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A new spectroscopic and imaging observation of SWIR aurora and airglow (1.1-1.3 μ m) at Longyearbyen with EISCAT Svalbard radar

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A new ground-based optical observation of aurora and airglow in short-wavelength infrared (SWIR) of 1.1-1.3 μ m is being planned in Longyearbyen (78.2^{o}N, 15.6^{o}E) in conjunction with EISCAT Svalbard Radar (ESR). Two state-of-the-art instruments, a SWIR imaging spectrograph and a monochromatic camera, have been developed to focus on study on dayside magnetosphere-ionosphere-atmosphere coupling processes in the high polar regions.

The 2-D imaging spectrograph, NIRAS-2, has fast optics and high spectral resolution for the challenge of twilight/daytime auroral observations from the ground. It has a field of view of 55 degrees and an angular resolution of 0.11 degrees/pixel. It covers the SWIR wavelength range of 1.1-1.3 μ m, where the sky background intensity is weaker than in visible light; it covers the strong auroral emission of $N_2{}^+$, the Meinel band (0-0) and the N_2 1st Positive band (1-2,0 -1). When a 30-μ m slit is used, the spectral bandpasses around 1.1 μ m are 0.53 nm and 0.21 nm for two gratings of 950 lpmm and 1500 lpmm, respectively. Test observations successfully measured airglow emission in the OH (5,2), (6,3), (7,4), and (8,5) bands at 1.07-1.33 μ m and in the O_2 IR band at 1.27 μ m. The 1500-lpmm grating and a 60-μ m slit allowed us to resolve the OH (5,2) band well with a signal-to-noise ratio of 5-6. The peak intensity of the $N_2{}^+$(0,0) band is about 10 times that of the OH (5,2) P_1(3) line. It was concluded that the spectrograph can detect auroras with a time resolution shorter than 30 sec and can investigate spatial and temporal variations due to solar wind-magnetospheric-ionospheric coupling and particle precipitations. For the upper mesosphere, the OH (8,5) band was sufficiently measured using a 950-lpmm grating and a 60-m slit. The rotational temperature can be estimated with a resolution of 10 minutes and an error of less than 3 K.

In addition to the spectrograph, we have developed a completely new SWIR camera, NIRAC, which focuses on auroral emission in the $N_2{}^+$ (0-0) band. The camera consists of several commercial SWIR lenses for security/defense applications, a plano-convex lens, a custom optical filter (center: 1112.76 nm, FWHM: 13.8 nm) and an InGaAs FPA (640 x 512 pixels). The entire optical system is fast (f-number 1.5), and the point spread function is less than 5 pixels at full width at half maximum, even near the edge of the FPA. The FOV is 92 x 73 degrees, slightly wider than the spectrograph.

Both instruments will be installed at The Kjell Henriksen Observatory/The University Centre in Svalbard (KHO/UNIS) by the end of FY2022. Taking advantage of the geographical location of this observatory, continuous 24-hour observation around the winter solstice is expected. Observational studies in conjunction with active and passive radio remote sensing such as ESR and VLF/LF radio receivers are also planned to accurately estimate the energy flux of precipitation particles associated with auroras and the associated changes in electron density and neutral and ion temperature. Scientific targets include dayside reconnection and wave-particle interactions monitored by auroral emissions, ion upflows seen as resonant scattering of $N_2{}^+$ ions, effects of high-energy particle precipitation on OH chemistry in the upper mesosphere, atmospheric wave activities, and disturbances of ionosphere in the E-F region. Observational strategies and future collaborations will also be discussed.