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A Spatially Resolved Spectrometer System for the ZT-40 Device

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A SPATIALLY RESOLVED SPECTROMETER SYSTEM FOR THE ZT-40 DEVICE

by

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ABSTRACT

A spatially resolved emission spectroscopy system designed for use on the ZT-40 device at the Los Alamos National Laboratory is described. The three-chord system consists of independent dispersive elements and detectors for each chord, on a common wavelength drive. The system has been installed and is currently in use on ZT-40. Preliminary results of CV (227.1 nm) line radiation measurements are presented.

I. INTRODUCTION

The need for spatial resolution of spectral line radiation arises anytime one has a nonhomogeneous plasma that one wishes to analyze by means of line radiation. Such line radiation measurements have inherent in them information about such plasma properties as ion density, and electron and ion temperature. Upon unfolding spatially resolved line measurements (for example, by Abel inversion for a cylindrical plasma) the spatial distribution of impurities, and under some assumptions, the temperature profile of the plasma may be obtained. Considerations such as these led to the application of radially resolved emission studies on the ZT-40[1] reversed field pinch at Los Alamos National Laboratory.

Previous spatial resolution techniques have involved single dispersing instruments onto which various chords across the plasma have been imaged at different times either by rotating the device[2] or using a rotating mirror.[3] Such systems have good spatial resolution but depend on either shot-to-shot reproducibility or very slow evolution of the plasma during the rotation of the mirror in order to build up a composite picture of the radiation source. A recent improvement of this technique, the spatial imaging detector system (SIDS), utilizes multiple detector elements and multiple images on the entrance slit of the spectrometer to achieve simultaneous sampling of multiple chords during a plasma shot.[4] This approach and the type of detectors involved work well for long-lifetime experiments where the 1 ms sampling rate of the detectors is sufficiently high compared to the time scales of the line radiation variations. Unfortunately an experiment whose lifetime is less than 1 ms demands a much faster type of sampling (such as fiber optically coupled photomultipliers). Such a system could be constructed based on the SIDS concept but would be costly and would still have the problem of chord-to-chord crosstalk inherent in any system utilizing simultaneous viewing of many chords with a single dispersion element.

Recent developments in commercially available, low cost, fairly high resolution (~ 0.3 nm FWHM) spectrometers make it possible to approach the problem from a different direction. A multichord detection system has been built at Los Alamos, based on utilizing separate spectrometers for each chord to provide spatial resolution, with all instruments on a common drive, enabling one to change wavelength concurrently in all channels. This system has proved to be an inexpensive (less than $1500 per chord) and easily expandable alternative to other types of spatially resolved detectors. It has the distinction of having no possibility of crosstalk between the chords because each chord is analyzed independently. Consequently, no random scattering into adjacent detectors can occur.

II. SYSTEM DESCRIPTION

The basic optical layout of the system is shown in Fig. 1. The entire system (three chords at present) is mounted on a 2-ft by 3-ft vertical panel located on a movable cart, which rolls in under the ZT-40 device. This allows access to the machine when the spectrometers are not in use, without loss of system alignment. The bottom mirrors can be used to provide twice the signal amplitude by effectively doubling the observation path length, as well as for alignment purposes. The spectrometers utilized are 0.2 m concave, holographic devices manufactured by Instruments SA, Inc. The spectrometers have photomultipliers attached directly over their exit slits and integral amplifiers with 1-μs RC filters contained in the same aluminum cases as the tubes. These amplifiers are shown in Fig. 2. Each amplifier has an FET input bypassed by a selection of three different anode resistors, providing three

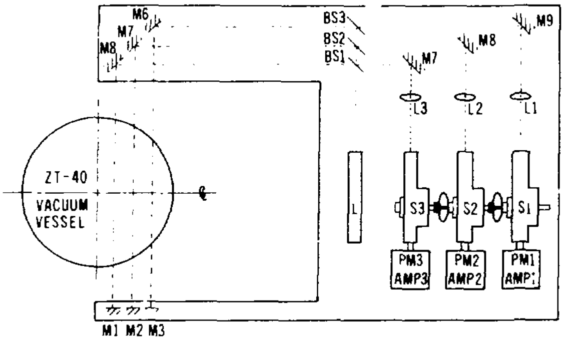

Fig. 1.
Schematic optical layout of the diagnostic. M refers to mirrors, B.S. to beam splitters (fused quartz), L to the alignment laser (HeNe), S to spectrometers, and PM and AMP are the phototubes and amplifiers respectively.

