High-power pulsed terahertz spectrometer

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***Abstract*—We present the latest development of Tydex LLC - a high-power pulsed terahertz (THz) spectrometer PTS-1. In PTS-1 THz radiation is generating by means of optical rectification under the Cherenkov phase-matching conditions. Thanks to the use of a high-power pump laser and because of the selected method of generating THz radiation, we succeeded in achieving a high average output power of THz radiation in our system.**

I. INTRODUCTION

PTS-1 is a comprehensive solution for broadband time-domain terahertz spectroscopy (THz-TDS).

In PTS-1, optical rectification of the femtosecond laser pulses in nonlinear medium is used to generate THz radiation. The optical rectification phenomenon involves formation of nonlinear polarization in a nonlinear medium exposed to a high-intensity optical pulse. Said polarization follows the envelope shape of the optical pulse. The nonlinear polarization pulse that occurs during optical rectification can be an efficient source of the THz radiation.

In PTS-1 generated pulsed radiation propagates in free space and detected by an electro-optical sampling method using an electro-optical detector (EOD-NIR) manufactured by Tydex LLC. PTS-1 comes with PC with Tydex-LN software installed. Tydex-LN allows to control the delay line; obtain data from EOD; process, export and import received data; automate measurements.

One of the key features of PTS-1, in addition to its high versatility and advanced software is the high average power generated by THz radiation.

II. RESULTS

Depending on dispersive properties of the nonlinear medium, THz wave generation can occur by a variety of mechanisms.

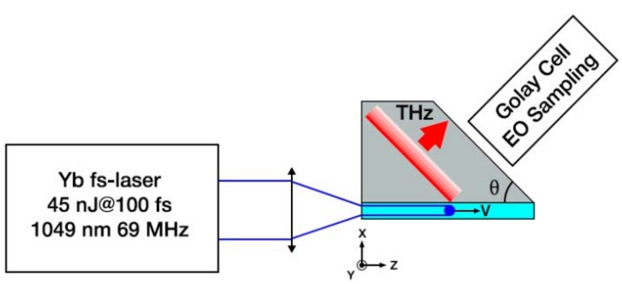

Fig. 1. Schematics of the sandwich structure and experimental setup.

When the velocity of the source (i. e. nonlinear polarization in a nonlinear crystal) coincides with phase velocity of a THz wave at specific frequency, collinear phase matching occurs. When the source propagates faster than the THz wave, another case of phase-matched excitation can occur. The wave propagating at angle θ to the source velocity vector V is also phase-matched to the source. It is known as Cherenkov phase matching.

To achieve a high optic-to-THz conversion rate (comparing to the collinear phase-matching scheme) we used a Cherenkov-like phase-matching scheme.

To produce a Cherenkov cone of terahertz waves, the optical pulse should be focused to a size of the order of or smaller than the terahertz wavelength [1]. For this purpose, the radiation of a Yb-doped solid-sate femtosecond pump laser (average output power - 3.14 W, central wavelength - 1049 nm, pulse duration ~ 100 fs, repetition rate - 69 MHz) was focused in the 10x10x1 mm 1% $MgO:LiNbO_3$ plate by a plano-convex spherical lens with a 75 mm focal length (Fig. 1). Phase matching is achieved between the moving optical pulse and a plane terahertz wave propagating under an θ angle (40.5°) to the laser path. To avoid total internal reflection of THz waves in the $LiNbO_3$ crystal, a HRFZ-Si prism was used [2]. To overcome high absorption of THz radiation within $LiNbO_3$ crystal, the pumping laser beam was aligned parallel and in close proximity to the $LiNbO_3$-Si interface.

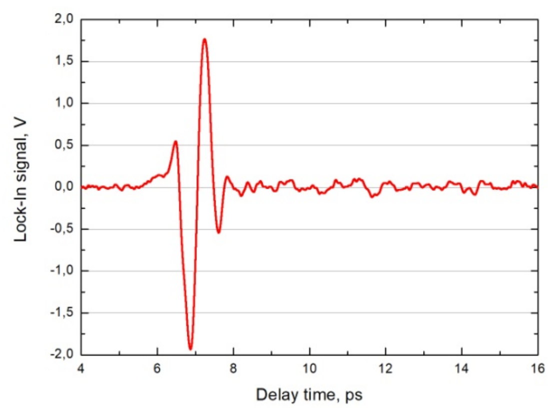

Fig. 2. The waveform of the THz pulse.

Two methods were used to measure THz radiation: electro-optical sampling and measuring with the Golay detector. The waveform of the generated THz pulse obtained by the EO sampling is shown in Fig. 2.

Average THz radiation power was measured by means of a calibrated Golay cell. For this purpose, the pumping beam was modulated by an mechanical chopper (modulation frequency was 20 Hz). To suppress any unwanted radiation (such as pumping laser radiation), the entrance aperture of the Golay detector was equipped with a low-pass filter (LPF) with cutoff frequency 10.9 THz. Amplitude of the THz radiation measured at the output surface of the silicon prism - 5.15 V. Golay cell sensitivity at 20 Hz modulation frequency is 24.5 kV/W. Taking into account the LPF losses (T_{LPF} = 70%), we've achieved ~ 300 μW average THz radiation power generated by the PTS-1.

Also, in PTS-1 we've achieved 0.1-2.5 THz operating range; no less than 60 dB dynamic range; 5 GHz spectral

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resolution (optionally, spectral resolution can be increased up to 2.5 GHz.)

III. SUMMARY

Here we presented the commercially available THz spectroscopic complex PTS-1 with an average output power of 300 μW and an optic-to-THz conversion factor of 10^{-4}. PTS-1 is ideal for scientific research applications because of the radiation propagation in free space, flexible optical scheme (easy customizable for the customer needs) and multipurpose software.

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