Multi-Wavelength or Spatially Resolving LIF Detection System

R. Hood\textsuperscript{1}, J. Berumen\textsuperscript{1}, S. Mattingly\textsuperscript{1}, D. Drake\textsuperscript{2}, F. Skiff\textsuperscript{1}

\textsuperscript{1}University of Iowa, \textsuperscript{2}Valdosta State University

Abstract

The analysis of a multi-wavelength or spatially resolved LIF detection system is presented. In this system plasma light from a small collection region is imaged onto a pair of 16-channel linear photomultiplier arrays. In the first configuration light is resolved spectrally using a pair of diffraction gratings tuned to image a range of wavelengths onto each PMT array. Since the signal from any combination of channels may be observed, fluorescence from multiple lasers (or fluorescence that is spread over several decay paths) can be observed simultaneously while still rejecting most background light. Conventionally, large-diameter narrow-bandwidth interference filters are needed to efficiently observe light from a low f-number light-collection first optic, as in our periscope design. In a second configuration of the system, the light from a single transition is resolved spatially on the photomultiplier detectors using a narrow-bandwidth interference filter. This configuration permits observation of ion fluctuations at Debye scale lengths ~0.5 mm.

Plasma Parameters

Experiments are performed in a 2 m long, 5 cm diameter, magnetized cylindrical plasma column generated using a continuous low power RF discharge in argon with a plasma density of \(10^8\) cm\(^{-3}\), pressure of \(1.8 \times 10^{-4}\) Torr, electron temperature of 2 eV and ion temperature of 0.1 eV.

Light Collection

Light is collected inside the chamber using a pair of periscopes (Figure 1). A slit (0.09 cm x 1.07 cm) in the light collection optics limits the plasma volume observed. The intersection of the periscope viewing volume and the laser beam define a viewing volume at each measurement location (volume ~ 0.1 cm\(^3\)). The collimated light exits the chamber through a pair of 10 cm windows.

Configuration 1

In the first configuration, plasma light goes into the LIF detection box (Figures 2 and 3) and is dispersed using a pair of 10 cm square diffraction gratings (1200 lines/mm, blazed at 450 nm). A range of wavelengths will fall across the PMT channels depending on the optics used. Currently, each channel is ~4 nm wide. In this configuration LIF occurring at multiple wavelengths may be observed simultaneously. This configuration also has the benefit that it is relatively easy to change the wavelength of LIF observed, since there is no need for different wavelength filters; instead, the grating is tuned and the appropriate PMT channel is selected.

Figure 2. Schematic showing plasma chamber and LIF detection box

Figure 3. Schematic showing layout of optics in LIF detection box

Configuration 2

In the second configuration (Figures 4 and 5), plasma light is resolved spatially. The light from the periscopes is imaged onto the PMT’s at the chamber window. A narrow-bandwidth interference filter is used to isolate LIF from a single transition. In this configuration the collection region may be resolved spatially either parallel or perpendicular to the B field depending on the orientation of the slit in the periscope. Currently, each PMT channel maps to ~0.5 mm along the B field.

Figure 4. Schematic showing plasma chamber and PMT orientation

Figure 5. Schematic showing layout of optics in PMT cannister

LIF Detection

Laser induced fluorescence is performed on the argon ion using single-frequency CW dye and diode lasers tuned to lines at 611 nm and 668 nm respectively. Each laser is chopped before being sent through the plasma (parallel to B). Data is acquired with photon counting at 1 MHz over all 32 PMT channels (or at 4 MHz over 8 PMT channels) using a pair of 16-channel Hamamatsu H10515B-200 PMT’s (Figure 6).

Figure 6. 16-channel PMT

Results

In Configuration 1, LIF has been observed using two lasers simultaneously over a single PMT array. 611.6600 nm and 668.61130 nm lasers were used to excite argon ion transitions producing LIF at 461 nm and 442 nm respectively. Figures 7 and 8 show the power spectra resulting from lasers chopped at 100 kHz and 250 kHz. In each of the figures the signal was summed over 3 PMT channels using a single 8 s file. The LIF signal is clear in both spectra. Figure 9 shows the signal from the 6 channels receiving LIF summed together. Again, the LIF signal is clear at the two chop frequencies.

Figure 7.

Figure 8.

Figure 9.

Conclusions

The first configuration allows the user to observe multiple LIF lines simultaneously and tune the detector continuously over a wide range of wavelengths. This allows the user to change the spectral lines being observed without needing to purchase specific filters. The ability to observe multiple lines simultaneously means that fluorescence from multiple lasers or fluorescence that is spread over several decay paths may be observed. The second configuration has yet to be tested, but may reveal information on fluctuations at new spatial scales.