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

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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 Ω^3 for optimally focused optical beams (Ω is the THz angular frequency) [1,2]. Hence, conversion efficiency is intrinsically small because of smallness of Ω 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 λ=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.

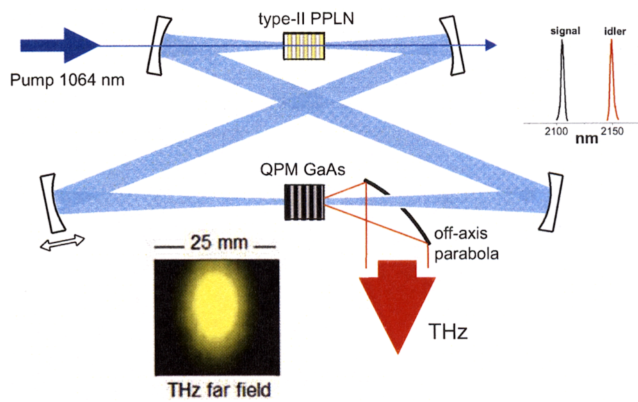

Fig.1 Conceptual scheme of resonantly-enhanced THz-wave generation. Near-degenerate doubly-resonant optical parametric oscillator produces two closely spaced ('signal' and 'idler') waves near λ=2.1 µm (inset). THz output is produced via difference frequency mixing in periodically-inverted GaAs. Another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

References

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