OSA (Senior Member), and the Combustion Institute (Board Member–Central States Section), and has also won several notable awards for research excellence.