令和５年度　未来研究ラボシステム　研究成果報告書

研究種目：共同 研究　　　研究期間：令和　５年 10 月 ～ 令和７年 10 月（予定）
研究課題名：テラヘルツセルフミキシング 信号の干渉・偏光情報による ターゲット認識

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研究成果：

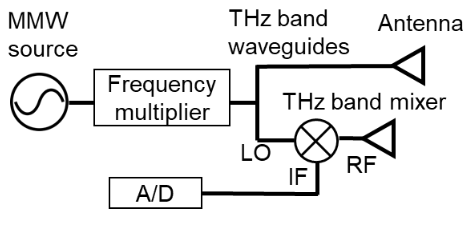
(概要) During FY2023, the 3D imaging demonstration using a single resonant tunneling diode (RTD) device was achieved by using the interference phase information of the self-mixing signal. The related results have been submitted to a top-level international conference. Meanwhile, the polarimetric signal at the 300-GHz band has been studied for recognizing the different materials. The preliminary results have been published in the THZMWP Symposium.

(本文)

As it was described in summary, the progresses of this research will be introduced in (a) and (b). **Then the future plans will be mainly** addressed **in (c) due to the changes of the research environment.**

(a) 300-GHz band 3D imaging enabled with the self-mixing signal of the RTD

Based on the previous studies on self-mixing signal of the RTD device, we realized 3D THz imaging using a resonant tunneling diode (RTD) transceiver with simple control circuits. The RTD operated as a self-oscillating mixer and a tunable oscillator simultaneously as shown in Fig.1. The RTD bias voltages ranged from 0.34 V to 0.38 V, corresponded to the free-run oscillating frequency ranged from 279.51 to 289.5 GHz. Since the voltage of the self-mixing signal VRTD is related to the oscillation frequency and the distance between and the imaging target with reflection, we can measure the distance based on the radar principle by applying it to a frequency-chirped signal to the RTD.



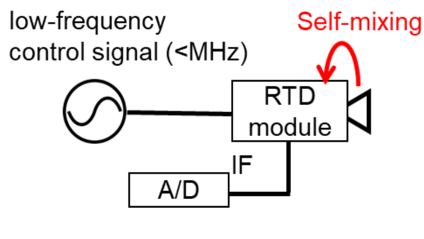
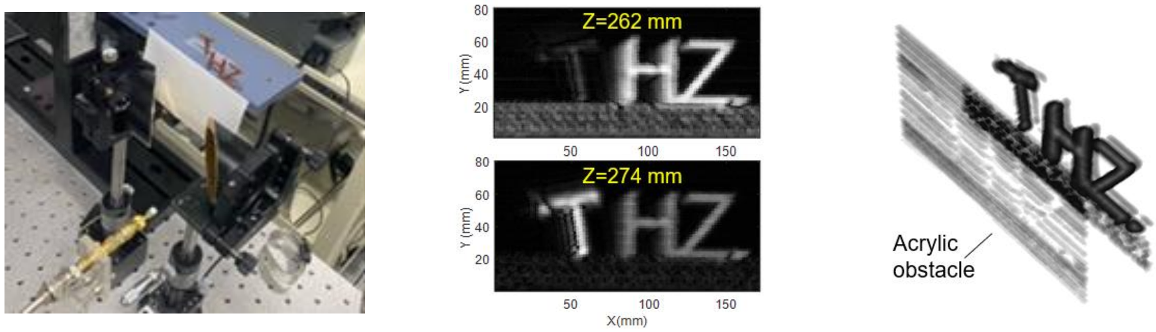


Fig. 1 Block diagram for the THz band 3D imaging system (a) Conventional system using frequency multiplexing and a mixer. (b) A single RTD operated as a self-oscillating mixer and a tunable oscillator is employed.

As a test bed, we demonstrate a 3D imaging experiment using a single RTD with a raster scan configuration in the 0.3-THz band as shown in Fig.2. Owing to the high sensitivity provided by the self-mixing feature of the RTD, the radar signal can be recognized at a maximum distance of 62 cm, even with a small output power of ~20 μW.



