INSTITUTE OF PLASMA PHYSICS

NAGOYA UNIVERSITY

# TECHNICAL REPORT



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# REPETITIVE DISPLAY SYSTEM OF LINE PROFILES FOR DOPPLER BROADENING MEASUREMENT

A. Mohri, K. Narihara and K. Haba

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Further communication about this report is to be sent to the Research Information Center, Institute of Plasma Physics, Nagoya University, Nagoya 464, Japan.

## Synopsis

Line profiles of impurities in visible and ultraviolet regions are repetitively displayed on a CRT with an interval of 250 μs or 500 μs, using a system composed of a Czerny-Turner monochromator with 1 m F.L., a self-resonant optical scanner, a photomultiplier shielded against hard X-rays and electronic circuits. The profile resolution is 0.035 nm FWHM. This system can be used in the environment of strong hard X-rays.

## 1. INTRODUCTION

Temperatures of impurity ions inferred from Doppler Broadening of their ultraviolet or visible lines give some information of the spacial structure of a confined plasma. When a plasma is confined by a relativistic electron beam (REB) ring, Bremsstrahlung due to the interaction of REB with the confined plasma and/or collisions of escaped energetic electrons with the wall produce strong hard X-rays. In this case an attention should be paid in the design of line profile measuring instrument to guard its light detector from the X-rays. This report describes a system which was made for the line profile measurement in experiments on REB rings.

The measuring instrument consists of a Czerny-Turner monochromator with 1 m F.L. and a 1200 G/mm grating, an optical scanner of 2 kHz and an X-ray shielding case (iron of low carbon content) enclosing a photomultiplier with quartz window and a preamplifier. In addition, electronic circuits are used to display line profiles on a CRT.

## 2. SCANNING OF LINE PROFILE

Figure 1 shows an illustrative drawing of the light detection part of the instrument. The image of a line at the exit slit 1 of the monochromator is focussed at the slit 2 by using the 10 mm dia. plane mirror of an optical scanner and a concave mirror with 38 mm F.L. The scanner (s-220-20 of General Scanning Inc.) is of self resonant type having the resonant frequency of 2 kHz. It uses a moving-iron galvanometer with an isogonic torsion rod that provides radial stiffness during the oscillation. The maximum angular excursion is p-to-p 20 degrees. The angular amplitude can be adjustable so that the scanning speed becomes controllable. The width of the slit 2 is set sufficiently narrow compared with the broadening of the line. Thus, the line profile is scanned every 250 μs when both the back and forth motions of the scanner are used or every 500 μs when the one-way directional movement is used. The oscillating amplitude is controlled by adjusting the input current to the driving coil of the resonator. For this feedback control, a tachometer (velocity pick-off coil) is attached to the resonator. A monitoring signal of rectangular waveform with a constant amplitude, which is converted from the tachometer signal, is led to the electronic circuits of the line profile display.

The resolving power of this scanner system is limited by the spherical aberration of the used concave mirror, since the slit 2 is not a matched curved slit but a straight one in this case. The obtained resolution is 0.035 nm in FWHM as will be explained later. However, with the use of this instrument, for example, it is possible to measure ion temperatures of fairly low z impurities (C, N, O, ...) above 60 eV.

The light out of the slit 2 is led into the X-ray shielding case inside which the light is bent twice with two mirrors before its reaching the photomultiplier so as to decrease the level of X-rays by their multi-scattering and/or absorption. The shielding case of low carbon iron has the outer diameter of 40 cm and the thickness of 17 cm. The preamplifier is also housed inside the shielding case to avoid electronic noises due to X-rays. Here, light guiding is provided by the use of mirrors coated with $MgF_2$. If we use an optical guide of glass fibers, fluorescent light caused in the fibers by the irradiation of X-rays would mask the true light signal.

