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Advancing Fire Science with Optical Frequency Comb Spectroscopy

Optical Frequency Combs (OFCs) seamlessly integrates accurate phase information in the frequency domain and ultrafast temporal information in the time domain. Serving as high-accuracy optical frequency synthesizers, OFCs facilitate fundamental scientific discoveries and drive the world's most accurate atomic clocks. At the same time, with their superior spectroscopic coverage and narrow linewidth, they have revolutionized molecular spectroscopy, offering unprecedented speed and sensitivity. In contrast to traditional methods that involve scanning with a single-frequency laser, OFC technology enables the simultaneous generation and resolution of over a million frequencies. This capability allows for the massively parallel interrogation of thousands of molecular absorption lines, offering a potential enhancement in performance by up to five orders of magnitude compared to conventional laser spectroscopy techniques.

Our project utilizes OFC spectroscopy to explore fire activities, encompassing molecular composition, dynamics, and real-time monitoring. In this poster, I will present preliminary results from a prototype experimental platform designed for rapid and sensitive detection of water vapor in a glass vapor cell and in the air. We have constructed the entire platform from scratch, including vapor cells, lasers, detectors, electronics, and the experimental control system. Our design prioritizes portability and reliability, distinguishing it from conventional laboratory setups and paving the way for on-field studies of wildfires. Alongside these initial findings, I will present a comprehensive roadmap for developing a broadband, ultrasensitive, and portable experimental system aligned with our long-term objectives. Additionally, I will touch on the potential interdisciplinary applications of our system in astrophysics.