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Optical Spectroscopy of Fireballs from Aluminized High Explosives¹

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Fireballs produced by explosive detonations in air generate a challenging environment in which to make measurements. Fireballs are typically optically thick, have high inherent luminosity, and exhibit high temperatures and pressures, making many combustion probes impractical for fireball applications. Nevertheless, characterizing the thermochemical environment within the fireball is of critical importance to the development of novel energetic systems, especially those for bioagent defeat or those designed for sustained overpressure (e.g. thermobarics). We have recently been able to quantify optical depth in aluminized fireballs during the time period of reaction of the added aluminum. We have found that attenuation lengths during this early period are of the order of a few centimeters. These measurements suggest that for similar explosives, optical probes (e.g. emission spectroscopy measurements, optical pyrometry) will sample only the outer few cm of the fireball. Thus, conditions near the air/detonation products interface will be over-represented in the measurement, and therefore oxidation reactions and temperatures may be over-estimated. Our second experiments involve multicolor pyrometry as a fireball diagnostic. Despite its apparent simplicity, accurate pyrometry measurements require information on emissivity variation with wavelength. We apply the UIUC heterogeneous shock tube to measure $\epsilon(\lambda)$ for alumina at elevated temperature. We find that $\epsilon(\lambda)$ changes significantly with temperature, starting at approximately $\epsilon \sim 1/\lambda$ at 2000 K and moving towards grey behavior at 3000 K. Based on these results, we present an optimized strategy for pyrometry of aluminized fireballs that works in the limit of optically thin or optically thick fireballs. Finally, we have developed a new broadband dye laser absorption technique that generates light pulses of very high spectral irradiance such that, even when the pulses are attenuated by 99%, the transmitted light is still enough to disperse into a high resolution absorption spectrum. We demonstrate this technique on a very optically dense Al/Bi₂O₃ explosive mixture, showing clear evidence of the ability to monitor key intermediates such as gas phase Al with detection limits at the ppb level and time resolution on the scale of nanoseconds.

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