Prospects of Terahertz Intensity Interferometry

Hiroshi Matsuo[1*], Hajime Ezawa[1], Hitoshi Kiuchi[1], Mareki Honma[1], Yasuhiro Murata[2]

[1]*National Astronomical Observatory of Japan, Mitaka, Tokyo 181-8588, Japan*
[2]*Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, Sagamihara, Kanagawa 252-5210, Japan*
[*]Contact: h.matsuo@nao.ac.jp

Abstract—Far-infrared and terahertz intensity interferometry is studied for future high angular resolution observation from space. The intensity interferometers were demonstrated by Hanbury-Brown and Twiss in radio and optical wavelengths, but low correlation efficiency, requirements for large dynamic range and missing phase information limited their application. We have proposed that fast photon counting detectors in terahertz frequencies give high correlation efficiencies and delay time measurements using photon bunches, which are used to define complex visibilities for an aperture synthesis imaging. The photon counting detectors serve for high sensitivity observations from space; several orders of magnitude more sensitive than heterodyne receivers.

To show the feasibility of the terahertz intensity interferometry, we have made numerical simulations to compare the performance to heterodyne interferometry. When the noise temperature is the same, intensity interferometers require longer integration time to obtain complex visibilities from delay time measurements. In this respect, the intensity interferometry is not a technology to replace existing interferometers. On the other hand, due to the long coherence time, intensity correlations are stable against atmospheric phase fluctuation. When interferometer observation is made at 1 THz under phase fluctuation larger than 100 μm in path length, amplitude correlations drop exponentially, but intensity correlations stay the same. So, the intensity interferometry can be applied to long baseline interferometers at high terahertz frequencies from ground.

Further advantage is the use of direct detectors and photon counting detectors. Since direct detectors do not measure phase information, their sensitivities are not limited by the receiver quantum limit. Fast photon counting detectors also serve for high dynamic range measurements; such that 1 GHz bandwidth SIS photon detectors with NEP less than 10^{-17} W/Hz$^{0.5}$ can count 10^8 photons/sec from bright terahertz sources.

Based on the simulation studies, a roadmap towards the space terahertz intensity interferometry is discussed. Using fast photon detectors, such as SIS photon detectors, the terahertz intensity interferometry is to be demonstrated in lab to show imaging performance. For ground-based astronomical observations, existing or planned telescopes in Atacama or in Antarctica could be used to demonstrate the intensity interferometry by observing bright compact sources, such as massive star-forming regions and proto-planetary disks. For the space terahertz intensity interferometry, combination of two cryogenic telescopes is proposed to observe compact and bright sources catalogues by IRAS and AKARI missions.