Feasibility Studies on Photon Counting Terahertz Interferometry

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Abstract—Feasibility studies on photon counting terahertz interferometry (PCTI) is presented for the future space-borne interferometer, including astronomical objectives, requirements on telescopes, photon counting detectors, array configuration, and imaging simulations.

In the past symposiums, we have discussed the intensity interferometer can be a powerful tool for imaging, and an experimental demonstration using Nobeyema Radioheliograph was presented. In terahertz frequency region, photon counting detector is useful for intensity interferometers, hence we named PCTI. In this symposium, we address some of the design issues and technical challenges, and discuss on feasibility of future space-borne interferometers.

From astronomical point of view, terahertz frequency region is important for observing exo-planet formation, star-formation in our galaxy and external galaxies, and active galactic nuclei. All of these observations require high angular resolution to identify the central activities of these sources. Within existing technologies, PCTI can provide both high angular resolution and high sensitivity, because photon counting detectors on each telescope can record photon signal referring to a precision onboard clock, and realize long baseline interferometry. Appropriate arrangement of satellite orbit and precision measurement of relative position of telescopes realize aperture synthesis imaging. Under low background observing condition from space, cryogenic telescopes with moderate diameter (< 1 m) will provide enough sensitivity for many far-infrared sources catalogued by IRAS and AKARI satellites. With maximum baseline of 20 km at 3 THz, angular resolution of 1 milli-arcsecond will resolve proto-planetary disks, active galactic nuclei and star-forming regions in external galaxies. Formation flight of multiple telescopes is one of the key technology and precision measurement of telescope position and time is needed, some of these are common to VLBI and gravitational wave telescopes in space.

The concept of PCTI is based on the delay time measurement using terahertz photon bunches and complex visibilities are defined by intensity cross correlations only. Since the intensity cross correlation drops more rapidly than amplitude correlation, telescope arrangements should be optimized according to the source structure, in other words the spatial filter of PCTI have relatively narrow bandwidth. Also, a large number of photon is needed to measure the delay time with enough accuracy, and a bright calibration source is needed within the field of view. Some of the imaging simulations will be presented and discussed.

Photon counting detectors are being developed using SIS photon detectors targeting NEP of less than 10^{-18} $W/Hz^{0.5}$ with low leakage junction of less than 1 pA. Assuming a post detection bandwidth of 1 GHz, astronomical terahertz photon at a rate of 100 M photons/sec can be countable. The photon counting capability of detectors are to be demonstrated.