Development of hyperspectral camera for auroral imaging using Galvanometer-mirror-scanning optics

M. Yoshinuma[1], K. Ida[1], and Y. Ebihara[2]
[1] National Institute for Fusion Science, [2] Research Institute for Sustainable Humanosphere, Kyoto University
e-mail (speaker): yoshinuma.mikiro@nifs.ac.jp

The aurora is a natural luminous phenomenon caused by interactions between precipitating particles and the constituents of the upper atmosphere. The spectrum of an aurora has information about its precipitating particles and atmospheric constituents, as well as mechanisms for auroral emissions. Comprehensive and simultaneous spectrum observations are needed to investigate the aurora. Filter camera measurements are commonly used to obtain wavelength-resolved images, but these are insufficient for obtaining detailed spectral information.

The hyperspectral camera for auroral imaging (HySCAI), which can provide a two-dimensional aurora image with a full spectrum, was developed to study auroral physics. HySCAI was installed at the KEOPS (Kiruna Esrange Optical Platform Site) of the SSC (Swedish Space Corporation) in Kiruna, Sweden, in May 2023 and began observations in September of the same year [1,2].

To realize the hyperspectral camera, a galvanometer mirror scanner was used to scan the slit image on the all-sky image plane in the direction perpendicular to the slit. A high throughput lens spectrometer with an EM-CCD detector is applied to acquire the spectra image of the light coming from the slit. The spectrometer equips two gratings, one is 500 grooves/mm for a wide spectral coverage of 400–800 nm with a spectral resolution (FWHM) of 2.1 nm, and the other is 1500 grooves/mm for a higher spectral resolution of 0.73 nm with a narrower spectral coverage of 123 nm. The absolute sensitivity is 2.1 count/s/R with 4 × 4 binning (256 × 340 images) at 557.7 nm. Initially, HySCAI had been designed to cover only half of the sky for higher elevation angles, ϕ >34 degrees in the north-south direction and ϕ >50 degrees in the east-west direction. At the start of the season in 2024, it was redesigned to cover all the sky.

HySCAI can obtain a two-dimensional distribution of the wavelength spectrum, making it possible to inspect the spectrum's shape and the surrounding conditions. This makes it possible to remove the increase in spectral intensity caused by background light, and data taken at dawn or when the moon is present can also be used.

Hyperspectral data is acquired every two minutes with 68s (= 0.2s×340) exposure time because of the time required for spatial sweeping. By stopping the spatial sweep, it is possible to observe the time-dependent changes in the spectrum. By changing settings such as the grating constant and the area of the spatial sweep, we can explore new observations of Aurora using hyperspectral data.

References

[1] M. Yoshinuma, K. Ida and Y. Ebihara, Earth Planets Space 76, 96 (2024).
[2] https://projects.nifs.ac.jp/aurora/en/

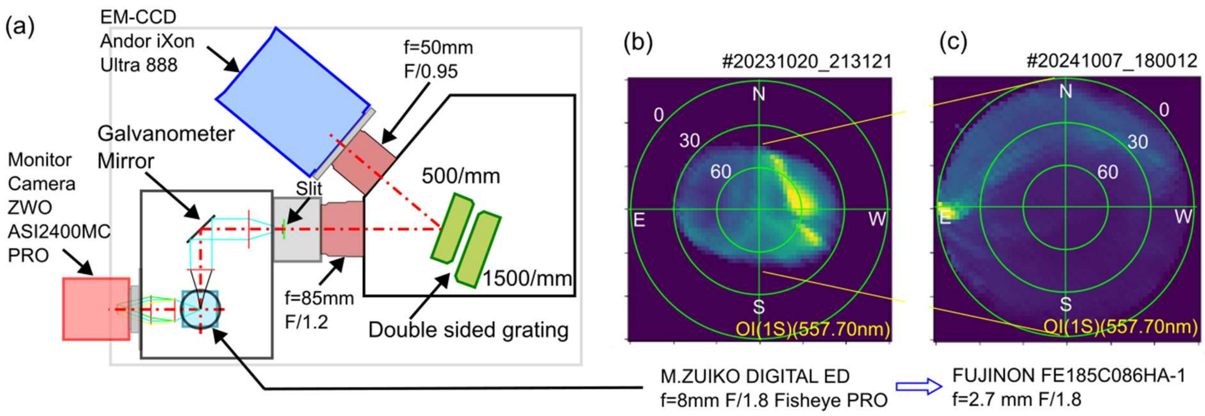

Figure 1. (a) The schematic view of the hyper spectral camera (HySCAI) using galvanometer mirror and lens spectrometer with EM-CCD. The fisheye lens has been replaced to improve the field of view. The monochrome image of the 557.7nm reconstructed from HySCAI data measured (b) before the replacement (21:31:21 UT on 20 October 2023) and (c) after that (18:00:12 UT on 7 October 2024). The field of view has been expanded by the replacement.