## 3. DISPLAY OF LINE PROFILE

Figure 2 shows the functional bock diagram of the electronic circuits for displaying line profiles on a CRT. Light singals from the preamplifier and the monitoring signals synchronous to the scanning mirror position are sent to the circuits. Those are shown in Fig.3. Light signals appear twice in an oscillatory period of the scanner, since the profile at the exit of the monochromater is scanned back and forth in the period. The monitoring signals of 2 kHz rectangular waveform are sent to a pulse shaper of a monostable multivibrator SN74LS. From the shaped rectangular signal two pulse trains of 50 μs width are extracted; one is synchronous with the negative going edge of the input signal and the other with the positive going edge. When both trains are summed, back or forth canned light signals appears alternately with the frequency of 4 kHz.
On the other hand, when only one pulse train is used, the

pulse frequency becomes 2 kHz and either back or forth scanned signal appears every period. Choice of these two operational modes can be made with a selection switch and a pulse mixer of a monostable multivibrator SN74121. Then, the pulses are sent to a synchronous BCD down counter SN74192, and these are also used as the triggering pulses of an oscilloscope for the profile display. The maximum count number (N), which decides the number of profiles on the CRT, is given by presetting the data inputs from 1 to 9. The counting-down starts by an external gate pulse from N and the count is cleared at N = 0. The count is converted to an analog signal by D/A convertor DAC HK 12 BGC. Thus, the output of the D/A convertor becomes a stepwise waveform having N steps. Figure 4 shows both the output waveforms of the 2 kHz mode and the 4 kHz mode for N = 9. The upper trace in each oscillogram is the train of light signals. In the case of the 4 kHz mode, a light signal appears on each step, while two signals appears for the 2 kHz mode.

When the light signals and the stepwise signals are added to be the vertical input of an oscilloscope and its horizontal sweep is triggered by the triggering pulses from the pulse mixer, then N line profiles can be displayed on the CRT, as is shown in Fig.5. In this way, we can follow time variation of an ion temperature seeing the successive Doppler broadened profiles with a repetition period 250 μs or 500 μs.

## 4. RESOLUTION OF THE SYSTEM

The light signal on the CRT shifts horizontally as the setting of the wavelength of the monochromator is changed, because the timing between the light signal and the angular position of the scanning mirror varies. Using this technique, the resolution can be found if the profile is adjusted to be narrowest. Figure 6 shows the result for He-Ne laser light where the heights of the entrance slit and the exit slit 2 are both 5 mm. The FWHM of the signal profile is 0.035 nm.

## 5. EXAMPLE OF APPLICATION

Figure 7 presents an example of the profile display of the impurity line CII 426.7 nm which is emitted from a plasma confined by a REB ring in SPAC-VI. The horizontal lines are successively swept every 250 μs and the 1 division (20 μs) corresponds to 0.04 nm. Here, the number of photons coming in the entrance slit is not enough to have a useful profile. In order to have a more clear profile, effective total photons should be increased. For instance, slower scanning might be an improvement. It is possible by decreasing the oscillation angle of the scanning mirror.

The background level of hard X-rays in this case is about $10^7$ R/hour but there is no trouble of the operation.

