Solar Optical Instruments at the National Astronomical Observatory of Japan

Takashi Sakurai

National Astronomical Observatory, Mitaka, Tokyo 181

Abstract

This article describes solar optical instruments of the National Astronomical Observatory of Japan.

1. Introduction

Optical instruments which are currently being operated at the National Astronomical Observatory of Japan for solar observations are reviewed in the following. The instruments are located at the Mitaka campus and at two stations; Norikura and Okayama. Okayama Observatory is a facility for both night time and solar observations.

2. Mitaka Campus

2.1. Sunspot Observation

Routine observations of sunspots have been conducted since 1938, by using a 20cm refractor made by Zeiss (figure 1). Sketches (solar image diameter = 24cm) and white light photographic observations of sunspots are made daily. Solar differential rotation and meridional circulation were studied by using these data (Kambry and Nishikawa 1990; Kambry et al. 1991; Yoshimura and Kambry 1993).

2.2. Hα Flare Patrol

Hα flare patrol observations have been carried out since 1957, with a 14cm refractor equipped with a birefringent filter made by Cecasi, France. Photographs were usually taken at 30 second intervals. In 1991, a system for automatic detection and subsequent light curve plotting of flares was introduced (figure 2). This system is made of a 4cm objective lens, a Halle Hα filter, and a CCD camera. The video signal from the CCD is digitized in a personal computer. In normal operation, a full disk image is taken every one minute. When a flare is detected, images of a limited area around the flaring region are taken at a rate of one frame per second. The pixel size corresponds to 4″ on the sun. A cross-comparison of measurements between the new system and the old photographic system has been conducted, and a satisfactory performance of the new video system was confirmed. In May 1992, the old photographic Hα flare patrol was replaced by the new system. Observations with this new video system is described by Suematsu and Tanaka (1994).

2.3. The Solar Flare Telescope

The main instrument at Mitaka is the Solar Flare Telescope (figure 3). The aim of the Solar Flare Telescope is to observe solar flares in four aspects, namely (1) the magnetic field, (2) the velocity field (Doppler shifts), (3) chromospheric fibril structures and flares in Hα line, and (4) growth and decay as well as motions of sunspots observed in continuum light. Initial results from this telescope are reported by Ichimoto et al. (1991, 1993) and by Sakurai et al. (1992a,b).

In order to perform the four measurements described above, we put four telescopes on a single mounting. The telescope optics and the mounting were built by Nikon. Four telescopes have the same field of view of 300″ × 400″, and the pixel size of CCD cameras corresponds to 0.8″ on the sun. Two telescopes are used to measure polarizations and Doppler shifts of spectral lines, by using birefringent filters. The other two telescopes observe the sun through wide band filters, and through a Zeiss birefringent filter for the Hα line, respectively. Hα images are recorded onto a laser video disk at a rate of one frame in ten seconds. Continuum images are recorded onto a video tape at a normal video rate, and the tape is recycled unless notable events are detected.

The birefringent filter for magnetic vector measurements, built by Nanjing Astronomical Instrument Research Center, has a pass band of 1/8 Å. The transmission peak is set at the blue wing of the Fe I 6303 Å line (Landé factor = 2.5). Circular polarizations are measured by using a KD*P modulator as a quarter-wave retarder, and a polaroid following the KD*P as an analyzer. Linear polarizations are measured in the same system by converting linear polarizations into circular polarizations. The conversion is made by quarter-wave plates in front of the KD*P modulator.

The Fe I 6337 Å line (Landé factor = 2.0) is used to measure the Doppler shift and also the longitudinal magnetic field. The birefringent filter for 6337 Å, also built by Nanjing Astronomical Instrument Research Center, has a pass band of 0.2 Å. The thickest calcite element in the filter is equipped with a KD*P crystal. By modulating the retardation of the KD*P, the transmission peak of the filter can be moved by ± 0.1 Å. The difference in signals from the blue and red wings gives information on the Doppler shift of the spectral line.

Vector magnetograms and Dopplergrams are taken every 3 minutes. At the end of a full-day observing run, data of about 0.5 GB are obtained and are written to a digital audio tape.

