Measurements of Receiver Noise Temperature of an Ni-NbN HEBM at 2 THz

Yoshihisa Irimajiri* and Akira Kawakami

National Institute of Information and Communications Technology (NICT), Koganei, Tokyo, 184-0015 Japan
*Contact: irimaji@nict.go.jp

***Abstract*— We are developing an HEBM at the 2 THz for SMILES-2 for the measurement of Oxygen atom at 2.06 THz and OH at 1.83 THz. We have reported a wide IF bandwidth of ~6.9 GHz for an Ni-NbN HEBM of which a magnetic thin film was deposited between an electrode and a superconducting strip to suppress superconductor under an electrode. In this work, we have measured receiver noise temperature of the same device with a length of 0.1 µm. In order to measure the receiver noise temperature using a thin beam splitter, a LO power was increased by cooling two triplers of an AMC source to 50 K. As a result, more than 100 µW was achieved at 1.85~1.97 THz. The uncorrected receiver noise temperature of an Ni-HEBM was measured to be T_{rx}(DSB) ~1,220 K. After the correction of the loss of a band pass filter at the 2 THz which was used to avoid direct detection effect, $T_{rx\_BPFloss\_corr}$(DSB) was ~810 K.**

I. Introduction

We are developing an HEBM at the 2 THz band for SMILES-2 [1] for the measurement of emission line spectra of Oxygen atom at 2.06 THz and OH at 1.83 THz. We have reported a wide IF bandwidth of ~6.9 GHz for an Ni-NbN HEBM of which a magnetic thin film was deposited between an electrode and a superconducting strip to suppress superconductor under an electrode [2]. We measured receiver noise temperature of the Ni-NbN HEBM to research whether the same device also shows good noise performance.

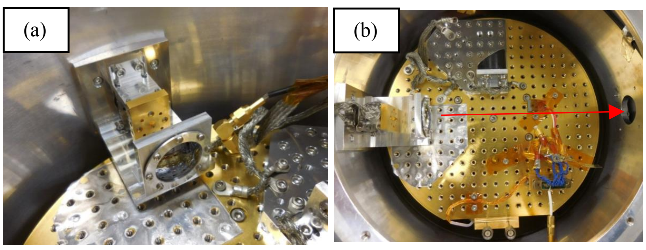

Fig.1. (a, b) Photographs of the two triplers installed at 50 K shield of the cryostat. The output of the THz source is collimated using an AR-coated@150 µm Si lens with f25. The LO signal is taken out from the window at the opposite side.

II. Experiment and Results

We measured the Ni-NbN HEBM with a length of 0.1 µm and a width of 0.5 µm using conventional Y-factor method. LO output power from an amplifier multiplier chain (AMC) was not enough to pump the HEBM if we use a thin beam splitter film to reduce contribution from RF optics. Therefore, to increase the power, two triplers of the AMC were cooled to 50 K attaching to a 50 K radiation shield of a 4 K mechanical cooler [3]. Figure 1(a, b) show photographs of two triplers installed in the cryostat. The output of the THz source is collimated using an AR-coated@150 µm Si lens with f25. The LO signal is taken out from the window at the opposite side.

Two triplers inside the cryostat and a 140-220 GHz band source outside the cryostat were connected by a WR5.1 waveguide made by stainless with a length of 73 mm (Fig. 2). The insertion loss of the waveguide was measured by a network analyzer to be -1.2~-1.8 dB at 140~220 GHz without a vacuum window of a 6-µm thick Mylar film. The measured waveguide consists of a copper-plated waveguide and a gold-plated thin waveguide inside.

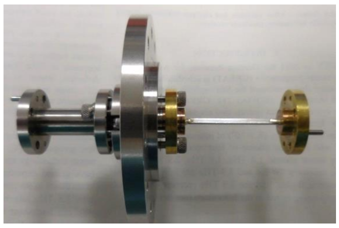

Fig.2. Waveguide (WR5.1) made by stainless to connect a 140-220 GHz band source at 300 K and two triplers at 50 K inside of the cryostat. The left part of the waveguide is plated by copper and right part (thin waveguide) is plated by gold. The measured losses are -1.2~-1.8 dB at 140~220 GHz. The waveguide was made in Japanese company (Oshima). The waveguide installed into a cryostat, however, is copper-plated inside in all parts.

