Raman-Shifting an ArF Excimer Laser to Generate New Lines for Obtaining Optical Diagnostic Based Information in Flow Fields

by

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The application of tunable excimer lasers in combustion and flow diagnostics is almost routine nowadays. The properties of this laser system that enable density and temperature measurements in supersonic and hypersonic flow fields to be conducted are; its high power, high repetition rate and high spectral brightness. The limitation imposed by this system on these measurements is the paucity of lines in the wavelength region, the vacuum-ultraviolet, where species of interest, such as OH, N_2, O_2, H_2, H_2O, CO, NO, etc., are susceptible to electronic excitation to high-lying states. To circumvent this problem one normally resorts to non-linear optical techniques such as frequency conversion via stimulated Raman Scattering (SRS), more commonly known as Raman-Shifting or Raman Mixing, to extend these non-intrusive and non-perturbing techniques to the shorter wavelengths in the VUV region and, for that matter to longer wavelengths in the infrared region, if the need arises.

The theoretical basis of SRS and its application are well documented in the literature. In essence, the Raman shift is a consequence of the inelastic scattering of the incident radiation by the sample. Most of the scattered radiation from the molecules of the sample is unchanged in frequency. However, a small fraction of the incident radiation is changed in frequency. This shift is a result of the fact that some of the incident photons on colliding with the molecules of the sample give up some of their energy and emerge with a lower energy resulting in the lower-frequency Stokes radiation. Other incident photons may increase their energy by colliding with the vibrationally excited molecules of the medium and emerge as higher-frequency anti-stokes radiation. The generation of the latter is the main objective of this project.

The process, however, depends on several factors, including the beam quality of the pump laser; the cross-section of the gaseous medium; the gas pressure, and the ambient temperature of the gas near the focal region. Furthermore, since the Raman-Shifting process is polarization sensitive, it is necessary to have all of the laser energy in a single polarization. These factors were taken into consideration in the execution of the project.

The implementation of the Raman-Shift was accomplished by focusing the 193nm output of an ArF excimer laser (Lamda-Physik LPX 150) into a 1-meter long high pressure recirculating Raman cell filled with H_2 gas. The laser system was modified in order to improve the mode quality of the pump beam to enhance the Raman-Shifting. To accomplish this feat, a prism beam expander and grating on the oscillator discharge provided wavelength tuning over the excimer gain profile. Furthermore, a triple-pass configuration, as opposed to unstable resonator optics, was employed in the operation of the amplifier cavity so that when the oscillator output radiation, focused by a 51-cm focal length fused silica lens through a 50 μm pinhole (serving as a spatial filter) and recollimated with a 25-cm focal length lens, was fed into the amplifier, it was injection locked, thereby providing tunable radiation with relatively low divergence.

The forward scattered radiation emanating from the impingement of the modified pump beam on the Raman cell was detected using an energy meter after the latter had been separated from it using a dispersing prism. Work is in progress to measure the conversion efficiency in this gaseous medium as a function of focusing geometry, gas pressure, and speed of the recirculating fan, as well as extending the technique to other gaseous samples such as deuterium, methane, nitrogen, and carbon monoxide.