2.4. STEP Full-Disk Magnetograph

Large-scale magnetic field distributions on the solar surface play an important role of determining the magnetic field structures in the corona and in the solar wind. As part of our observatory's contribution to the Solar Terrestrial Energy Program (STEP project), a full disk solar magnetograph was constructed (figure 4). The system of polarization measurements is similar to the Solar Flare Telescope, and uses a birefringent filter, two KD*Ps, and a CCD camera. The pixel size corresponds to 5″ on the sun. The whole system is set up on the optical bench in the observing room. A heliostat mirror system of 20cm in diameter is used to feed the sun light into the observing room. The spectral line used is that of Fe I at 5324.2 Å (Landé factor = 1.5). The heliostat and the birefringent filter were made by Nanjing Astronomical Instrument Research Center, and the imaging optics was built by Nikon. The instrument is now in the phase of test observation.

3. Norikura Coronagraph Station

At Mt. Norikura, 2800 m above sea level, three coronagraphs are in operation (figure 5). The oldest 10cm coronagraph, made in 1950 by Nikon, has been used to measure the intensities of the coronal emission line at 5303 Å. It is also used for photographic observations of coronal structures and prominences.

The 25cm coronagraph, also built by Nikon in 1971, is equipped with a spectrograph and a CCD camera, and the mapping of the sun using the Helium 10830 Å line is conducted on an almost routine basis. A single pixel of the CCD covers 1″× 0.2Å, and spectral strips of 2Å width are recorded. A raster scan of the full-disk, made of four swaths of 500″ wide, is completed in 30 minutes.

The newest 10cm coronagraph is mounted on the old 10cm coronagraph. This instrument takes digitized images of the solar corona by using four interference filters as follows:

wavelength	bandwidth
5303Å	3Å
5876Å (He D_3)	4Å
6563Å (Hα)	3Å
6630Å (continuum)	21Å

The field of view is 2600″ × 2400″. The acquisition of one set of data takes 2 minutes. The photometric accuracy of this system is about 10^{-6} times the sun-center brightness. The initial results are reported by Ichimoto et al. (1992).

4. Okayama Observatory

At Okayama, the 65cm coude-type solar telescope was built in 1967 by Nikon (figure 6). In 1982, a photoelectric vector magnetograph was installed and has been in operation since then. The spectral line used is Fe I 5250 Å (Landé factor = 3.0). The photomultipliers measure the intensity of the wing of this line (27 – 80 mÅ from the line center), which is modulated according to its polarization state by a rotating quarter-wave plate. A typical observing run of about an hour covers an area of $500'' \times 450''$ with $10''$ steps. The polarimetric accuracy of this instrument is of the order of 10^{-4} for the integration of 1 second. The maps of solar active regions taken with this vector magnetograph are published every year. Major research topics studied in the first ten years of this instrument is summarized in Makita et al. (1993).

5. Future Plans

In order to conduct systematic, long-term observations of the solar activity, we are proposing to construct the Solar Cycle Telescope. This facility is made of (a) small refractors equipped with various filters to measure the magnetic fields, velocity fields, and solar images in various wavelengths, and (b) a 1m-class telescope and a spectrograph which will be used for high precision spectroscopic observations of the sun's velocity and magnetic fields. The facility will be operated continuously over at least one solar cycle, and the accumulated data will be used for the study of the driving mechanism of the solar activity cycle. The Solar Flare Telescope, the automatic Hα flare patrol telescope, and the STEP full disk magnetograph are part of the phase (a) of this project. The next step is to automatize sunspot observations, and to initiate spectroheliographic observations of the full solar disk in Ca K and He 10830 Å lines. The phase (b) of this project aims at high dispersion spectroscopic and polarimetric observations of the full solar disk by raster scanning. For Stokes profile observations we plan to use the Fe I line at 1.56 μm. For Doppler measurements a Zeeman-insensitive line (such as Fe I 5576 Å) will be used.

