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NINE-CHANNEL POLYCHROMATOR FOR OBSERVATION OF TIME-DEPENDENT SPECTRAL LINE PROFILES

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Abstract

The instrument (polychromator) described observes time-dependent spectral-line profiles by simultaneous measurement at nine different wavelengths of light intensity as a function of time. A cylindrical lens magnifies the dispersion of a Jarrell-Ash Model 82000 Ebert Monochromator and forms an image on a light-pipe holder. Light pipes transfer light from various sections of the image--i. e., different wavelengths--to photomultiplier tubes, and the responses are displayed on oscilloscopes. The instrument has been used to look at total wavelength spans of 15 A and 20 A.

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Introduction

This instrument (polychromator) is designed to provide time-dependent profiles of broadened spectral lines. It simultaneously measures light intensity as a function of time at nine closely spaced wavelengths. The primary purpose of this instrument is to provide a means of measuring the ion density in a decaying hydrogen plasma of 10^{15} to 10^{16} ions/cm^3 by observation of the Stark-broadened hydrogen emission lines. Similar instruments have been constructed in other laboratories.[1,2,3]

The instrument uses a Jarrell-Ash Model 82000 Ebert Monochromator with the exit slit removed (see Fig. 1). The linear dispersion of the monochromator is 16 A/mm.

To provide additional linear dispersion, a cylindrical lens with its axis parallel to the entrance slit is used (a spherical lens would give unwanted magnification parallel to the slit). An image of the entrance slit is formed in the plane of the removed exit slit. Light from this image passes through a 3/8-in.-wide slot in the face plate of the monochromator, through the cylindrical lens, is reflected over the top of the monochromator by two plane mirrors, and finally is focused on a light-pipe holder 51 in. from the cylindrical lens. The mirror arrangement makes the instrument more compact. The light from the monochromator diverges in the direction parallel to the slit at the acceptance angle of the monochromator but is imaged (with magnification) in the direction perpendicular to the slit. Light from nine sections of the image (corresponding to nine different wavelengths) enters light pipes and is carried to 1P21 photomultiplier tubes. The responses are displayed on oscilloscopes.

The Lens

The cylindrical lens is a polished cylinder of Plexiglass. This shape was chosen rather than a thin lens primarily for ease in construction. To provide means of focusing and aligning, the lens is mounted on a microscope stage which is attached to the front plate of the monochromator. The final linear dispersion may be changed by installing a lens of different diameter. Lenses 1.47 and 1.12 in. in diameter have been used, giving final linear dispersions of 0.34 and 0.26 A/mm, respectively.

Focus is achieved by using white light and the zero-order image of the diffraction pattern. Since the wavelength drive of the monochromator is not designed to reach zero order, the wavelength drive arm must be disconnected and moved by hand to zero order. Chromatic aberration is quite noticeable, but has not affected focusing enough to cause serious loss in resolution.

Light Pipes

The nine light pipes are 1/16-in.-thick Plexiglass and are 4 in. high at the entrance end (approximately the height of the image formed by the cylindrical lens). They taper to 5/8 in. at the phototubes. In most of our use so far, the light pipes have been spaced nonuniformly but approximately symmetrically about the center light pipe, with a separation of 2.25 in. between outermost light pipes. The spacing of the light pipes may be varied, giving additional flexibility to the instrument.

Resolution

The monochromator forms a curved image of a straight entrance slit, and the curvature is dependent on the wavelength setting of the monochromator. To maintain wavelength resolution the slit is stopped vertically, so that a relatively straight portion of the image is used. In our work with the polychromator a spherical lens is used to image an extended plasma light source on the entrance slit. Stopping the slit vertically selects a small portion of the image, hence also gives good spatial resolution. Slit widths of 10μ and 25 μ have been used according to the light level available.

Curves of polychromator response as a function of wavelength are given in Fig. 2. Such curves are useful in determining the wavelength separation of the channels. They were obtained by rotating the grating so as to scan the image of a narrow spectral line (H_β) across the light pipes. The outputs of all photomultipliers were connected together and the total signal fed into a recorder. Each peak corresponds to a different channel, the different amplitudes are due primarily to differences in the photomultiplier sensitivities. The resolution of each channel is about 0.5 A, much less than the half-width of any spectral lines studied (typically 3 to 5 A). When the 10-μ slit is used, the resolution is determined primarily by the light-pipe width, hence one does not see a large difference between the response curves with 10-μ and 25-μ slits.

