Development of a High-Power Laser-Integrated Backward Terahertz-wave Parametric Oscillator

Yuma Takida, Hiroaki Minamide

RIKEN Center for Advanced Photonics, RIKEN
E-mail: yuma.takida@riken.jp

1. Introduction

Non-destructive sensing using sub-terahertz (sub-THz) waves offers promising applications for industrial fields, thanks to their attractive properties, such as higher spatial resolution than millimeter waves. To realize a practical sensing system, a compact, robust, and high-output-power sub-THz-wave source is essential. As a strong candidate to meet these requirements, we recently demonstrated laser-driven backward THz-wave parametric oscillators (BW-TPOs) by using a slant-stripe-type periodically poled lithium niobate (PPLN) crystal [1–4]. The primary advantage of the BW-TPO is the mirrorless configuration owing to the counter-propagating interaction, where a pump photon is down-converted to backward-propagating THz-wave and forward-propagating idler photons without an optical cavity. This makes turn-key and alignment-free robust operation possible.

In this work, we have developed a compact all-in-one module of an injection seeded BW-TPO with a footprint size of 13.9 cm by 5.5 cm, as shown in Fig. 1.

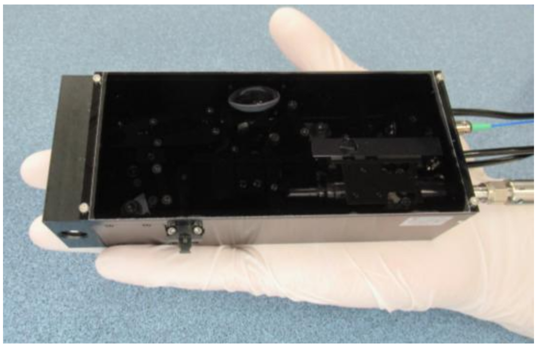

Fig. 1. Photograph of the developed palm-sized all-in-one BW-TPO module.

2. Experiment

In this BW-TPO module, the driving pump source of a passively Q-switched Nd:YAG microchip laser, BW-TPO gain medium of a slant-stripe-type PPLN crystal mounted on a motorized rotation stage, and all the optical components including a simple layout for injection seeding to the idler wavelength were assembled in a palm-sized package. From this compact module, the monochromatic backward-propagating THz-wave output was obtained with a maximum peak power of 15 W at 0.33 THz. Furthermore, by tuning the quasi-collinear phase-matching condition in the PPLN crystal, mode-hope-free frequency tunability from 0.29 to 0.35 THz was demonstrated.

Using the developed BW-TPO module, THz-wave imaging in reflection geometry was performed. The BW-TPO module and whole optical setup for reflection imaging were assembled on the optical breadboard that was mounted on a 2-axis motorized translation stage, while the position of the sample to be imaged was fixed. Fig. 2 shows the result of 0.3-THz reflection imaging with an area size of 150 mm by 200 mm with a 1-mm step without signal averaging. This result demonstrates the robust operation of the developed BW-TPO module.

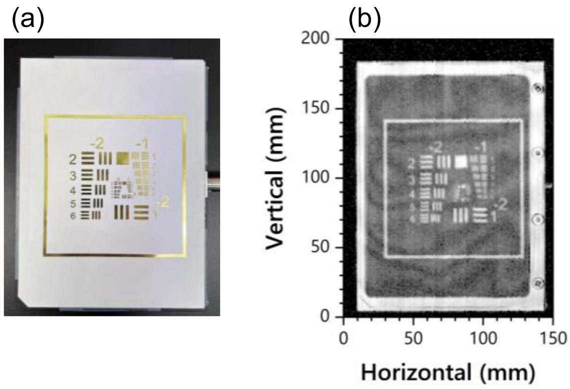

Fig. 2. (a) USAF 1951 test target pattern sample and (b) 0.3-THz reflection imaging result.

3. Conclusions

We have developed a palm-sized compact all-in-one BW-TPO module. Such a bright, frequency-tunable, and compact sub-THz-wave source is promising for real-world non-destructive sensing applications.

Acknowledgements

We thank Prof. H. Ito, Prof. M. Kumano, Dr. J. E. Muldera, Dr. D. Yadav, Dr. A. E. De Los Reyes, Dr. Y. Xu, Mr. Y. Yoneda, and Dr. K. Nawata for fruitful discussions. This work was supported in part by Innovative Science and Technology Initiative for Security, Grant Number JPJ004596, ATLA, Japan.

References

[1] K. Nawata *et al.*, Sci. Rep. **9** (2019) 726.
[2] Y. Takida *et al.*, APL Photon. **5** (2020) 061301.
[3] J. Muldera *et al.*, Opt. Express **31** (2023) 23966.
[4] J. Muldera *et al.*, Opt. Express **33** (2025) 22049.