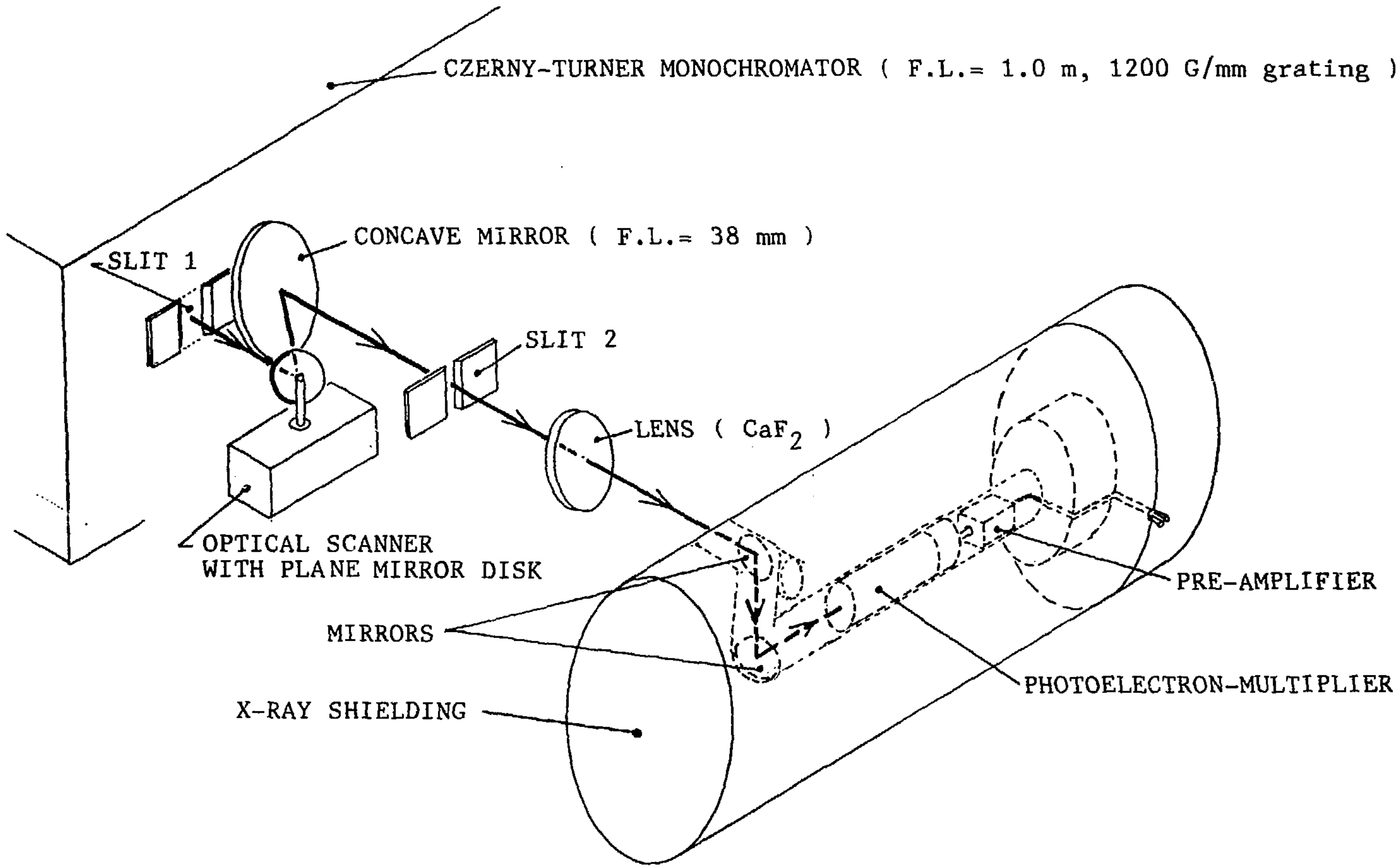


Fig.1 Schematic drawing of the optical system for line profile measurement.