Improvements

The polychromator is presently being modified to increase its sensitivity and versatility. The modifications include an increase in the number of channels from nine to eighteen, the use of straight, rather than tapered, light pipes, and the incorporation of a second cylindrical lens.

A long-focal-length thin cylindrical lens, oriented with its axis perpendicular to the axis of the original (dispersing) lens, is being added to provide focusing of the image in the vertical dimension, with unit magnification. Use of this lens with the tapered light pipes affords about 100% increase in sensitivity by concentrating the light near the vertical center of the light pipes (the transmission of the tapered light pipes is low for light incident on the front of the light pipes near the upper or lower edges). Even larger gains are to be expected in the modified instrument, as the small vertical dimension of the image (about 0.5 in.) will allow the use of straight, rather than tapered, light pipes. Furthermore, the formation of a true (but curved) image at the light-pipe holder permits masks to be placed over the ends of the light pipes, with apertures shaped to conform to the curvature of the image, thus permitting use of a larger portion of the entrance slit without loss of resolution. The new light pipes are also wider and very closely spaced, permitting continuous wavelength coverage over the range of the spectrum covered by the instrument by removal of the masks.

Provisions are being made to cool the photomultipliers to reduce the dark current.

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Footnotes

*Work done under the auspices of the U. S. Atomic Energy Commission.

†United States Air Force

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3. C. Breton, M. Carpet, F. Waelbroeck, in Proceedings of the Fifth International Conference on Ionization Phenomena in Gases, Munich, Aug. 28-Sept. 1, 1961, Volume II (presumably) (North-Holland Publishing Co., Amsterdam, 1962).

Figure Captions

Fig. 1. Schematic drawing of the polychromator. Light from the monochromator is imaged on the light-pipe holder by the cylindrical lens; nine light pipes carry light of nine different wavelengths to the photomultipliers.

Fig. 2. Polychromator response vs wavelength. The upper curve was made with a 10-μ entrance slit; the lower curve was made with a 25-μ entrance slit. Each peak corresponds to a different channel. The relative spacing of the peaks is determined by the spacing of the light pipes; the outermost channels here are separated by 19.4 A.

