

Application of a Cooled CCD for Amateur Astronomers to Alignment of an Imaging Polychromator

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Synopsis

A cheap cooled CCD manufactured for amateur astronomers was used as the imaging detector of a soft X-ray polychromator for plasma spectroscopy. A computer program to control the CCD and to process its image data was developed using Turbo-C of PC9801 personal computer. Using this CCD system, rough alignment and adjustment of the soft X-ray polychromator was made.

KEYWORDS: cooled CCD, polychromator, image detector, plasma spectroscopy

Introduction

A spectroscopic measurement which has spatial resolution is important for plasma study. This is especially true for a plasma without axial symmetry like the LHD-plasma.¹⁾ Such measurement is realized by using the combination of a polychromator and an image detector.²⁾ A soft X-ray polychromator was designed³⁾ and is now under adjustment for the measurement of the LHD plasma. Recently, a cooled CCD system can be purchased for the high sensitivity imaging measurement. But such a system is still very expensive. A cooled CCD itself as an element can be obtained cheaply, because amateur astronomers began to use one to take a picture of heavenly bodies. So we developed an imaging detector system using such a cheap cooled CCD. The system was applied to the alignment of the soft X-ray polychromator.

Experimental Setup

The system setup is shown schematically in Fig. 1, and the soft X-ray polychromator is shown in Fig. 2. Since the details of the soft X-ray polychromator have been given elsewhere⁴⁾, only a very simple description is given here. The polychromator, which is based on the Rowland circle mount, consists of two chambers, a main chamber and a detector chamber. The main chamber contains the entrance slit and a concave grating. The radius of the grating is 10 m and the groove density is 1600 gr/mm. The incidence angle is set at 88.5° . To get the spatial resolution, an additional horizontal slit is located between the entrance slit and the grating. The detector chamber contains a two stage MCP and a fluorescent screen which converts the soft X-ray to visible light. Two chambers are connected by a bellows which makes the detector chamber movable to choose the wavelength region.

The light source used for the alignment of the polychromator is an X-ray tube attached in front of the entrance slit. The axis of the X-ray tube is set in parallel to the direction of the entrance slit. The observed line is a characteristic X-ray emission of aluminum, Al - K α at 8.34 Å. The soft X-ray diffracted by the grating is amplified in MCP then converted to visible light on the fluorescent screen. The sensitive area of the MCP is 53 mm \times 53 mm, the diameter of channel in MCP is 15 μ m and the channel pitch is 19 μ m. The image on the screen is transferred to the CCD surface through a camera

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lens.

The cooled CCD is ST-6 manufactured by SBIG (Santa Barbara Instrument Group). The ST-6 system consists of a CCD head, a CPU box, and a power supply. The CCD head is cooled by a thermoelectric system. The control of the CCD head and the data transfer are made by a personal computer via RS232C interface. The detecting area of the CCD is $8.6 \text{ mm} \times 6.5 \text{ mm}$, and the pixel number is 375×242 . The image data on the CCD are AD converted with a 16 bit ADC.

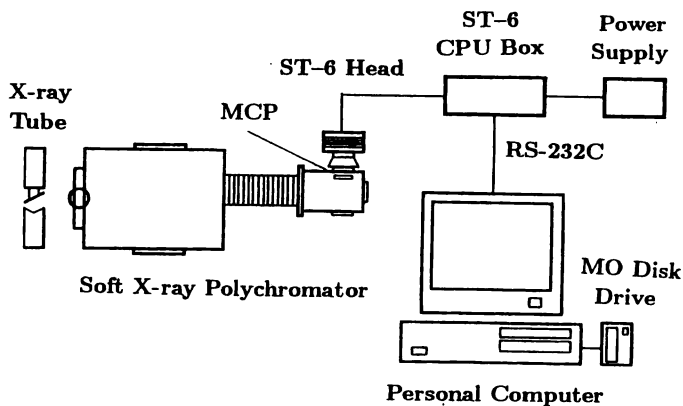


Fig.1 Schematic drawing of the set-up for the alignment of a soft X-ray polychromator

