

Spectroscopic Measurement of Terahertz-wave based on Nonlinear Optics

Shin'ichiro Hayashi⁽¹⁾, Seigo Ohno⁽²⁾, Katsuhiko Miyamoto⁽³⁾, Yoshiharu Urata⁽⁴⁾, and Norihiko Sekine⁽¹⁾

(1) National Institute of Information and Communications Technology, Tokyo, Japan; hayashi@nict.go.jp

(2) Tohoku University, Miyagi, Japan; seigo@tohoku.ac.jp

(3) Chiba University, Chiba, Japan; k-miyamoto@faculty.chiba-u.jp

(4) PHLUXi, Inc., Tokyo, Japan; urata@phluxi.com

We propose a spectroscopic measurement method in the terahertz region based on wavelength conversion between terahertz-wave and infrared using a nonlinear optics. Wavelength conversion techniques with reference infrared beams allow the spectra in the terahertz region to be determined as traceable to the national standard. In this study, as a reference infrared beam, we used high-brightness 1.5 μm beam generated by Nd:YAG MOPA system based injection-seeded PPLN-OPG and KTA-OPA for terahertz-wave spectroscopic measurement. The energy of one pumping photon split into two photons, a terahertz-wave and a signal wave. When detecting the terahertz-wave, mixing the terahertz-wave with the intense pumping (reference) beam at the input region of the MgO:LiNbO₃ crystal, up-converted signal photons are created in difference-frequency mixing. Then, by injecting the terahertz-wave satisfying noncollinear phase matching condition, the up-converted signal was seeded and parametrically amplified by the nonlinear MgO:LiNbO₃ optical parametric amplifier [1].

In our experimental apparatus, shown in Figure 1, the frequency stabilized pumping beam is generated using a PPLN-OPG seeded by a stabilized 1.539 μm laser beam (continuous wave, power: 4 mW) as traceable to the national standard. The generated pulses are amplified by a KTA-OPA amplifier pumped by a SLM Nd:YAG laser based MOPA system (duration: 1 ns, energy: 3 mJ/pulse). Figure 2 shows the 1064 nm pumping energy dependence of output peak power of frequency stabilized 1.5 μm beam when the amplified seeding peak power of 50 kW. As the pumping 1064 nm energy increases, as the output peak power of stabilized 1.5 μm also increases monotonically. When the pumping 1064 nm energy is 1.7 mJ/pulse, the maximum output 1.5 μm peak power is about 0.35 MW. The frequency of up-converted beam for the terahertz-wave spectroscopic measurement is detected using "spectral drill" resonator [2]. We used a MgO:LiNbO₃ crystal with a high-resistivity Silicon prism as an efficient input coupler for the terahertz-waves. The angle between the frequency stabilized pumping beam and the signal beam satisfies the non-collinear phase-matching conditions in the crystal. These are very promising for extending applied research into the terahertz region, and we expect that these will open up new research fields such as wireless information communications in the terahertz region.

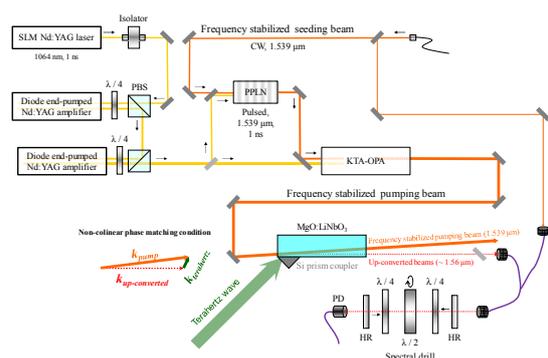


Figure 1. Experimental apparatus.

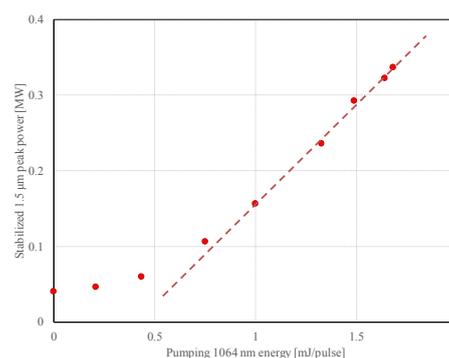


Figure 2. Pumping 1064 nm energy dependence of output frequency stabilized 1.5 μm peak power.

This work was partially supported by JSPS KAKENHI Grant Number 18H01908, 18K04967, and Tohoku University - NICT Matching.

References

- [1] S. Hayashi, K. Nawata, T. Taira, J. Shikata, K. Kawase, and H. Minamide, "Ultrabright continuously tunable terahertz-wave generation at room temperature," *Scientific Reports*, vol. 4, pp. 5045, 2014.
- [2] S. Ohno, "Spectral drill: a geometrical phase shifter within a Fabry-Pérot cavity," *OSA continuum*, vol. 1, pp. 136-143 2018.