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Klein Douwel, R.J.H.; Luque, J.; Jeffries, J.B.; Smith, G.P.; Crosley, D.R.

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LASER-INDUCED FLUORESCENCE OF CH AND CH$_2$O IN ATMOSPHERIC PRESSURE METHANE/AIR BUNSEN FLAMES

Robert J.H. Klein-Douwel, Jorge Luque, Jay B. Jeffries, Gregory P. Smith, and David R. Crosley

Molecular Physics Laboratory, SRI International
333 Ravenswood Avenue, Menlo Park, California 94025

Laser-induced fluorescence of CH B$^3\Sigma^+$$v'$=1 is excited in atmospheric pressure Bunsen flames using rotational levels above and below the predissociation limit. There is significant rotational, vibrational, and electronic energy transfer even when levels above the predissociation limit are excited. At atmospheric pressure rotational energy transfer produces a variation in the fluorescence quantum yield with rotational level and gas temperature. Laser-induced fluorescence of CH$_2$O exciting A-X 4,$^0$ allows formaldehyde detection at an excitation wavelength quite near (and often overlapped) with the CH B-X (1,0). The formaldehyde structure is contained inside the CH in the premixed inner cone of the Bunsen flame. Excitation of CH$_2$O A-X 4,$^0$ provides an LIF strategy that minimizes the variation of the population of the excited level over the 700-1800 K temperature range important in the flame.

INTRODUCTION

Partially premixed Bunsen type flames form the mode of combustion of nearly all the natural gas consumed in residential appliances and the vast majority burned in small commercial applications, such that usage constitutes over 25% of U.S. natural gas consumption. These flames consist of two stages: a rich premixed flame forms an inner cone and a lean diffusion flame constitutes an outer cone. These partially premixed flames are a key target of present and future pollutant emission regulation. NOx emissions will be the subject of increasingly stringent requirements, and it is likely that CO, aldehydes and aromatics will also come under scrutiny. The consequences of operation under marginal conditions are of particular concern for NOx and air toxics. Understanding the structure of these flames can provide guidelines for burner design efforts to meet the regulatory requirements while still maintaining reasonable efficiency.

A model burner has been designed to study a partially premixed Bunsen flame using laser-induced fluorescence (LIF) diagnostic techniques. The emphasis of the measurements is an understanding of the flame structure and the chemistry leading to pollutant formation. The diagnostics focus on measurements of CH as a marker of the premixed flame front and the key precursor to prompt NO, and on formaldehyde as a potential air toxic from incomplete hydrocarbon combustion. Our strategy for CH measurement uses excitation of predissociative transitions in the B-X (1,0) band with detection of (1,1) fluorescence, attempting to minimize quenching effects on quantitative determinations at atmospheric pressure. The existence of non-predissociative and highly predissociative rotational levels in the same vibrational state provides a unique scenario to test the effects of rotational relaxation (and vibrational and electronic energy transfer as well) in laser-induced fluorescence measurements. The existence of an overlapping hot band excitation of formaldehyde, A-X 4,$^0$, allows simultaneous or near-simultaneous detection of this species. The temperature bias encountered with the usual ground state excitation strategy is largely avoided by using this band. After discussing diagnostic development and application, planar LIF (PLIF) images in Bunsen flames are presented.