Future formation-flight satellite mission FACTORS: Development of far-ultra-violet imagers and simulation of Alfven wave observations

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We report the science objectives, design of instruments, and recent updates of the development of the far-ultra violet (FUV) imager for the future polar orbiting satellite FACTORS. This design is also applicable to the FUV imager on a geostationary orbiting satellite. In addition, we report the simulation results of Alfven wave parameters obtained with a formation flight of 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 multi-satellite formation flight 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 3) neutral-ion coupling in the auroral thermosphere. Multi-satellite observation of small-scale plasma parameters and simultaneous auroral imaging data in the altitude range from ~300 km to 4000 km enables us to understand dynamical spatial and time variations of Alfvenic wave acceleration, field-aligned current, particle distribution function and small-scale auroral emission.

We describe the design and development of visible and FUV imagers for this mission. Both visible and FUV images are required to have high-spatial and high-time resolution capability to observe the dynamical morphology of small-scale aurora. Therefore, we set the instrumental requirement for the visible imager to measure small-scale faint aurora with a spatial resolution of ~1km x 1km at apogee (~4000km altitude), a time resolution of ~10 frames/sec and sufficient sensitivity for auroral intensity of ~1 kR. The FUV imager is also required to have high-spatial and high-time resolutions, i.e., a few km x a few km, several frames/sec, to observe small-scale aurora, and sufficient sensitivity for auroral emission at ~1 kR. The candidate auroral emission is OI 135.6 nm, and/or N2 LBH band (140-180 nm). In contrast to the night-side operation of the visible imager, the FUV imager is required to be operated in the sunlit conditions, as the contribution of the FUV imager to the mission objectives is significant. Therefore, occulting optics may be a key in developing this instrument.

We designed and developed the test model of the FUV imager which consists of a commercial CCD detector which has a FUV sensitivity, objective lenses made of FUV-transparent CaF2 glass, rotational stage and vacuum chamber. We are going to carry out the accurate measurement of FUV spectroscopic sensitivity characteristics using the FUV-UV monochromator light source in ISAS/JAXA soon. In addition, we plan to perform a radiation test to the FUV detector in 2021, and demonstrate the performance required for the FUV imager. These technical issues are similar to the FUV imager designed to be on a geostationary satellite and are currently conducted by NICT, Japan.

Concerning the simulation of Alfven wave parameters obtained with a formation flight of FACTORS satellites, we investigated whether the frequency and wavelength of a propagating plasma wave could be derived by two satellites. The time series data of waveforms were produced by observing a pseudo plane wave with the two satellites based on the orbital conditions at which the satellites are actually launched. The plane wave was assumed to be the Alfven wave in the polar region actually observed by the FACTORS satellites. The actual Alfven wave is a plane wave with a finite frequency width, but we assumed a monochromatic wave here. The initial placement conditions of the two satellites at the apogee were examined for three cases: horizontal distance of 10 km, travel distance of 10 km, and vertical distance of 10 km. The wave number vector was derived for the given monochromatic wave by applying the wave propagation direction analysis algorithm called the Means method to the data of the three magnetic field components observed by the two satellites. The instantaneous phase was obtained by applying the Hilbert transform to the waveforms observed by the two satellites. Then, we established a method to derive the frequency and wavelength of the wave in the inertial system by using the time series data of the derived wave number vector, the derived instantaneous phase, and the distance between the two satellites. It was shown that the wave frequency and wavelength can be derived under the three initial placement conditions of the two satellites without assuming the dispersion relation of the plasma wave, but the derivation was limited depending on the angle between the wave number vector and the inter-satellite distance vector.

Keywords: small-scale aurora, Alfven wave, instrument

