Terahertz wave generation and detection in GaAs crystals enhanced by using tapered parallel plate waveguides as focusing optics

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GaAs is a III-V semiconductor with zinc-blende structure and direct band gap of 1.43 eV at room temperature. GaAs has excellent potential as a nonlinear optical material for the generation and detection of terahertz (THz) waves with the excitation at the optical communication wavelengths (1.260-1.675 μm), where cost-effective, compact, and stable femtosecond lasers are available as a pump source. GaAs has several advantages over other nonlinear crystals, such as a large nonlinear coefficient (d_{eff} =65.6 pm/V), low absorption and dispersion in the THz frequency range, and relatively small difference between the optical group and THz refractive indices. The last property allows for achieving good optical-THz phase matching conditions in the weakly noncollinear Cherenkov geometry. As indicated in Table 1, Cherenkov phase-matching angle in GaAs is around 12° [1], which is substantially smaller than in other representative nonlinear optical crystals. Due to the small Cherenkov angle, a long interaction length of the optical and THz beams is possible in GaAs [2] and no coupling optics is required to couple the generated THz waves to free-space radiation. In this paper, the authors report the results of their research and development of THz emitters and detectors using GaAs as a nonlinear optical medium and tapered parallel plate waveguides (TPPWGs) as a focusing device for THz waves [3-5]. We present a fully GaAs-based THz-TDS scheme that offers broadband (~3 THz) THz generation and detection and the dynamic range as high as 10^6. In this scheme, the noncolinear Cherenkov phase-matching is implemented in ~6-10-mm long GaAs crystals. Using TPPWG allows for improving the scheme performance by a factor of ~2-3.

Table 1. Optical properties of nonlinear optical crystals

Crystal	r_{li} [pm/V]	d_{eff} [pm/V]	Optical index @ 1.55μm	Group index @ 1.55μm	THz index @1THz	Cherenkov angle @ 1 THz
DAST	r_{11}=47@1535nm r_{11}=77@800 nm	d_{11} =615	2.131	2.249	3.07	42.9°
$LiNbO_3$	r_{33} =30.9@633nm	d_{33} = 168	2.138	2.18	4.76	63°
ZnTe	r_{41} =4.0@633nm	d_{33} = 68.6	2.733	2.8	3.17	28°
GaAs	r_{41} =1.5@1.5μm	d_{36} =65.6	3.374	3.54	3.59	12°

Note: The values of the nonlinear optical coefficient for optical rectification $d_{eff} = - n_{NIR}^4 r_{li}/4$ are taken from [6]. Here, n_{NIR} is the refractive index in the near infrared region and r_{li} are the electro-optic coefficients.

References:

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