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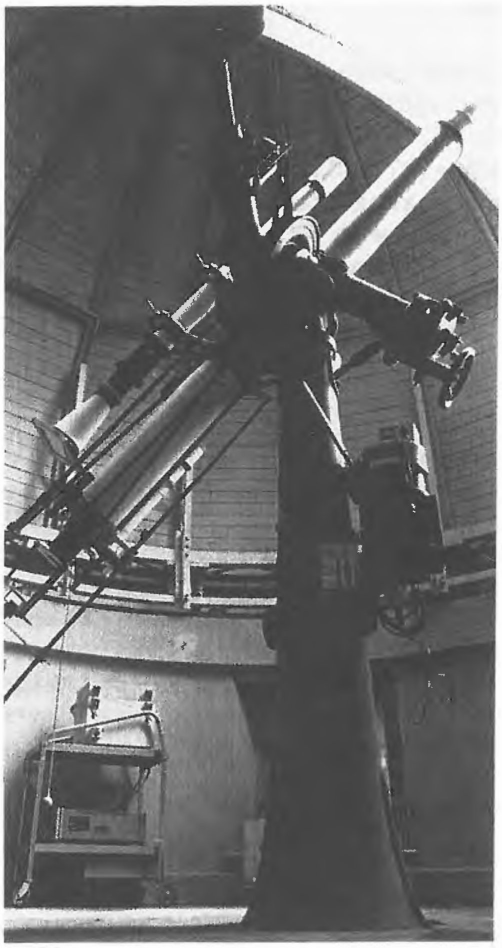


Fig. 1 The Zeiss 8-inch refractor at Mitaka.

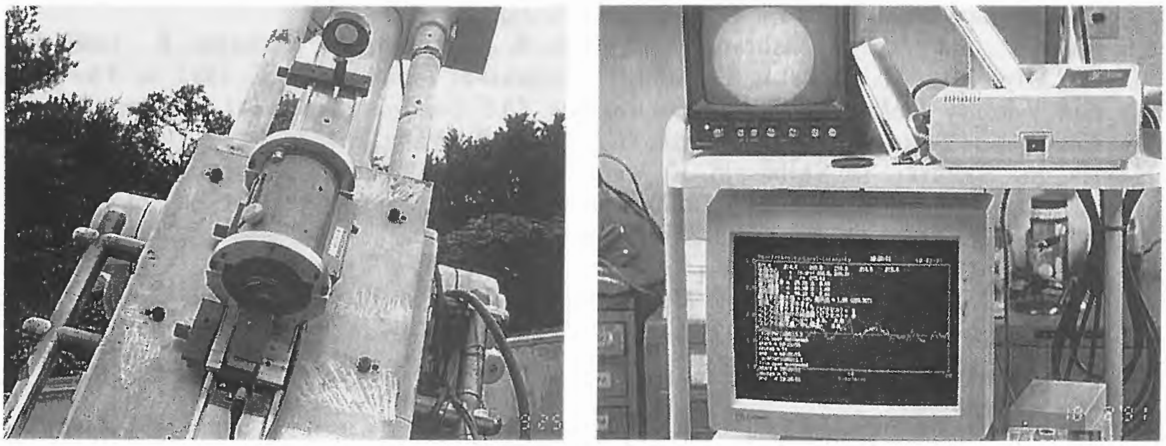


Fig. 2 The Hα flare patrol telescope (left) and the analysis system (right) at Mitaka.