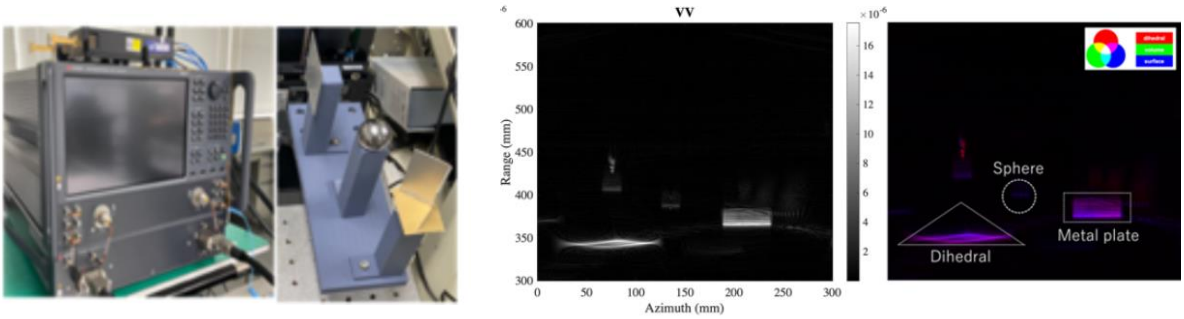
(a) (b) (c)

Fig. 2 The imaging target consists of three characters, "THZ" made using a 3D printer, with a width of 15 mm. The characters "HZ" are placed 10 mm ahead of "T". (a) Photograph of imaging setup." (b) Surface images of "HZ" or "T" with different distances z. (c) 3D view including an obstacle at the front.

Compared with the conventional methods shown in Fig.1 (a), the proposed method can significantly reduce the cost and complicity of the THz band 3D imaging system.

The preliminary imaging results using polarimetric information at the 300-GHz band

As another techniques introduced with this project, we have recently developed a Vector network analyzer (VNA)-based THz polarimetric imaging system at NICT and presented our preliminary work at the Symposiu. The phase information can be extracted accurately from the THz band mixing signal. Hence, the polarimetric information can be extracted to distinguish different shape of the targets (Fig.3). Compared with the 3D imaging method introduced in (a), this method aims at the large-scale 2D imaging, which enables much faster imaging speed. The application of this method using the self-mixing signal obtained with RTD will be further studied during FY2024.



(a) (b) (c)

Fig.3 THz fast 2D imaging using VNA system; (a) experiment setup; (b) conventional 2D imaging result; (c) target classification using polarimetric information.

(b) Research plans in FY2024

The applicant will start a new laboratory in Ibaraki Univ. from April of 2024. However, **this research project has been published in several symposiums based on the new patents, and there are many** potential **collaborators (companies) have been connected with our group through the Co-Creation Bureau of Osaka Univ..** In this case, one of the co-I, Prof. Fujita has invited the applicant as the visiting professor of our department. In this case, we can keep these relations at the Osaka Univ. since finding out the killer applications is emergently required for the THz band imaging techniques. It is really appreciated that

Prof. Fujita and the stuffs in Co-creation bureau will keep collaborating with the applicant for this project.
Meanwhile, the applicant can also focus more on this research topic with the help of the B4 students in Ibaraki Univ. since the RTD will be the main research topic of the applicant.
As one of the main goals (3D imaging) has been achieved this year, the applicant will focus on combining the polarimetric techniques (provided by NICT side) to the self-mixing signal of the RTD instead of that using the expensive VNA equipment. Based on these results, we hope that we can bring the novel THz imaging technique to the real applications by collaborating with the companies.

研究経費（R5 年度）の内訳 ：

備品費	消耗品費	旅費	謝金	その他	合計
974,293 円	41456 円	249,440 円	0 円	0 円	1,265,189 円

共同研究者等 ：

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(2)研究協力者（氏名・所属・学年（学生の場合))

N/A

発表論文等（令和 6 年 3 月 31 日現在）：

〔雑誌論文〕

N/A

〔著書〕

N/A

〔学会発表〕

[1] Suyun Wang, Li Yi, Study on Terahertz Polarimetric Imaging for Target Recognition、シンポジウム「テラヘルツ科学の最先端 X」、2023/12/20.

[2] Li Yi, Inose Yuta, Masayuki Fujita, Resonant Tunneling Diode Oscillator for Integrated Terahertz Active Three-dimensional Image Sensors, 2024 IEEE Symposium on VLSI Technology & Circuits. (Submitted)

〔その他〕

[1] JST 新技術説明会に出展

[2] 易利、冨士田誠之、猪瀬裕太，特願 2023-210597，信号補正装置および信号補正方法

外部資金獲得状況・申請状況 ：

科研費基盤研究 B（不採択）

参考となる HP 等 ： N/A