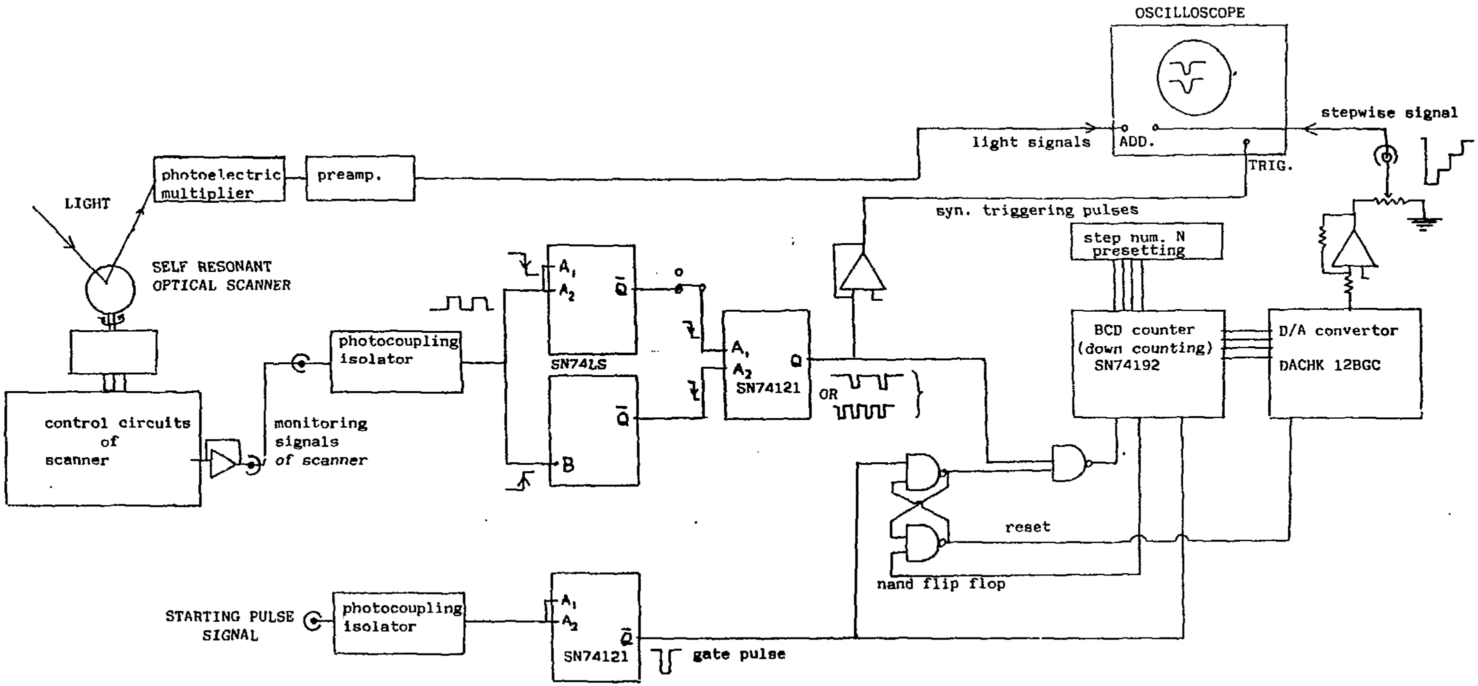


Fig. 2 Functional block diagram of the circuits for displaying line profiles.

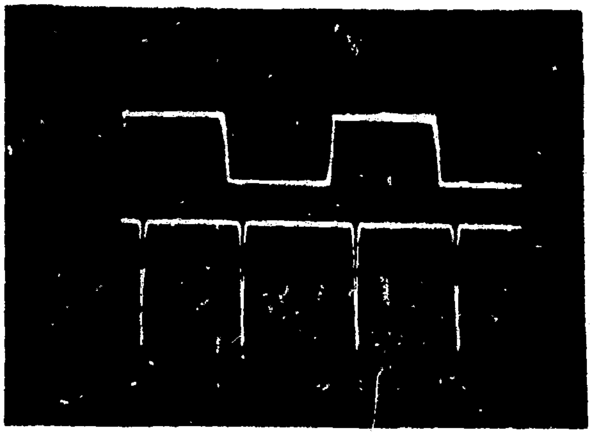

Fig. 3 Wave forms of the monitoring signal ( upper trace ) and the light signal ( lower trace ).

