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Test observations of natural lights by the mid-infrared laser heterodyne spectrometer with the hollow optical fiber coupler

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Mid-infrared (IR) laser heterodyne spectroscopy can achieve an ultra-high wavelength resolution of λ/dλ >1,000,000 (frequency resolution: <30 MHz) at ~10 μm in wavelength (~30 THz in frequency). The high dispersion observations for planetary atmosphere enables to measure wind velocities with a resolution of several 10 m/s and to detect trace gases including isotopomers. Notable successes for those targets have been accomplished on Venus, Mars, Jupiter, and Titan, by ground-based telescopes with heterodyne spectrometers. The spectrometers used in those observations consist of many optical elements to combine observed and laser lights. The size and weight become large, and their optical geometry requires high stability.

Fiber optics can simplify, downsize, and reduce the weight for those instruments. With this benefit, a near-IR heterodyne system with fiber couplers has been proposed as a space-borne instrument (Rodin et al., 2015). On the other hand, in mid-IR, there has been no fiber coupler with high transmission yet. In this study, we applied a new hollow optical fiber coupler to mid-IR laser heterodyne spectrometer. The coupler developed by Toyama University has high transmittance (~61%) for CO2 laser light. The next step is to utilize them in the application for natural light measurements.

We evaluated the capability of the mid-IR laser heterodyne spectrometer with fibers and a fiber coupler for natural lights from the Sun and black body source. The results are as follows: (1) For the hollow fiber, the transmission efficiency of 89.6 %/m was achieved for incoherent natural light from the Sun. (2) Incoherent light from a black body source and coherent light from CO2 gas laser through fibers are mixed by a beam splitter. This heterodyne spectroscopy could achieve a similar sensitivity as the heterodyne instrument without fibers. (3) Two kinds of incoherent lights and a coherent light from CO2 gas laser through fibers are mixed by a hollow fiber coupler. The two lights are from a black body absorbed by a C2H4 gas cell and from the Sun absorbed by the Earth's atmosphere. Obtained spectra are similar to spectra generated by numerical calculation.

Our current heterodyne test system with the fibers and the fiber coupler showed 10,000K of system noise temperature. It is about 3 times worse than our system without the fiber coupler, indicating that the test system with the fiber coupler needs an integration time of 9 times longer to achieve the same noise intensity. We are now justifying the coupling of natural light source to the fiber input, because the incident angle of observed light from the expected telescope is larger than the ideal angle for the input of the fiber. We will also report the results of this evaluation and improvement.