Spectral investigations on short-wavelength infrared aurora and airglow (0.9-1.6 μm): Ground-based observations in the both polar regions and developments of 2-D imaging spectrograph with high resolutions

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Dayside aurora, polar patch, and airglow are the key phenomena for the understanding of the dayside magnetosphere, ionosphere, and neutral atmosphere coupling process. Those phenomena have been mainly monitored by active/passive radio remote sensing such as HF/VHF/UHF radar, GPS/GNSS and LF wave receiver, and riometer, but spatial and temporal resolutions by those measurements are basically not so good in comparison to optical measurements. Short-wavelength infrared (SWIR) wavelength is crucially important because lower sky irradiation by Rayleigh scattering may allow us to conduct ground-based optical observations even on the dayside. In order to make spectral investigations on the dayside and a feasibility study for the future dayside optical measurements, we operated a Czerny-Turner type 1-D imaging spectrograph at Syowa station (69.0°S, 39.6°E, from March to October in 2018) and Kiruna (67.8°N, 20.4°E, from late August in 2019).

The spectrograph with two selectable gratings (150 lpmm and 600 lpmm), whose spectral ranges and those per pixel are 510 nm and 119 nm, and 0.50 nm/pixel and 0.11 nm/pixel, respectively, focuses on continuous measurements of SWIR aurora (N_2 1st Positive band and N_2^+ Meinel band) and SWIR airglow (mainly, OH 3-1 band). We presented two events on 6 and 8 May 2018 in which strong intensifications of SWIR aurora emissions are found synchronized with auroral breakup at Syowa station. This is the first study that show absolute intensity of N_2^+ Meinel band (1-0 and 0-0) and N_2 1st Positive band (0-0, 1-2, and 0-1) in the unit of Rayleigh and temporal evolutions of the emissions with high temporal and wavelength resolutions less than 30 seconds and 1.0 nm respectively so far. With regard to airglow, $P_1(2)$ and $P_1(4)$ emissions in OH 3-1 band allow us to estimate OH rotational temperature near the mesopause with errors less than 8 K for data of signal-to-noise (S/N) ratio greater than 2, which show good correlations to neutral temperature measured simultaneously by co-located Fe resonance scattering lidar. The continuous measurements of OH rotational temperature make it possible to study a variability of atmospheric waves and temperature changes due to energetic particle forcing in polar regions.

In addition, we are currently developing a 2-D imaging spectrograph with a fast optical system and a wide field-of-view (FOV). This spectrograph is designed for SWIR wavelength ranging from 1.09 to 1.25 microns that covers strong auroral emissions in N_2^+ Meinel band (0-0) and N_2 1st Positive band (1-2, and 0-1). FOV and angular resolution are 55 degrees and 0.11 degrees per pixel, respectively. If a 30-microns slit is used, wavelength resolutions are 2230 and 5070, with two different gratings (950 lpmm and 1500 lpmm). The S/N ratio for 1 kR emissions can be expected to be larger than 1.0 in a few seconds exposure time. Therefore, we can investigate temporal variability of dayside reconnection and pulsating auroras with sufficient sampling rates of a few seconds. This spectrograph will be installed at The Kjell Henriksen Observatory/The University Centre in Svalbard, Longyearbyen (78.2°N, 15.6°E). Taking advantage of its location, 24-hours continuous observations can be expected (solar zenith angle larger than 96 degrees)

near the winter solstice. Additionally, collaborative studies with active/passive radio remote sensing such as EISCAT Svalbard radar and LF radio receiver will be done in the near future to evaluate spatial and temporal characteristics of dayside aurora.

Keywords: Aurora, Airglow, M-I coupling, Mesosphere and Lower Thermosphere , Short-wavelength infrared, Imaging spectrograph

