R009-26
B 会場 ：9/27　AM2 （10:45-12:30）
12:15～12:30

ファイバーとファイバーカップラーを用いた惑星大気観測用中間赤外ヘテロダイン分光器の開発

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Development of mid-IR heterodyne spectrometer with fibers and a fiber coupler for the observation of planetary atmospheres

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Fiber optics enables significant improvements of optical instruments to reduce their size and mass achieving higher efficiency and stability. It also enables the simultaneous measurement of multiple targets that can only be accessed through fibers. All of these are essential for onboard instruments for planetary orbiters, landers, rovers, aircraft, etc. This technology has been widely applied in visible and is beginning to be adopted in near-IR. In mid-IR which also has rich spectral information, the progress was limited by transmission materials for fibers. Recent hollow fiber technology enables to achieve higher transmission efficiency. We have applied this hollow fibers to mid-IR laser heterodyne spectrometer.

Mid-IR laser heterodyne spectroscopy is a method in which the light from the target is mixed with the light from a local oscillator (LO). Its frequency is down-converted to the intermediate frequency. This method can achieve a high wavelength resolution of λ/d λ>1,000,000 around 10 μ m (in frequency, df <30 MHz around 30 THz). This has enabled to resolve planetary wind velocities with a resolution of several 10 m/s and achieved unique results such as the wind changes associated with global dust storms on Mars and the super-rotation of Venus and Titan. However, precise convention of two optical paths is needed, so high-precision optical-axis adjustment with many mirrors makes the spectrometer large and complex., so iIt was unsuitable for instruments aboard spacecraft. We have tried to solve this problem by utilizing a hollow fiber that has high transmittance in the mid-IR region.

In this presentation, we report the feasibility test results of a laser heterodyne spectrometer in the mid-IR region using a hollow fiber and a fiber coupler. (1) For the hollow fiber, transmission efficiencies of >85%/m were achieved for both CO2 lasers and quantum cascade lasers, and transmission efficiency of 89.6%/m was achieved for sunlight, i.e., incoherent natural light. It was also confirmed that heterodyne spectroscopy of lights from black body and CO2 laser through fibers using a beam splitter can achieve the same sensitivity as that without fibers (Nakagawa et al., Applied Optics, 2023). (2) For hollow fiber couplers, we have demonstrated that heterodyne spectroscopy of CO2 lasers and quantum cascade lasers with a fiber coupler is as sensitive as the system with a beam splitter (Nakagawa et al., Applied Optics, 2023). In addition, the heterodyne spectrometer using a CO2 laser as the LO showed system noise temperature was the same as the quantum noise limit. System noise temperature was calculated by the Y-factor method, which uses the ratio of spectral power of black bodies that has two different temperatures 673 K and 293 K.

With these results, we have shown for the first time that it is possible to construct the heterodyne spectrometer using fibers and a hollow fiber coupler. Although these results were obtained with a laboratory system, we are now assembling a portable heterodyne spectrometer attached to a telescope. This system will be used for the test observations of the Venusian atmosphere using the Hitomi telescope at Sendai astronomical observatory in July 2023. The observation targets CO2 absorption around 10.3 μ m at limb and calculates mesospheric wind velocity in the Venusian atmosphere by Doppler shift.