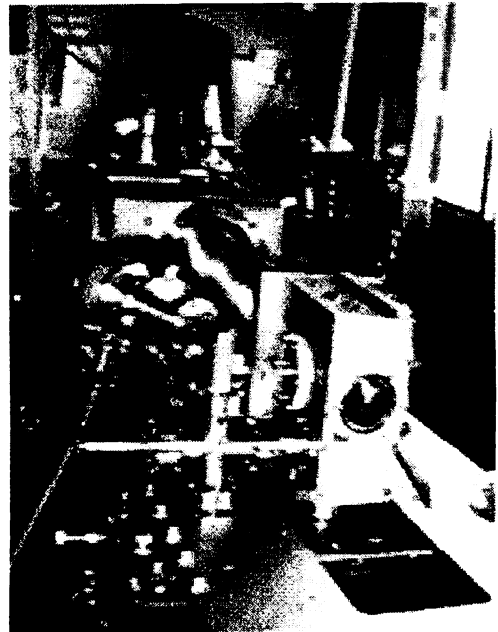


Fig.2 Outlook of the Soft X-ray polychromator

Computer Program

Although a computer program for taking pictures of heavenly bodies is attached to the ST-6 system, it does not fit to the use for plasma spectroscopy. So we built a new computer program, IMAGEST6 for ourselves. The program language is Turbo-C of NEC-PC9801 personal computer and its compatible. The commands sent from the personal computer to the CPU of ST-6 are structured in packets.⁹⁾ The image data are sent in binary code. It is important to note that the binary data "0x1a" cannot be accepted as a number because it means the end of file. Therefore, the system call should be used to accept "0x1a" data.

The size of the program is 120 kB and the size of a image-data file is 181.5 kB. Since the data size is big, an MO disk drive will be necessary to store the data files. External timing trigger can be given through the mouse connector.

The flow chart of the operation of the IMAGEST6-program is shown in Fig. 3. When the program starts, a menu appears asking the choice of Take image, Process image, or Quit. To take image data, the ST-6 system should be ready before starting the program. To take data, set the temperature of CCD at first. Wait for a while, then set the offset value of the ADC amplifier in ST-6. Then select the trigger mode, manual trigger or external trigger. The exposure time can be adjusted from 0.01 sec to 600 sec. After taking an image, the download of the data from ST-6 to the computer takes about four minutes, which is determined by the ADC speed, not by the RS232C data transfer speed. If the data is good, it is saved to a hard disk. Before the hard disk becomes full, the files should be moved to an MO disk.

To process image data, the ST-6 system is not necessary. Select the file to be processed, six kinds of processes are available as shown in Fig. 3. Except the gray scale image, all the figures of

processed data can be printed out with a printer. Changing data file or data directory is easy.

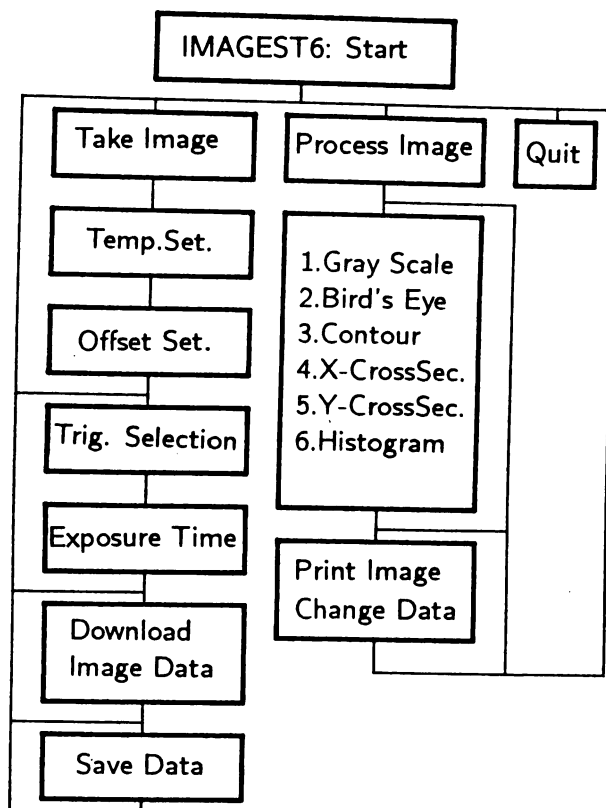


Fig. 3 Flow chart of the computer program for the control of CCD and the image data processing.

