Tunability enhancement of injection-seeded THz parametric generator

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***Abstract*— Recently, the output power of injection-seeded THz-wave parametric generator (is-TPG) was improved drastically. It already reached few tens of kW@peak. However, the tuning range was limited. In this paper, we report the improvement of the is-TPG tuning range. Suppression of THz-wave absorption in the crystal by total reflection of a portion of the pump beam at the crystal surface increased the upper limit of the tunable range from 3.0 to 5.0 THz.**

I. Introduction

Terahertz (THz) wavelengths lie between the microwave and infrared regions of the electromagnetic spectrum. Technological development in this regime has been slow, due to the lack of bright THz-wave sources[1]. However, this gap has rapidly diminished in recent years, due to advancements in laser technology and optoelectronic devices, allowing THz-wave production using a variety of approaches (e.g., photoconductive switching, optical rectification, and quantum cascade laser technology).

For years, we have worked on the development of a high-power THz-wave source, based on parametric processes in a $LiNbO_3$ crystal. In 2001, we created an injection-seeded THz-wave parametric generator (is-TPG) with 300mW output[2]. Recently, the peak output power of is-TPG approached few tens of kW[3] by introducing a new pump laser with shorter pulse width[4].

However, the tunability of is-TPG was still limited less than 3 THz due to the strong absorption loss inside the $LiNbO_3$ crystal[5]: the absorption increased with the frequency. Thus, despite THz-wave generation in the crystal, subsequent passes through the crystal significantly weakened the THz-wave, preventing high-frequency THz-wave generation. In order to suppress this absorption loss, we tilted the $LiNbO_3$ crystal slightly so that the THz waves were generated at the very near-surface of the crystal. Thus we have realized much wider tunability up to 5 THz.

II. Results

Figure 1(a) shows the experimental setup for THz wave generation. The pump beam and seed beam were injected into the nonlinear crystal at the angle of incidence required to meet non-collinear phase-matching conditions. This resulted in the generation of a coherent, single-frequency, widely tunable THz-wave. The THz-wave generated within the nonlinear crystal exhibited total internal reflection, due to the large refractive index mismatch between the $LiNbO_3$ crystal and air. To avoid reflection losses, an undoped Si prism coupler was placed on the y-surface of the nonlinear crystal. The THz-wave

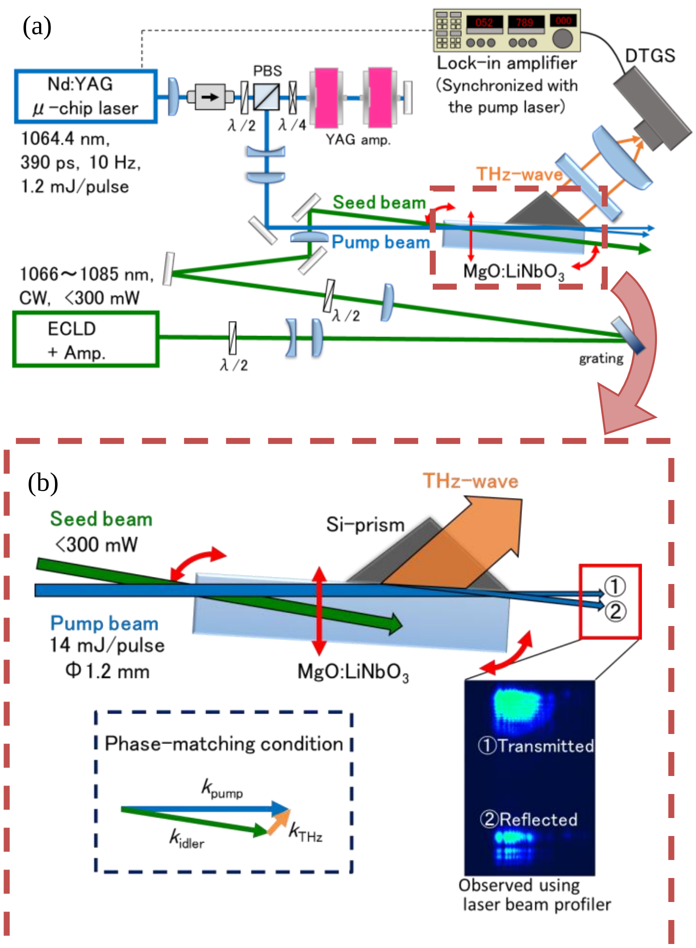

Fig. 1 (a) Experimental setup. (b) Enlarged view of the crystal.

energy was measured using a THz-wave pyroelectric detector with a lock-in amplifier synchronized with the pump laser.

Figure 1(b) shows enlarged view of the crystal. This is the main improvement in this work. In this setup, a portion of the pump beam propagated along the crystal (shown as "1" in the inset of the figure); the remaining portion of the pump beam was totally reflected at the crystal surface where the THz-wave was generated (shown as "2" in the inset of the figure). Such placement allowed THz-wave generation at the near-surface of the crystal; the absorption effect of the THz-wave was suppressed, resulting in enhanced power output.

In this work, we also switched the seed laser for a new external cavity diode laser (ECDL) with a transposed Littman design[6] (Spectra Quest Lab. inc, λ-master 1040); this laser has

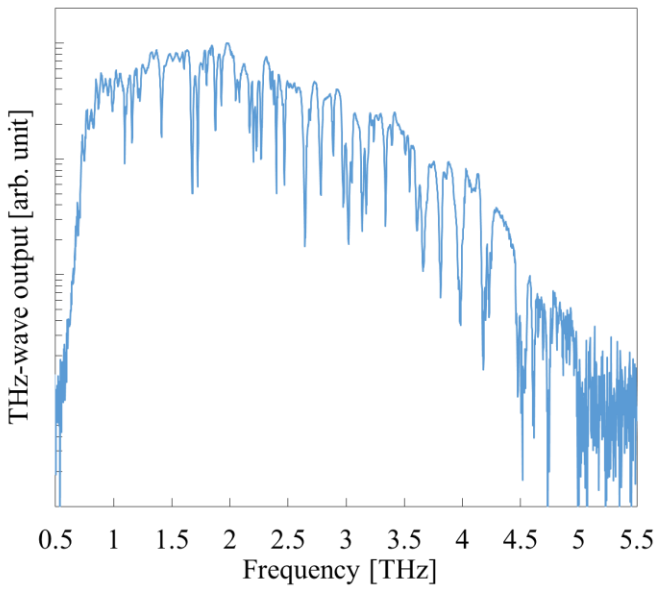

Fig. 2 Spectrum of the setup described in Fig. 1. The upper limit of the tuning range increased from 3.0 to 5.0 THz.

wide tunability (980–1090 nm), a wide mode-hop-free tuning range, and is nearly free of amplified spontaneous emission (ASE) effects. Thus, the ECDL is well suited for tuning range optimization of the is-TPG.

Figure 2 shows the tuning spectrum of the modified is-TPG. In our previous work[3], the upper limit of the tuning range was ~3 THz. However, with the new set-up, we were able to reach 5 THz. The water absorption lines in the spectrum were consistent with those from previous report[7], confirming the validity of the data.

III. Summary

In this work, we succeeded in improving the tuning range of the is-TPG. The upper limit of the tunable range approached 5 THz, as opposed to 3 THz in our previous report. The improvement in tunability was attributed to the suppression of THz-wave absorption in the crystal by total reflection of a portion of the pump beam at the crystal surface. With this, the is-TPG is a useful THz-wave source, with high power and wide tunability. We expect that the is-TPG described will play an important role in a wide range of applications, including THz spectroscopy and imaging.

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