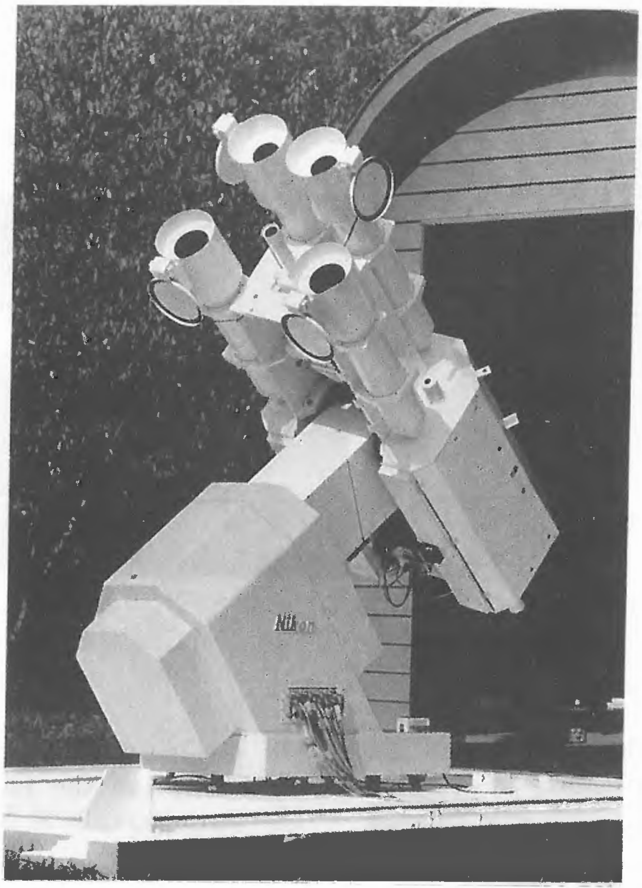


Fig. 3 The Solar Flare Telescope at Mitaka.

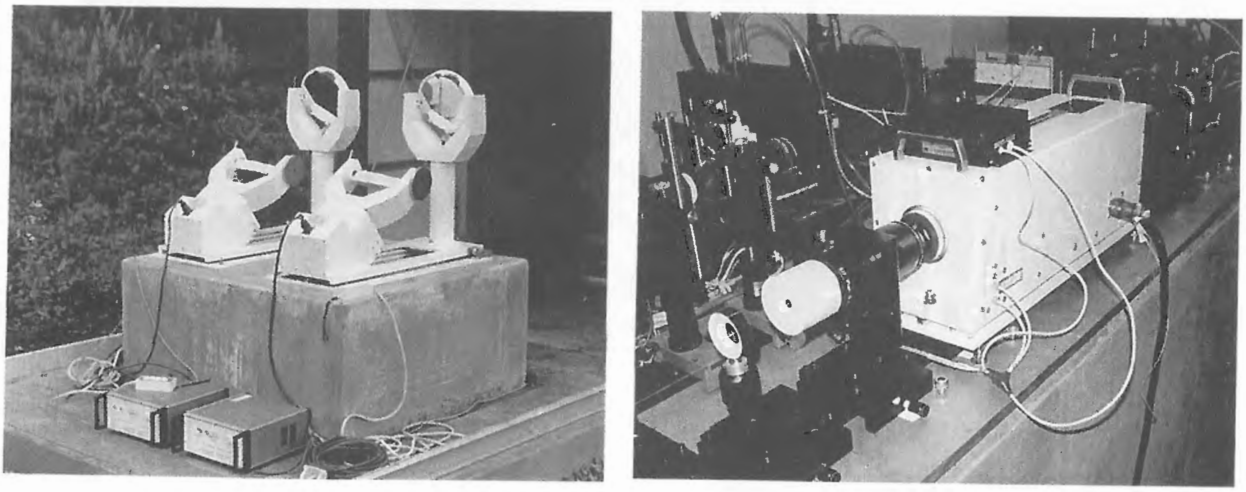
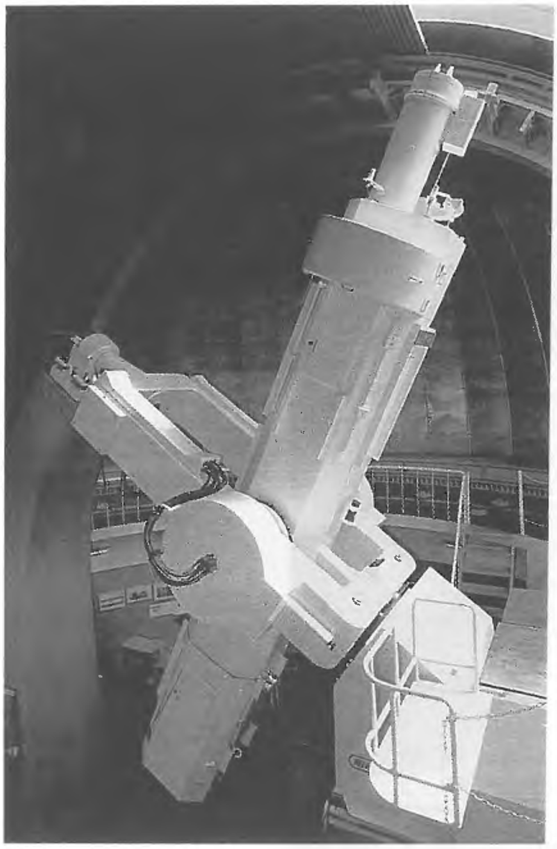