Experimental Results

The alignment of the polychromator started by fixing the grating at the right position and direction using He-Ne laser. Next, the X-ray tube was attached in front of the entrance slit. Each chamber was evacuated to about 3×10^{-6} Torr using turbo molecular vacuum pumps. The distance between the target in the X-ray tube and the entrance slit was 300 mm. The distance between the entrance slit and the grating was 270 mm. The distance between the grating and the MCP surface should be 605 mm for Al-K α line ($\lambda = 8.3$ Å). To find the right position and direction of the MCP, the detector chamber was moved in two directions and rotated on the axis of the MCP. At each position the image of the target on the MCP was monitored with the cooled CCD system. When the width of the Al-K α line became minimum, it was considered that the MCP was located at the right position and the alignment was completed.

Figure 4(a) shows a bird's eye view of the Al-K α line image after the alignment. The width of the entrance slit was $10 \mu\text{m}$, the temperature of the CCD was -20°C , and the exposure time was 10 sec. The x-axis shows the wavelength, where 100 pixels correspond to 0.24 Å. The y-axis shows the vertical position at the target, where 50 pixels correspond to 2 mm. Such bird's eye view plot was very powerful to find the right position of the MCP. The spectrum of the Al K α line at the center of the target is shown in Fig.4(b). The FWHM of the line was found to be 0.09 Å. This resolution was much poorer than the expected value (~ 0.01 Å), so more precise alignment is necessary. Figure 4(c) shows the spatial distribution of the light intensity of Al-K α line. It was found that the bright region was about 6 mm.

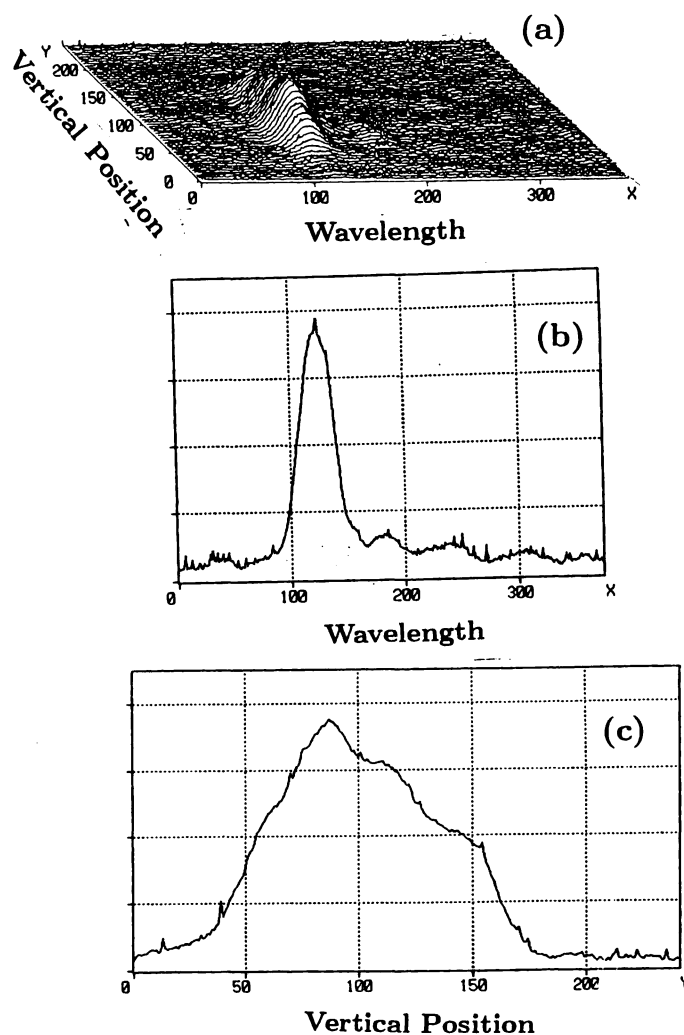


Fig.4 Spatial distribution of Al-K α line spectrum of the X-ray tube.
 (a) Bird's eye view plot. (b) Spectrum at the center of the X-ray tube.
 (c) Vertical distribution of the line intensity.

Thus it was shown that the cooled CCD for amateur astronomers can be used as the image detector of a polychromator for plasma spectroscopy. The computer program described in this note is free to use for everyone. The person who wish to use the program, please contact to the first author.

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