The output power of the LO at the 2 THz was measured by a pyroelectric detector. As a vacuum window, a 6-µm thick Mylar film was used. In this measurement, the waveguides plated by copper inside in all parts were used. The measurement setup and the result are shown in Fig. 3(a, b). The power increased ~4 times compared to the original one also thanks for VDI giving a new tripler. More than 100 µW was achieved at 1.85~1.97 THz. We also measured the output power without water vapor absorption using a pyroelectric detector which is set in a nitrogen gas filled box. The measured result indicates the deep depression at 1.87 THz, 1.92 THz, and 2.04 THz shown come from water vapor absorption.

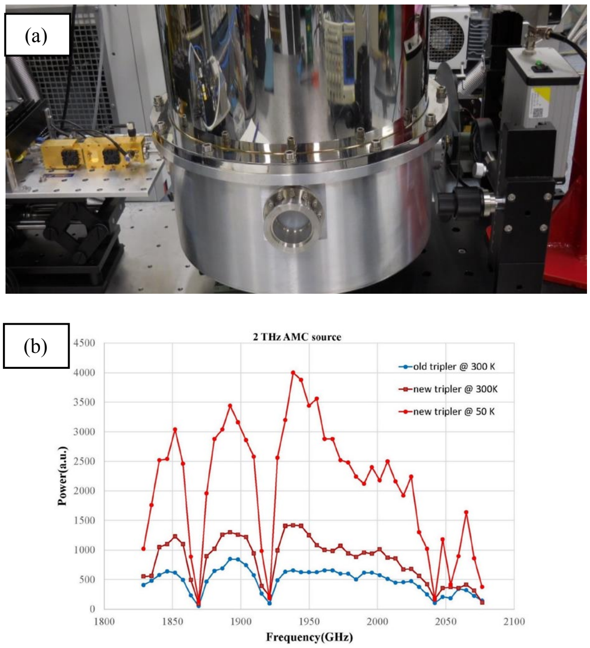

Fig.3. (a) Measurement set up of an output power of a cryogenic LO using a pyroelectric detector. (b) Measured LO power of original triplers at 300 K (blue line), new triplers at 300 K (brown line), and cryogenic triplers at 50 K (red line). The LO power increased ~4 times compared to the original one. More than 100 µW was achieved at 1.85~1.97 THz. The deep depression at 1.87 THz, 1.92 THz, and 2.04 THz come from water vapor absorption.

In order to measure receiver noise temperature, the LO signal was taken out from the cryostat and reflected by a polyester beam splitter (BS) with a thickness of 4 µm of which the reflection coefficient is ~5 %, and was fed into an HEBM cooled by an another LHe dewar (Fig. 4). As a first step experiment, the BS and HEBM were put outside the cryostat because alignment is difficult inside the cryostat at the high frequency.

By pumping the HEBM at an optimal level, the uncorrected receiver noise temperature (T_{rx}) was measured to be ~1,220 K(DSB). After the correction of the loss of a band pass filter at 2 THz which was used to avoid direct detection effect, $T_{rx\_BPFloss\_corr}$(DSB) was ~810 K. We measured the same HEBM device which shows a wide IF bandwidth.

Fig.4. Photograph of measurement set up of receiver noise temperature of the Ni-NbN HEBM. The LO signal was taken out from the cryostat and reflected by a polyester beam splitter (BS) with a thickness of 4 µm of which the reflection coefficient is ~5 %, and was fed into an HEBM cooled by an another LHe dewar. As a first step experiment, the BS and HEBM were put outside the cryostat because alignment is difficult inside the cryostat at the high frequency.

III. Summary

We measured receiver noise temperature of the Ni-NbN HEBM to be ~810 K ($T_{rx\_BPFloss\_corr}$) using a cryogenic LO of which two triplers are cooled to 50 K. We confirmed the Ni-NbN HEBM which shows a wide IF bandwidths of ~6.9 GHz also shows a good performance in noise temperature. We plan to develop a waveguide-type HEBM at 2 THz with a corrugated or a spline-profile horn for the applications of atmospheric observations. We expect the LO coupling could be better for the waveguide mixer.

References

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