Frequency Tunable THz Source based on Optical Down-conversion in Orientation Patterned GaAs.

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Abstract: The generation of narrow-band THz radiation is demonstrated in orientation patterned GaAs structures via frequency down-conversion of short optical pulses. Frequency of THz radiation is tunable in the range 0.8-3 THz. Optical to THz power conversion efficiency reaches 0.1%, corresponding to internal photon conversion efficiency of 10%.

THz generation via optical down-conversion in non-linear crystals has been first demonstrated in the early 1970s [1] and it has been thoroughly investigated in a variety of materials. While this method of THz generation is widely used by researchers, it is limited by low conversion efficiency of optical power to THz radiation, which typically is 0.001%.

The efficiency of the optical down-conversion process is limited by three factors:

- The Manley-Rowe photon conversion limit
- Short interaction length between THz and optical pulses
- Absorption and dispersion of nonlinear optical materials

THz generation in orientation-patterned (OP) GaAs has a potential to overcome all of these limitations. First of all, GaAs offers high transparency and low dispersion for near IR and THz radiation. Secondly, interaction length between optical and THz pulses can be extended by quasi phase-matching [2,3]. What is the most exciting is that conversion efficiency can potentially exceed the Manley-Rowe limit by means of a cascaded down-conversion process. While the cascaded process has yet to be demonstrated, efficient THz generation in OP GaAs is indeed observed.

In this study we used OP GaAs structures fabricated by diffusion bonding of thin GaAs wafers [4] and epitaxially grown (MBE-HVPE) samples. The pump laser source was an amplified Ti: Sapphire system (Spectra Physics OPA-800) combined with a DFG crystal. The typical pulse duration was ~100 fs, the repetition rate was 1 kHz, and the pulse energy was up to 3.5μJ with a wavelength ranging from 3.5-4.5 μm.

A THz signal was detected using a bolometer and a calibrated opto-acoustical detector (Golay Cell). Temporal and spectral characteristics of THz radiation were measured in a Michelson interferometer.

Figure 1: Interferogram of THz signal.

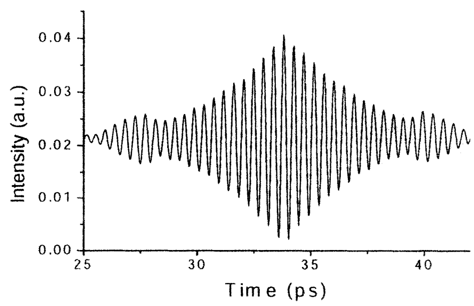


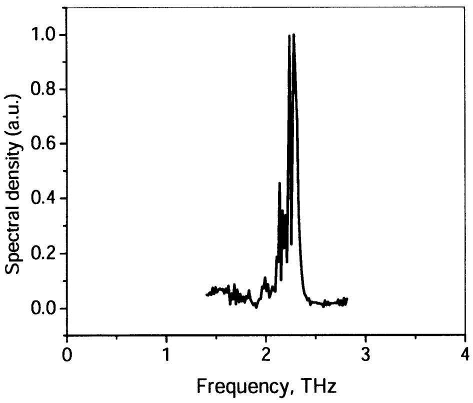
Figure 1 shows an interferogram of the THz signal generated in a 6-mm-long diffusion-bonded GaAs (DB-GaAs) stack, with a cross-section of about 1x 1 cm and an average domain-

reversal period of 504 μm. The pump wavelength was 3.5 μm.

While it is not possible to extract exact pulse-share from this data, it clearly shows that the THz signal consists of several oscillations decaying in time, which is expected due to residual absorption of GaAs in the THz spectral range.

Taking a Fourier transform of the interferogram, we calculated the spectrum of the THz signal, shown Figure 2. It is centered at 2.2 THz and has a width of about 200 GHz.

Figure 2. Spectrum of THz signal

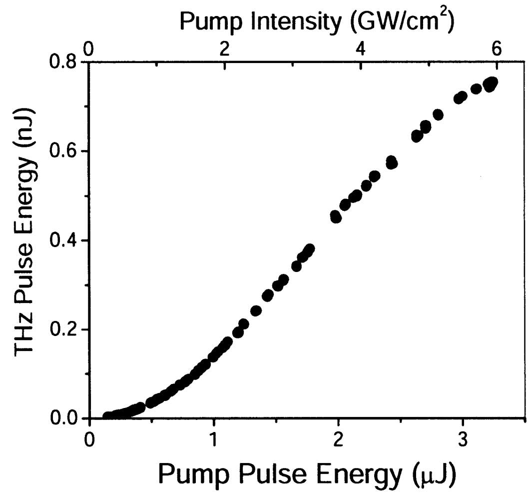


The central frequency of the THz signal is determined by domain period and pump wavelength. We have demonstrated generation of THz signals in the range 0.8-3 THz by varying domain period from 500 μm to 1300 μm and pump wavelength in the range of 2.0-4.4 μm.

The most interesting part of these results is the high power and photon conversion efficiency. It exceeds previously demonstrated results by almost two orders of magnitude.

There are two factors contributing to the improved conversion efficiency. First of all, quasi-phase matching extends interaction length between THz and optical beams. Secondly, the selection of the pump wavelength of 3.5 μm reduces the impact of non-linear absorption effects in GaAs, extending the THz generation to pump intensities above 1 GW/cm^2. A decrease in conversion efficiency due to non-linear optical effects becomes evident at a pump intensity above 3 GW/cm^2, as shown in Figure 3.

Figure 3: Output THz pulse energy as a function of pump intensity/pump pulse energy, measured for a DB-GaAs sample pumped at 3.5 μm.



The maximum power conversion efficiency observed in this experiment was close to 0.1%. Accounting for the reflected pump power, this corresponds to internal photon conversion efficiency of 10%.

We expect that further optimization of THz generation in OP-GaAs will enable observation of a cascaded down-conversion process, where an optical photon undergoes several stages of down-conversion generating multiple THz photons. The number of cascading stages will ultimately be limited by material dispersion. We estimate that 3-10 cascading stages can be observed in OP-GaAs, extending conversion efficiency beyond Manley-Rowe limit.

References:

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