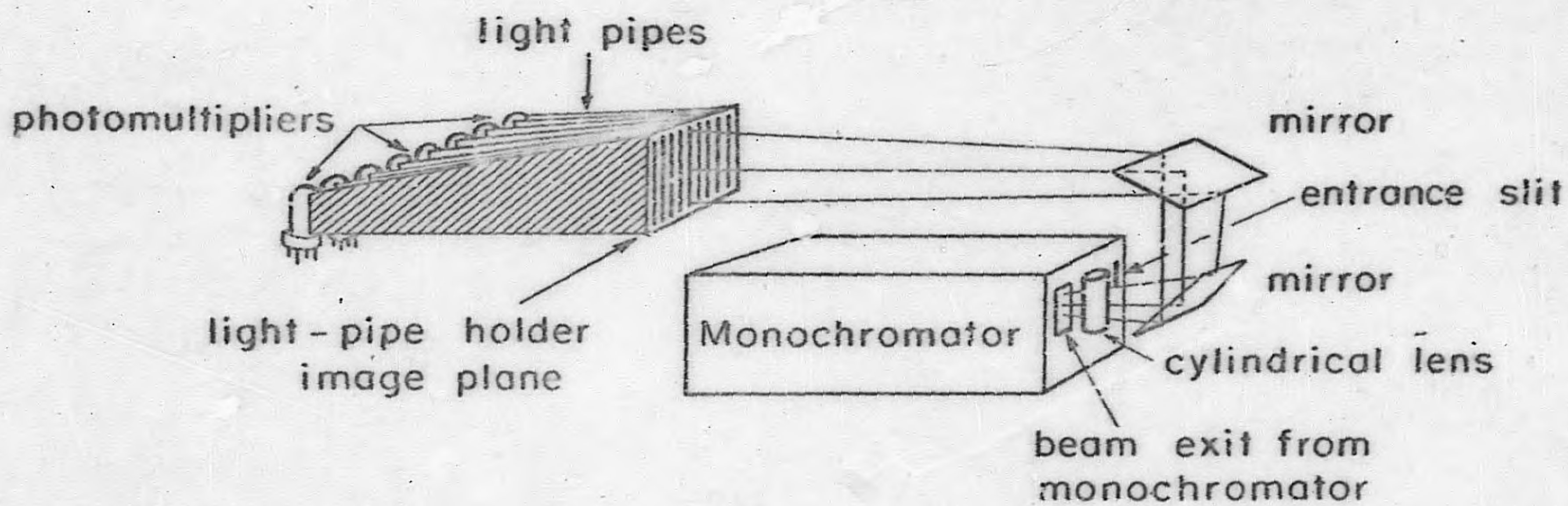

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Fig. 1.

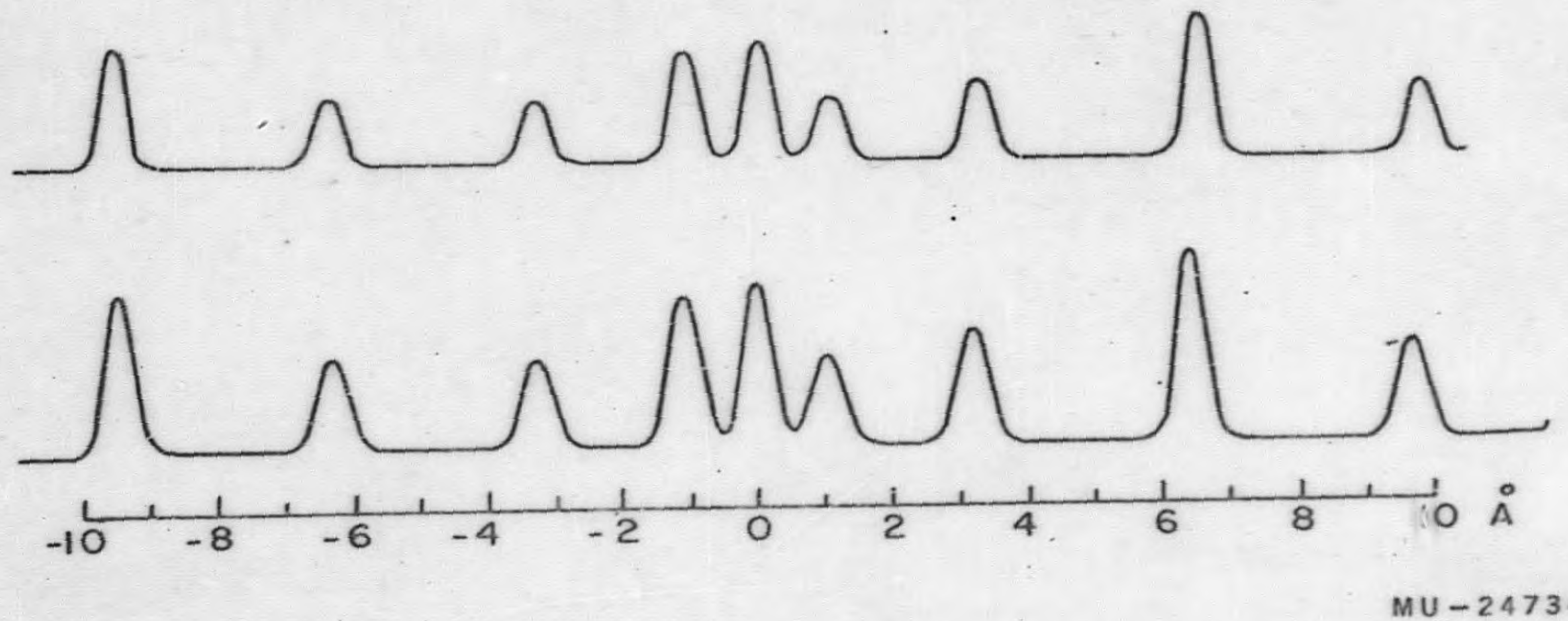

Fig. 2.

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