Optical Diagnostics for the Study of Propellants and Energetic Materials

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Extended Abstract

When energetic materials are ignited, shock waves, smoke trails, metal particles, flame zones, and high temperature gases are generated. In order to study the complex ignition, deflagration, and detonation mechanisms in these systems, new optical diagnostics are needed. Advances in optical techniques have enabled the measurement of both scalar and vector quantities in complex high speed, multiphase, and reacting flows. Solid rocket propellants and explosives, however, present unique challenges due to their high speed reactions, extreme temperatures, high optical densities, and complex compositions. In this paper, quantitative optical diagnostics designed specifically for making measurements in these harsh environments are reviewed. Recently, single point and line-of-sight integrated temperature, pressure, and composition of metallized energetic materials have been studied using laser induced breakdown spectroscopy, tunable diode laser absorption spectroscopy, interferometry, and coherent anti-Stokes Raman spectroscopy (CARS). New diagnostic techniques like line and two-dimensional (2D) CARS, 2D absorption spectroscopy, and multi-color imaging pyrometry have also been used to image complex combustion systems in order to elucidate detailed multiphase interactions. For three-dimensional (3D) measurements, volumetric laser-induced fluorescence, laser-induced incandescence, Rayleigh scattering, background-oriented Schlieren, plenoptic imaging, and x-ray techniques have also been developed. For environments plagued by severe temperature gradients and shock waves, however, techniques with distortion cancellation capabilities are needed. Here, we discuss both traditional digital holographic techniques and holographic phase distortion correction methods for accurate particle sizing, 3D particle localization, and particle velocity estimation in metalized energetic materials. Additional optical techniques focused on in-situ smoke particle sizing and strain measurements are also discussed along with enabling technologies like burst mode lasers, ultra-high-speed cameras, wavelength modulation, and spatial encoding methods. Finally, the future of optical diagnostic development specifically for studying propellants and energetic materials are discussed.

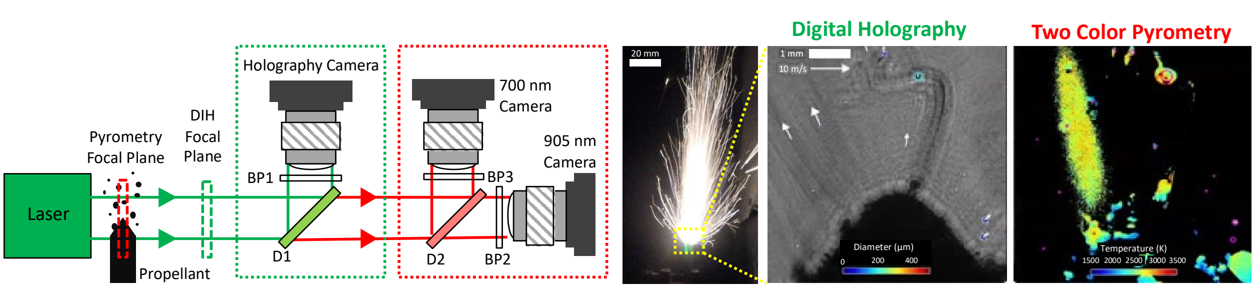

Figure 1: *Optical diagnostics for simultaneously quantifying particle location, size, velocity, and temperature in an aluminized solid rocket propellant flame are shown. Here, digital holography and two color imaging pyrometry are utilized.*