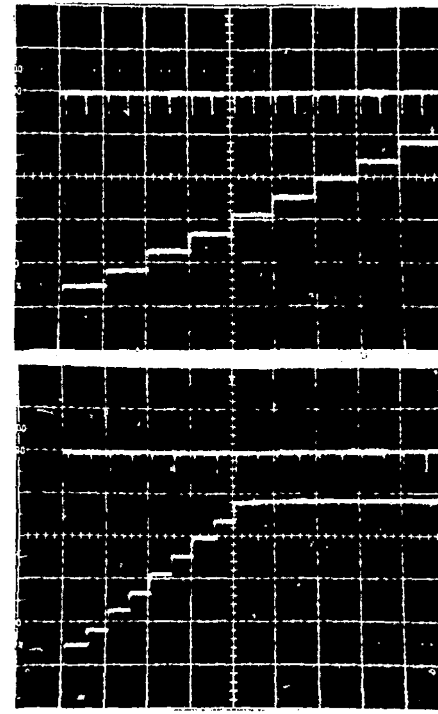

Fig. 4 Stepwise signals from the D/A convertor.
(a): operational mode of 2 kHz,
(b): operational mode of 4 kHz.
Upper traces are the synchronous light signals.

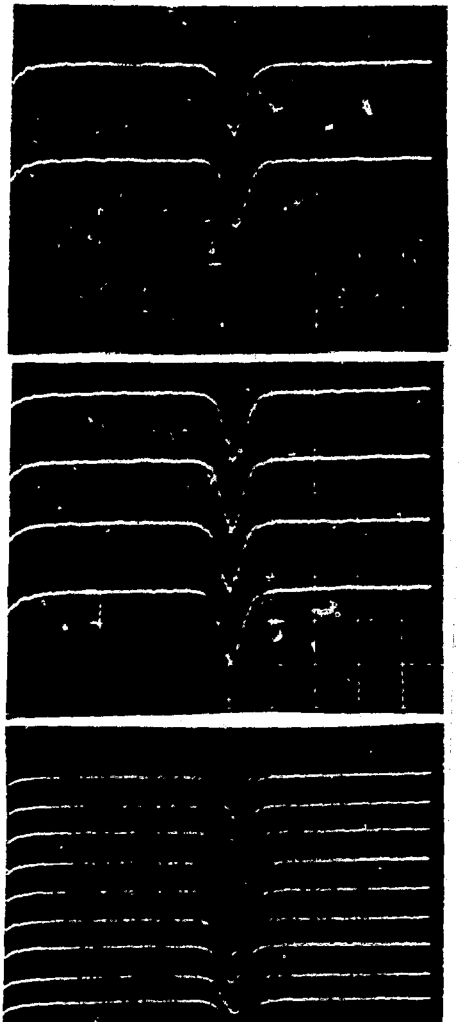

Fig. 5 Line profiles displayed on the CRT for N=2, N=4 and N=9 cases. Here, He-Ne laser light is used. The horizontal 1 division corresponds to 0.05 nm wavelength.

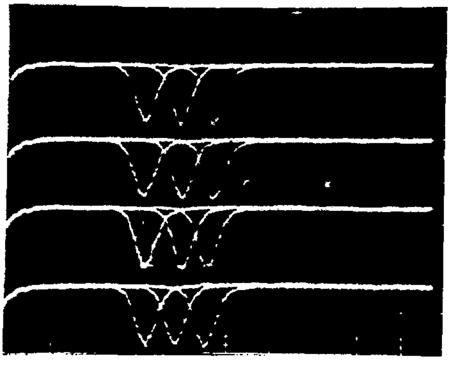

Fig.6 Shifts of the light signal position for the change of equivalent wavelength by ± 0.05 nm in the case of the narrowest width of the profile.

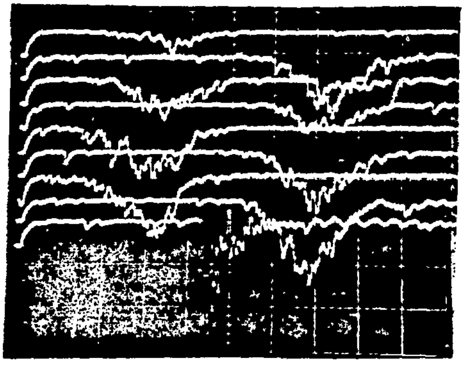

Fig. 7 An example of the profile display of CII 426.7 nm lines emitted from a plasma confined by a REB ring in SPAC-VI device.
The time duration between the successive traces is 250 μs and the horizontal 1 division corresponds to 0.04 nm wavelength.