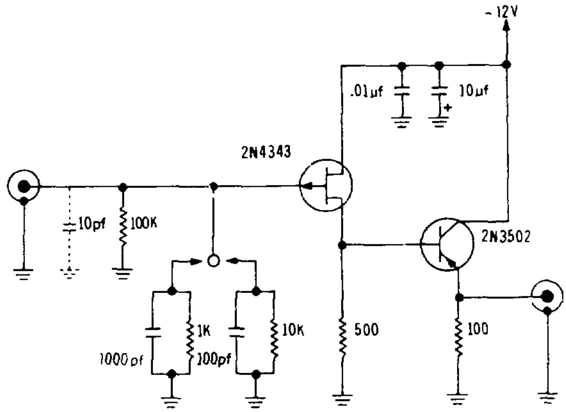

Fig. 2.
Schematic of the phototube amplifiers. The input switching (1 kΩ, 10 kΩ, 100 kΩ) provides three decades of sensitivity. The output is designed to handle the 50 Ω load inherent in LeCroy 2256S digitizers.

decades of sensitivity. This selectivity has proven useful in enabling observation of both weak and strong lines with the same instrument without any system modifications. RCA type 1P28 phototubes are utilized which respond to wavelengths between 190.0-700.0 nm.

The wavelength drives are ganged in order to provide a common wavelength setting for moving from line to line. This multiple grating, single drive feature is what sets this system apart from other multiple spectrometer systems. It allows one to move rapidly from line to line, after calibration, without having to independently set a number of different instruments to exactly the same wavelength. Because the individual drives are not completely identical, this ganging is only accurate over about a 20.0 nm region. Larger changes require readjustment of the drives to compensate for the 0.05 nm maximum misalignment that may occur from one instrument to the next in 20.0 nm. This operating window is wide enough to encompass such useful sets of lines as the CV-CIII lines at 227.1 and 229.7 nm without realignment.

The drive coupling is accomplished by a spring steel universal joint commercially designed for potentiometer shaft connections. The joint provides a means of compensating for imprecise shaft alignment without introducing any loss of precise rotational coupling. Final shaft connections are collet-type couplings to prevent rotation during the tightening process.

Optical paths and collimation of the source region in the plasma are provided by first surface mirrors and a 15-cm focal length quartz lens in each channel. The spectrometers utilize a pair of 50 μm slits to define the 0.3 nm bandpass of the system. Transmission and response characteristics of the vacuum vessel windows and the spectrometer-photomultiplier systems are provided by mounting a Cd lamp and quartz lens assembly on the lower arm of the system and passing the source radiation through the entire system, with and without the device rolled under the torus.

Final data acquisition and reduction are provided by LeCroy Research Corporation type 2256S analog/digital converters (8 bits, 1024 words). A Prime 400 computer controls operations and data acquisition and reduction for ZT-40.

III. RESULTS

The system has been used to study the OIV-V system of lines at 278.1 nm and the CV line at 227.1 nm in the ZT-40 plasma. Radial profiles of the CV signals are shown in Fig. 3. Portions of the observed signal (comparable in size to that seen for r > 13 cm) are believed to be background radiation in the area of the line caused by bremsstrahlung and recombination radiation. The signal-to-background ratio is approximately 5:1 for this particular line under these operating conditions. This profile was obtained during a sequence

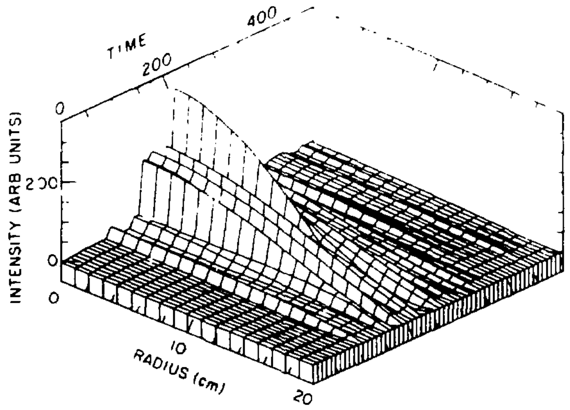

Fig. 3.
Sample CV (227.1 nm) line radiation data (polynomial fit).

of 500 kA, aided reversal discharges in ZT-40. The profile shown is a three-dimensional computer polynomial fit to the data from the three chords in use at that time. Further analysis of these data utilizing an absolute calibration and a simple, uniform ion density model allowed an estimate of the temperature profile to be made in this mode of operation in the ZT-40 plasma. Detailed descriptions of these results and comparison of the profiles to those obtained by other diagnostics, such as space resolved Thomson scattering,[5] will be reported elsewhere.

This system has proved to be quite versatile and is presently being upgraded to six chords for use in the experiment when the metal vacuum vessel is installed in early 1981. The six chords of plasma viewed at that time will be 0.875 inches in diameter in contrast to the 2-inch diameter chords in the earlier experiments. This will provide a better collimation of the source light and consequently better resolution. The system will be set up such that, of the eight radial observation ports, any six adjacent ports will be accessible on a given shot, enabling studies of central and edge effects in the plasma. Studies are currently under way to investigate the feasibility of using a second exit slit beside the normal slit. This second slit would enable observation of the background radiation next to the line of interest, which would then be subtracted to give a better signal-to-noise ratio for the line. This would allow a clearer interpretation of the data.

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