Narrow-band Terahertz Pulses Generated by Difference-Frequency Mixing of CO_2 Laser Lines

S. Ya. Tochitsky, C.Sung, and C.Joshi
Neptune Laboratory, Department of Electrical Engineering, University of California, Los Angeles, CA 90095 USA

***Abstract*— 2 kW, 200 ns pulses were produced in a noncollinear phase-matched GaAs crystal. The terahertz source tunable in the range 0.5-3.0 THz with a step of 40 GHz is pumped by a dual-beam TEA CO_2 laser.**

I. Introduction

MANY applications such as spectrally selective analysis of biomedical and semiconductor samples as well as chemically selective imaging will benefit from a narrow-band, high-power source tunable in the terahertz (THz) frequency range between 0.3 and 3THz. The most successful techniques for generating narrow-band THz pulses have come from frequency down-conversion of the existing 1-µm and 10-µm lasers. According to Manley-Rowe relations the maximum power conversion efficiency for DFG at a frequency of $\omega_3=\omega_1-\omega_2$ (where ω_1 and ω_2 are input frequencies) is limited by the ω_3/ω_1 ratio. Therefore, for applications where a high THz power level is necessary, CO_2-laser-based sources have a natural advantage in the down-conversion process. Recently in a single-shot experiment we have demonstrated the efficient generation of megawatt-power, 250 ps THz pulses by mixing two CO_2 laser lines in a GaAs crystal at room temperature.[1] However, a practical THz source must be easily tunable and pumped by a relatively compact, high-power pump laser running at 1-100 Hz.

In this paper we report the generation of THz difference frequency radiation by mixing the output of a compact, dual-beam TEA CO_2 laser in different nonlinear crystals. We compare a noncollinearly phase-matched GaAs, a collinearly phase-matched GaSe and a quasi-phase matched (QPM) GaAs structure. The measured power at 260 µm (1.15 THz) was ~2 kW for standard 200-ns long pump laser pulses. By selecting different line pairs a step-tunable radiation in the THz range was obtained.

II. Results

The experiment has been performed with a dual-beam CO_2 laser built at the Neptune Laboratory using commercial TEA lasing sections running at 1Hz. This dual-beam laser used one spark gap to trigger two parallel CO_2 lasing sections, thus providing jitter-free operation for two optical pulses. By choosing lines with approximately the same gain coefficient we extracted more than 1J per line simultaneously. A grating placed in each section allowed to cover the spectral range for the difference frequency from 0.5-4.5 THz with a step of 30-40 GHz.

As seen in Fig.1, the DFG power for noncollinear phase matched GaAs is >1 kW for wavelengths longer than 200 µm, and the THz output decreases to 20 W at 3 THz due to the phonon absorption. Cooling the crystal to ~ 80K should decrease the absorption and power above 1 kW is projected for the whole range of 0.3-3 THz (see solid line in Fig.1). A 2x4x2.5 cm^3 crystal was used for the measurements.

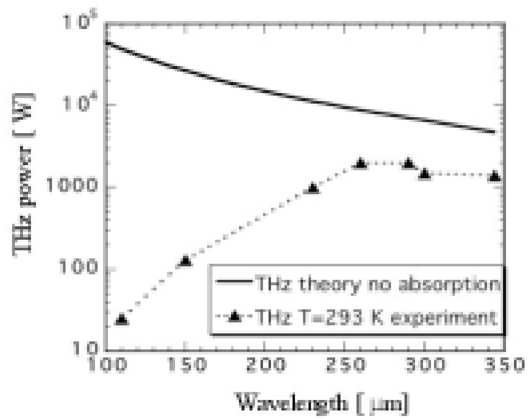

Fig.1 Calculated (solid line) and measured (dotted line) THz DFG power produced in a noncollinear phase-matched GaAs crystal.

We also developed Teflon bonding technology for fabricating large-aperture QPM GaAs structures. The average Teflon layer thickness was measured to be around 5 µm Structures with such boundaries between materials with different refractive indicies were modelled as a sequence of etalons and good agreement was achieved between the calculated and measured incident angles for which transmission of a 10 µm beam was maximum. Using a 2x2 cm^2 stack of five (110) commercial GaAs wafers (725±25 µm), we detected about 0.7 µJ of energy at 343 µm. This was smaller by a factor of ~2 than a theoretical value calculated without taking into account losses. In the experiment the nonparallelism of GaAs wafers available caused a drop in transmission of a pump and, therefore a lower THz DFG efficiency. Such a QPM GaAs structure can be improved in the future by the use of prefabricated parallel GaAs slabs. The power achieved by now is smaller than that of the THz DFG source in Fig.1, however, some experiments can benefit from a simple, drop-off THz generator with a very low sensitivity to angle misalignment.

References

[1] S.Ya. Tochitsky, J.E. Ralph, C.Sung, and C.Joshi, "Generation of megawatt-power terahertz pulses by nincollinear difference-frequency mixing in GaAs", J. Appl. Phys., 98, 026101 1-3, 2005.

978-1-4244-2120-6/08/$25.00©IEEE.