# THz source based on resonantly-enhanced difference frequency generation in periodically-inverted GaAs

K. L. Vodopyanov[a], J. E. Schaar[a], P.S. Kuo[a], M. M. Fejer[a], A. Lin[a], J. S. Harris[a], W. C. Hurlbut[b], V. G. Kozlov[b], D. Bliss[c], C. Lynch[c]

[a]Stanford University, Stanford, CA 94305, USA
[b]Microtech Instruments, Inc., Eugene, Oregon 97403, USA
[c]Hanscom Air Force Research Laboratory, Bedford, Massachusetts 01731, USA

**Abstract— We report mW-average-power widely tunable (0.5-3.5 THz) monochromatic THz source based on frequency mixing in periodically-inverted GaAs, between the two closely spaced 'signal' and 'idler' waves, inside the resonant cavity of an optical parametric oscillator.**

## I. Introduction And Background

Optical generation of THz waves through the nonlinear process of parametric down-conversion in electrooptic (EO) crystals is attractive because one can utilize compact and efficient diode-pumped lasers. In the case of difference frequency generation (DFG), THz output scales as the product of the two pump powers and as $\Omega^3$ for optimally focused optical beams ($\Omega$ is the THz angular frequency) [1,2]. Hence, conversion efficiency is intrinsically small because of smallness of $\Omega$ in comparison with optical frequencies.

## II. Results

Here we describe a novel approach to create a compact highly efficient tunable (0.5-3.5 THz) room temperature monochromatic THz source, based on the concept of intracavity THz generation via resonantly-enhanced difference frequency mixing. Near-degenerate doubly-resonant optical parametric oscillator (OPO), based on periodically-poled lithium niobate crystal (PPLN, type-II phase-matching), synchronously-pumped at 50 MHz repetition rate by 7-ps pulses at 1.064 µm, produces two closely spaced ('signal' and 'idler') waves near $\lambda$=2.128 µm (Fig. 1) [3]. The frequency spacing can be easily tuned by changing PPLN temperature, from zero to > 5THz. The THz output is produced via difference frequency mixing in periodically-inverted quasi-phase-matched (QPM) GaAs, having an appropriate inversion period (typically 0.5-2 mm), and extracted by an off-axis parabola with a hole in its center for the optical beam. Undoped GaAs is a superior EO crystal for THz generation because of (i) small THz absorption coefficient (typically >10 times less than in commonly used crystals: lithium niobate, ZnTe, CdTe), (ii) small mismatch between the optical and THz refractive indices, (iii) high thermal conductivity, and (iv) decent nonlinear optical coefficient. Three types of periodically-inverted GaAs [4] were used in our experiments: diffusion-bonded GaAs stacks (DB-GaAs), optically-contacted GaAs (OC-GaAs), and orientation-patterned GaAs (OP-GaAs) grown by MBE and HVPE epitaxial methods.

Because of high Q of the OPO cavity (roundtrip loss 3-20%), we were able to achieve the average signal + idler intracavity power of 20-100W near 2 µm, far exceeding that of the pump at 1-µm, of only 9 W. The peak intensity of the moderately focused intracavity 2-µm optical beams at the GaAs crystal reached >$10^8$ W/cm$^2$ which is sufficient [2] for getting high THz conversion efficiency. Our approach allowed generating of 1 mW of average THz power, in a diffraction-limited beam, potentially scalable to 10-100 mW provided that the optical losses in the OPO are decreased and a ring cavity is employed (at the moment we are using linear cavity configuration). We also observed recycling of optical photons via Raman-like cascaded process during THz generation, which makes it possible to substantially surpass Manley-Rowe conversion limit.

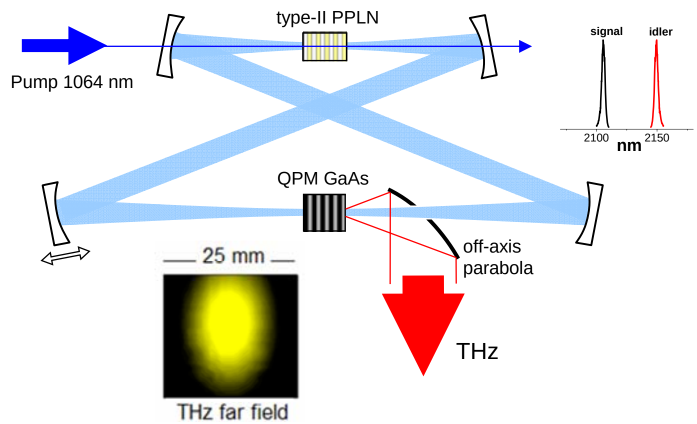


Fig.1 Conceptual scheme of resonantly-enhanced THz-wave generation. Near-degenerate doubly-resonant optical parametric oscillator produces two closely spaced ('signal' and 'idler') waves near $\lambda$=2.1 µm (inset). THz output is produced via difference frequency mixing in periodically-inverted GaAs. Another inset (bottom left) shows far field of the THz beam.

## References

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