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THz band heterodyne spectroscopy with superconducting HEBM receiver

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Terahertz band heterodyne spectroscopy plays an important role in the study of the physical and chemical conditions in both astronomical targets and terrestrial and planetary atmospheres. The Nagoya University Southern Observatory has employed mm/sub-mm SIS receivers at Pampa la Bola in the Atacama desert, Chile (alt. 4860m), to carry out a broad range of work on both astronomy and atmospheric remote sensing. In addition, the National Institute of Information and Communications Technology of Japan has succeeded in constructing a balloon-borne superconducting submillimeter-wave limb emission sounder in the 0.6 THz frequency band. Currently, the University of Tsukuba is planning a project for a THz band radio telescope in Antarctica. For such projects, the preparation of 1.5-4.0 THz band heterodyne receivers is a common thread.

We are developing 1.5-4 THz band quasi-optical superconducting hot-electron bolometer mixer (HEBM) receivers for astronomical and atmospheric remote sensing applications. The microbridge of the HEBM was made at room temperature from a 4-7 nm thick niobium titanium nitride (NbTiN) film deposited on a 20 nm-thick AlN buffer layer, using a helicon sputtering technique with a slow deposition rate. The mixer was cooled to 4.2 K by using a vibration-free close-cycled mechanical 4 K pulse tube cryocooler with the temperature fluctuation of 1.6 mK. The performance of a large volume NbTiN HEB mixer was studied at 1.47 THz by changing local oscillator (LO) power with the mixer bias voltage fixed. The intermediate frequency (IF) signal measured at 1.5 GHz had a maximum peak as a function of the bias current of the mixer. The corrected receiver noise temperature was 1600 K at around the IF maximum peak. It was also found that the IF signal was the most stable at around the IF maximum peak under the condition that the instability of LO pumping level was induced by small mechanical vibration of the cryostat. This novel device will enable us to observe plasma gases such as ionized carbon and various highly excited transition lines of key species involved in photochemistry of planetary atmospheres.

Keywords: terahertz, superconductor device, heterodyne spectroscopy