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Design and development of visible and far ultraviolet auroral imagers for the future satellite mission FACTORS

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We report the recent status of design and development of auroral imagers at visible and far-ultraviolet (FUV) wavelengths for the future satellite mission FACTORS. In addition, we also concern the science objectives with these imagers. FACTORS stands for Frontiers of Formation, Acceleration, Coupling, and Transport Mechanisms Observed by the Outer Space Research System, which will be proposed as a next generation polar orbiting formation flight multi-satellite mission. Major scientific targets are: 1) energy transport in the magnetosphere-ionosphere (MI) coupling system and their relationship to small-scale auroral phenomena, 2) particle transport in the MI system by ion outflow, and. Observation of small-scale plasma parameters and simultaneous auroral imaging data obtained with multi-satellite measurements in the altitude range from ˜300 km to ˜3500 km enable us to understand dynamical spatial and time variations in the MI coupling system, such as an Alfvenic wave acceleration and small-scale discrete aurora. Field-aligned current, particle distribution function, and Poynting flux obtained with FACTORS are the key parameters to reveal small-scale aurora.

We are designing and developing visible and FUV imagers for this mission. To observe dynamical morphology of small-scale aurora, both visible and FUV images are required to have high-spatial and high-time resolution capability. For the visible camera, called VISAI, we require the spatial resolution of ˜1km x1km at apogee (˜3500km altitude) with a time resolution of ˜1 to 10 frame/sec and the sufficient sensitivity for auroral intensity of ˜1 kR. Target auroral emission should be permitted lines for the high-time resolution imaging, and N2 1PG (670nm) or N2+ 1NG (391 or 428nm) is candidate. We have established high-spatial and high-time resolution auroral imaging measurement with MAC on the Reimei satellite and AIC on the LAMP rocket. We require the capability of VISAI to achieve the field- of-view (FOV) of 8deg x 8deg which mapped area on the auroral emission layer is ˜500km x 500km with the spatial resolution of ˜1.5km x 1.5km when the satellite is at the apogee. We carried out the optical design of objective lens (f=120mm, F/1.5). We are selecting an appropriate CMOS sensor to satisfy the required FOV and spatial resolution.

We developed the engineering model (EM) of VISAI with a candidate CMOS detector (Caeleste, ELFIS2), a commercial objective lens (Tholab, f=200mm, F/8.3), and an interference filter 620nm with the bandwidth (FWHM) of 3nm. We calibrated the sensitivity of VISAI-EM using the integrated sphere in NIPR on Jan. 7, 2025. By changing the intensity of integrated sphere from 1kR/nm to 100kR/nm (at 630nm), we captured 100 images for each exposure time (1s, 0.1s, 0.01s) . We also measured dark frame by turning off the lamp of integrated sphere. Using these data, we determined the read noise of 21 count r.m.s., dark noise in a room temperature of 1000 count/s/pix with the A/D conversion unit of 0.259 el/count, which is consistent with the specification of the Caeleste ELFIS2 CMOS. We estimated the counts for the case of VISAS by converting the counts using the lens parameters between the EM lens and FACTORS lens including pixel binning. We finally examined the SNR of auroral image including the read noise, dark noise, and photon shot noise, and validated that SNR of ˜20 with a 0.1 s exposure time for 1kR auroral intensity.

Concerning the FUV imager, called FUVI, we are discussing to observe only OI 135.6nm aurora or both of OI 130.4nm and 135.6nm. We designed the FOV of FUVI of 14deg x 14deg, which is wider FOV of VISAI. The advantage of FUVI is the capability of FUV auroral observation in a sunlit condition. To avoid the solar contamination in the visible range, we adopt the image intensifier (II) with MCP as a 2D array detector. We fabricated the candidate II without coating of the photocathode (i.e., bare MCP) for FUVI. Using this II, we developed the engineering model (EM) of FUVI, and going to test it with UV light in FY2025 to check the performance of bare II. In addition, we will investigate the coating material of photocathode (e.g., CsI) to gain signal-to-noise ratio obtaining better sensitivity of FUV aurora and sufficient suppression of solar visible contamination. We will procure the II with coating, and make testing or the capability to compare with the bare II.