Fig. 4 The STEP full-disk magnetograph at Mitaka; the heliostat mirrors (left) and the birefringent filter (right).



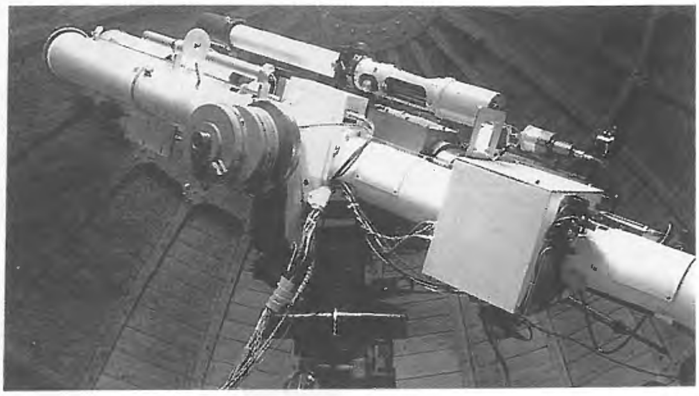
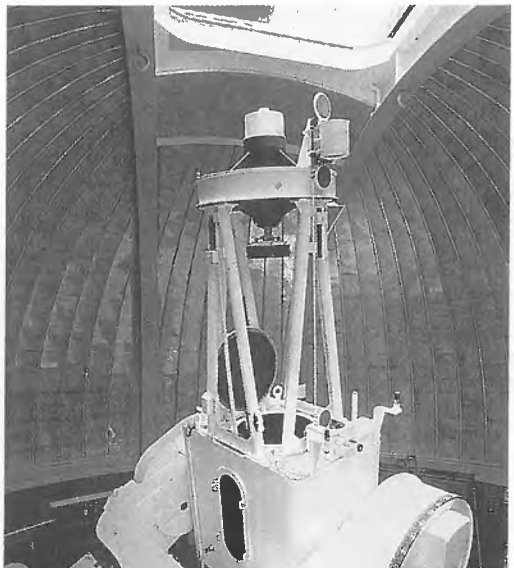


Fig. 5 The 25cm-aperture coronagraph (left) and the 10cm-aperture (right) coronagraphs at Norikura.



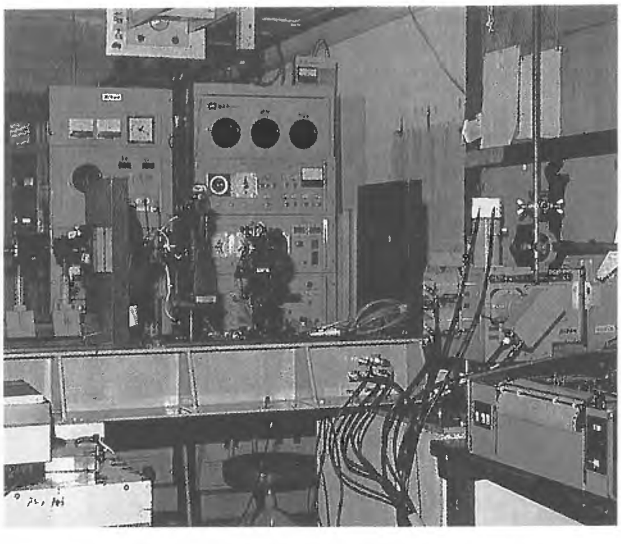


Fig. 6 The 65cm coude-type solar telescope (left) and the photoelectric magnetograph (right) at Okayama.