# Design and development of visible and far-ultra-violet auroral imagers for the future polar orbiting satellite mission FACTORS

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We report the science objectives, the current design and development of auroral imagers at visible and far-ultra-violet (FUV) wavelengths for the future polar orbiting satellite mission FACTORS. FACTORS stands for Frontiers of Formation, Acceleration, Coupling, and Transport Mechanisms Observed by the Outer Space Research System, which is going to be proposed as a next-generation formation flight multi-satellite mission. We are discussing to submit a proposal to JAXA within a few years to be launched in mid 2030s. 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, 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 Reimei/MAC, and the similar concept objective lens made of fused silica, which has radiation hard capability, can be used. We designed VISAI with an objective lens (f=110mm) with a combination of 1024pix x 1024pix. a back-illuminated CMOS (1pix.=15um x15um). This camera has the 8 deg x 8 deg field-of-view (FOV) of which mapped area on the auroral emission layer is ~500km x 500km with the spatial resolution of 1km x 1km (with 2pix x 2 pix binning) at the apogee which satisfies the requirement.
We developed the engineering model (EM) of VISAI with the 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 RMS, 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 plan to observe OI 135.6nm aurora with similar or slightly wider FOV of VISAI. The strong advantage of FUVI is that it is capable to observe FUV aurora 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 surface of MCP (that is bare MCP) for FUVI, and going to test it with UV light with the objective lens made of CaF2 aspherical lenses (f=50mm, F/2.5) in early FY2025. In addition, we will investigate the MCP coating material (e.g., CsI) to satisfy both of sensitivity of FUV aurora and insensitivity of solar visible contamination, and going to test the efficiency compared with the II with bare MCP.
In this presentation, we give the science target, observation plan, designs, status of developments, and recent test results of VISAI and FUVI.

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