Sources of electromagnetic radiation with terahertz (THz) frequencies have been actively investigated during the last decade for applications in imaging and spectroscopic sensors. Femtosecond optical pulses have been shown to efficiently generate THz waves in quasi-phasematched (QPM) gallium arsenide (GaAs) [1]. In this work we demonstrate a picosecond system creating a near diffraction-limited THz source with 1 mW of average power, an optical-to-optical efficiency of 0.01%, and a tunable frequency from 0.65 – 3.4 THz in QPM GaAs. Our approach is based on intracavity difference-frequency mixing in QPM GaAs of the signal and idler waves of a near-degenerate type-II PP:MgOLN OPO synchronously pumped with a CW-modelocked solid-state IR laser. GaAs is attractive for this application due to its large nonlinear coefficient as well as low THz absorption.

The 1064 nm source pumps a type-II PPLN crystal, in which orthogonally polarized signal and idler waves are generated near 2100 nm and 2150 nm, respectively. In the synchronously-pumped doubly-resonant
oscillator (DRO), both the signal and idler waves resonate inside a low-loss optical cavity, generating large intracavity powers, resonantly enhancing the difference frequency generation of the THz output power, which is proportional to the product of signal and idler powers [2]. The SP-OPO employs a novel offset cavity configuration which avoids the “DRO mirror” back-conversion problem generally present in linear DRO cavities (Fig. 1). The thin film plate polarizers separate the orthogonally polarized signal and idler waves, allowing for independent control of the length of the cavity for the signal and idler waves. By placing a piezoelectric actuator on one cavity end mirror and using optical power leaking through a highly-reflecting cavity mirror, a dither-and-lock control system will be built to stabilize the length of both cavities.

THz generation through signal and idler difference frequency generation (DFG) requires nearly-degenerate phasematching. Type-II QPM PPLN creates orthogonally polarized signal and idler waves which allows operation through degenerate phasematching as shown in Figure 2a where by convention the idler is the longer wave.

By changing the temperature of the PPLN crystal, we can tune the wavelengths of the signal and idler waves and thus their THz difference frequency. The generated THz waves spanned 0.65 – 3.4 THz by engineering varying QPM gratings in OC-GaAs (optically contacted), OP-GaAs (orientation patterned), and DB-GaAs (diffusion bonded). Figure 2b shows that measured THz frequencies follow QPM theory.

When the nonlinear gain is large enough the THz wave mixes with the idler to create a second red-shifted idler (satellite) and another wave at the same THz frequency. This process continues between the THz wave and subsequent satellites, and each process adds additional energy to the THz wave increasing the optical

![Figure 2: a) Temperature tuning curves of Type II QPM PPLN. b) THz frequencies generated in QPM OC-GaAs, OP-GaAs, and DB-GaAs.](image-url)
conversion efficiency. Figure 3 shows the signal and idler resonating inside the OPO and two measured satellites. Each wave of Figure 3 is normalized to unity to illustrate correct spacing and excellent lineshape. The signal and 1\textsuperscript{st} satellite are horizontally polarized, and the idler and 2\textsuperscript{nd} satellite are vertically polarized, as expected from the symmetry of the nonlinear susceptibility tensor of GaAs.

Currently, 1 mW of average THz power is created in diffusion-bonded gallium arsenide (DB-GaAs) with a frequency of 2.9 THz in 100 μs bursts of 50-MHz-repetition rate pulses. We believe that the duration of these bursts is limited by self-heating in the high-loss sample of DB-GaAs currently available. Future work will include maintaining DRO operation at 1 mW of average THz power utilizing a dither-and-lock length-stabilizing control system. Larger signal and idler beams inside GaAs and less mid-IR GaAs absorption will reduce the effect of nonlinear refraction and allow higher circulating powers for a given pump power. Both considerations will increase the efficiency of THz generation. Use of cascading to further increase the THz conversion efficiency will be explored.

References
