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Thesis abstract

Development of instantaneous temperature imaging in sooty flames

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Temperature is a dominant parameter in combustion processes. Temperature characterises the enthalpy of reaction and controls many of the important chemical and physical processes, which also influence composition of the combustion products. Laser diagnostics are the preferred tool for measurement of many flame parameters, including temperature. The laser-based diagnostic techniques have the potential to provide in situ, nonintrusive, temporally, and spatially precise, information that is unrivalled by alternative methods. A variety of laser-based thermometry techniques have been developed. However, most of these techniques are best suited to clean combustion environments and have restrictions in the presence of particles, such as dust, coal, biomass and soot. This limits the capacity to investigate and understand many systems of practical significance.

Two-line atomic fluorescence (TLAF) is a laser thermometry technique based on the relative temperature-dependent population of two energy levels within an atomic species. The temperature is deduced from the ratio of the fluorescence signals associated with the transitions. Not only does TLAF offer two-dimensional measurements, the inelastic nature of the TLAF technique, when spectrally shifted emissions are used, enables filtering to be used to minimize interferences from spurious scattering, thus allowing measurements to be performed in particle-laden environments. Of the atomic species available, indium seeded into the flame has been identified as a suitable thermometry species for TLAF. The TLAF technique in the linear excitation regime has previously been demonstrated to be feasible in sooty environments. Under such conditions, the linear TLAF results are plagued by low signal-to-noise ratio (SNR), thus preventing useful single-shot imaging that requires higher SNR.

This dissertation reports on the single-shot temperature imaging in sooty flames, based on the development of two-line atomic fluorescence in the nonlinear excitation regime (NTLAF), with neutral indium atoms as the seeded thermometry species. A series of systematic studies have developed the NTLAF and demonstrated its applicability to a range of flames, especially flames containing soot. Aspects of NTLAF that have been investigated include seeding concentration, linearity limits, effect of flame stoichiometry (Medwell et al. (2009)), effect of soot (Chan et al. (2011a)), and a comparison of different solvents (Chan et al. (2010)). The NTLAF thermometry technique has been shown to provide temperature measurements that are comparable with alternative techniques (Medwell et al. (2010)). More recently, with the use of an optimal solvent, it has been

demonstrated that the single-shot uncertainty of the technique can be reduced down to ~60 K (Chan et al. (2011b)). The technical feasibility of the NTLAF technique to be used concurrently with laser-induced incandescence (LII) technique, to provide simultaneous single-shot imaging of temperature and soot concentration has also been demonstrated (Chan et al., 2011b).

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