X-ray Induced Fluorescence in High-Intensity Lighting Plasmas

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Introduction

High-intensity discharge (HID) lighting is one of the most energy-efficient, good color-rendering, light source technologies available. There is a great deal of scientific interest in this technology as result of the prospects for continued improvements, particularly in the area of energy efficiency. Increased understanding of the physics of these complex systems is sought to enable such improvements.

The availability of a high flux of high-energy photons from the Advanced Photon Source has stimulated consideration of the possible use of a variety of nonperturbing x-ray diagnostics for examination of high-intensity discharge plasmas. In recent work at the APS, we demonstrated that high-energy x-ray induced fluorescence can be used to study the quantities and distributions of light-producing atoms in a commercial HID lamp.[1]

Experiment and Results

Figure 1 shows one of the commercial high-intensity discharge lamps examined in these experiments. At operating temperatures (1000 – 10,000 Kelvin), the vapor in the arc tube consists primarily of Hg at approximately 10 atmospheres of pressure, but also contains trace amounts of Dy and Cs atoms arising from the metal-halide salts DyI_3 and CsI. Although present in only trace quantities, Dy and Cs are responsible for most of the visible light production. The lamp also has an outer glass jacket that is used to retain heat.

The SRI-CAT 1-ID undulator beamline was used for these measurements. The incident photon energy is tunable from 45 to 100 keV with an energy spread of $\Delta E/E=10^{-3}$ and a nominal photon flux of 10^{12} photons/sec.[2]

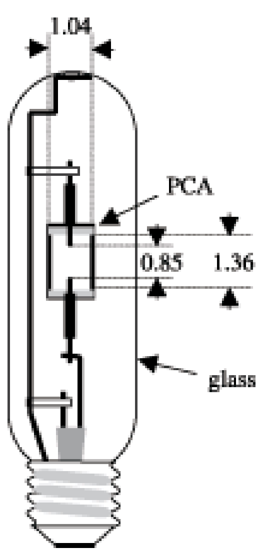

FIG. 1. The 150 watt metal-halide lamp used in the present experiment. The polycrystalline alumina (PCA) arc tube is dosed with 90 torr of Ar, 16 mg of Hg, 6.8 mg of DyI_3, and 1.2 mg of CsI.

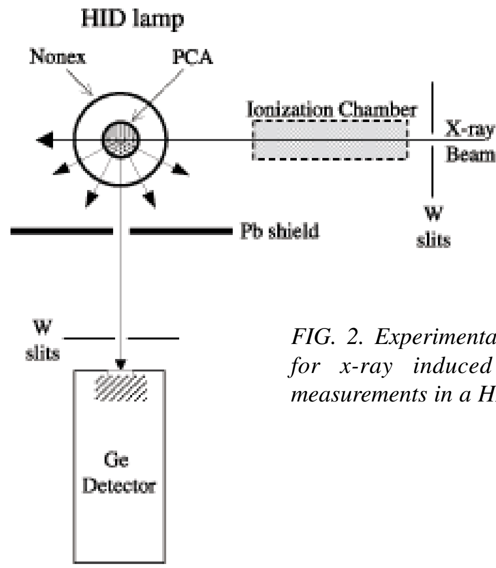

FIG. 2. Experimental arrangement for x-ray induced fluorescence measurements in a HID lamp.

Figure 2 shows the experimental arrangement with the x-ray beam intersecting the lamp and discharge. Fluorescence induced in the discharge is collected perpendicular to the incident beam by a Ge detector. A set of x-ray apertures restricts the field of view of the detector, providing 3-dimensional spatial resolution. Absolute calibrations of the elemental densities are obtained either from measurements of the collection geometry or by comparison with a "standard" cell containing a known density of Dy in aqueous solution.

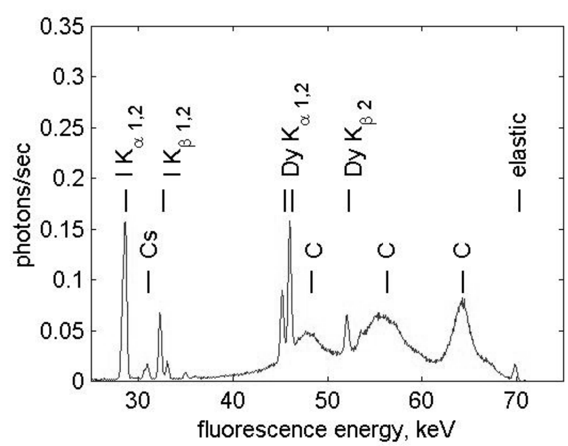

FIG. 3. A typical x-ray induced fluorescence spectrum with 70 keV incident photons. C denotes Compton scattering.

A typical fluorescence spectrum for an incident energy of 70 keV appears in Fig. 3, indicating the presence of the trace species

I, Cs, and Dy in the arc. Spectra acquired from different points in the arc lamp can be used to obtain spatial distributions of the absolute densities of these elements. The ability to measure these kinds of distributions is a great step toward improving our understanding the chemical equilibrium in these lamps, i.e., the various densities and spatial distributions of the light-producing species.

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References

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