High Enthalpy Flow Visualization

using Laser Induced Fluorescence of Nitric Oxide

M. Kirschner, T. Sander, C. Mundt, Institute for Thermodynamics,
University of the Federal Armed Forces Munich, (June 2013)

Application Note

Laser induced fluorescence using the A-X(0,0) band for excitation is a promising approach to examine high enthalpy flow. Spectroscopic investigations within this excitation wavelength band intend to identify appropriate transitions that maximize fluorescence signal and minimize possible interference with other species. First results from qualitative measurements of nitric oxide in a test cell are presented.

1. Introduction

Ground based facilities offer the only practical means for investigation of high enthalpy real gas effects and the simulation of flow properties that prevail during re-entry or high speed vehicles flying through the atmosphere of the earth or that of other planets. An arc heated plasma wind tunnel (total enthalpy up to 20 MJ/kg) is operable at the Institute for thermodynamics at the University of the Federal Armed Forces Munich.

An arcjet flow presents a challenging environment for conducting measurements since it is a chemically reacting high enthalpy flow. In context of a plasma wind tunnel, laser induced fluorescence provides qualitative and quantitative flow field visualization and characterization, hence numerical simulations and radiation models can be verified and validated.

2. Theoretical Background

Considering a molecular system, where rotational relaxation is either frozen or completely equilibrated, a two level energy model would be appropriate to describe the fluorescence signal. Relation (1) shows the dependency of the NO LIF intensity F_{LIF}, as long as the fluorescence is linear to the input laser irradiance E_{Laser} (linear regime).

$$F_{\mathrm{LIF}} = E_{\mathrm{Laser}} \frac{h\nu}{c} \frac{\Omega}{4\pi} A\, l\, N_1^0\, B_{12} \frac{A_{21}}{A_{21}+Q_{21}} \qquad (1)$$

where $h\nu$ is the photon energy, h Planck's constant, ν the frequency of the emitted fluorescence, c the speed of light, Ω the collection solid angle, A the area of the focused laser beam, l the length of the measurement volume, N_1^0 the state population density of the NO molecules before excitation, B_{12} the Einstein coefficient for absorption and $q_F = A_{21}/(A_{21}+Q_{21})$ the fluorescence quantum yield, with decay rates A and Q. For the selection of suitable excitation wavelengths, highly populated rotational levels, sufficient laser energy, and high Einstein coefficients for absorption have to be considered.

3. Experimental Method

Laser light from a Nd:YAG pumped (Quanta-Ray Pro-290, pulse energy 550 mJ, wavelength 355 nm, repetition rate 10 Hz) dye laser (Radiant Dyes, Coumarin 47, frequency doubled by a BBO) is used for the excitation of the NO molecule. The laser light sheet is formed with a spherical lense (f = 500 mm) and a cylindrical lense (f = -50 mm). The induced fluorescence signal is collected perpendicular to the plane of the laser light sheet, focused with a lense (f = 200 mm) and detected by an ICCD camera (Andor DH334T-18F-E3).

4. Results

In order to find strong transitions for NO visualization, the laser is tuned across the absorption lines and the total fluorescence is monitored. An excitation spectrum measured at a temperature of 293 K with the aid of a NO-containing test cell is shown in Fig. 1a in comparison to a simulated spectrum shown in Fig. 1b. The good agreement between measured and simulated spectrum hereby confirms the technical feasibility of the method and hardware chosen.

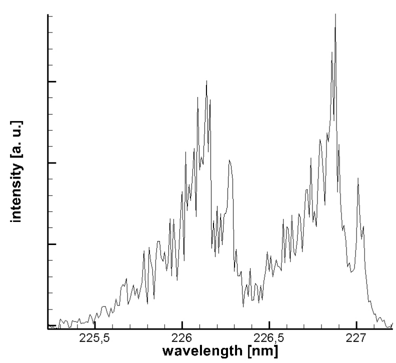

Fig.1a Measured excitation spectra of NO.

High Enthalpy Flow Visualization

using Laser Induced Fluorescence of Nitric Oxide

M. Kirschner, T. Sander, C. Mundt, Institute for Thermodynamics,
University of the Federal Armed Forces Munich, (June 2013)

Application Note

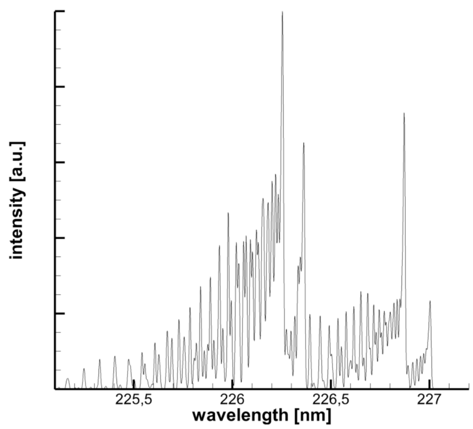

Fig. 1b Simulated excitation spectra of NO [LIFBase].

Contact
Dr.-Ing. Tobias Sander
Institute of Thermodynamics
University of the Federal Armed Forces Munich
85577 Neubiberg,

Phone: +49 (0)89 6004 4118
E-mail: tobias.sander@unibw.de