Three modes of the nonstationary holographic current excitation in a gallium oxide crystal

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Introduction

A number of holographic techniques are used for characterization of photorefractive materials [1]. The method of the nonstationary holographic currents (non-steady-state photo-EMF) uses the direct conversion of a phase-modulated optical signal into electric ones providing the information on space-charge and photoconductivity formation [2]. The effect appears as an alternating current in a semiconductor medium illuminated by an oscillating light pattern. Since no light difraction is required for observation of the effect, the technique can be applie to the centrocymmetrical crystals. In this paper we study three main modes of signal excitation, i.e. the cases of zero, dc and ac applied electric fields, in a monoclinic gallium oxide crystal β-Ga_2O_3, which is commonly recognized as a perspective material for short-wavelength photonics and power electronics [3].

Results and discussion

In spite of the high crystal transparency for the chosen wavelength $\lambda = 457$ nm the reliable detection with the signal-to-noise ratio of 0-40 dB is achieved. The phase of the signal corresponds to the electron type of photoconductivity.

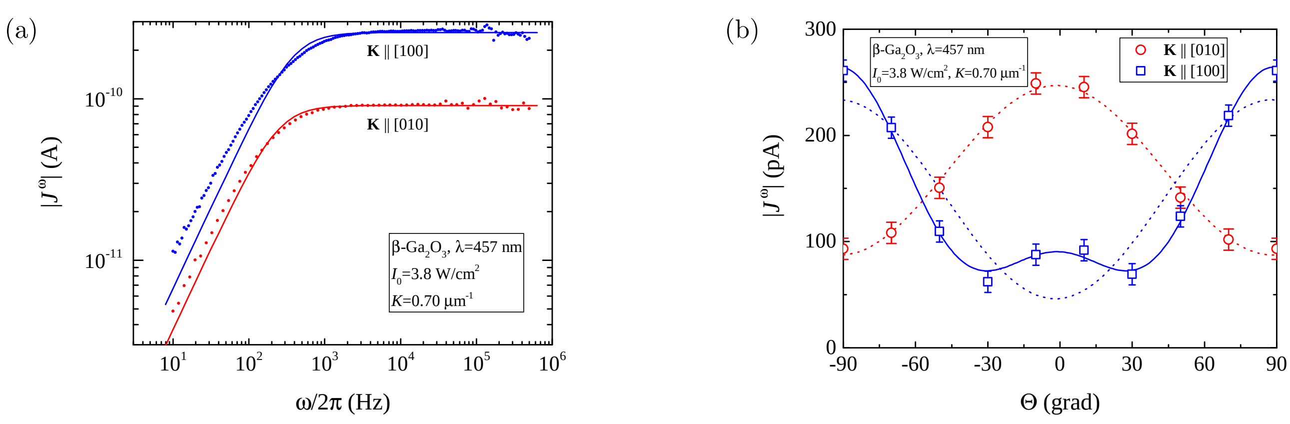

Figure 1: Frequency dependencies of the nonstationary holographic current for the diffusion mode of excitation (a). Dependencies of the signal amplitude on the angle between polarization and incidence planes (b).

The frequency dependencies for the diffusion mode of signal excitation ($E_0 = 0$) have well known shape with the growing and frequency-independent parts (Fig. 1,a). The crystal anisotropy reveals itself in the experiments with different orientations of the grating vector K (Fig. 1,a). The polarization dependence of the signal is also observed (Fig. 1,b), and we attribute it to the corresponding polarization dependence of the quantum efficiency. The values of the photoconductivity and diffusion length are estimated: $\sigma_0 = 2.3 \times 10^{-9}$ Ω^{-1}cm^{-1}, $L_D = 200$ nm along the [100] axis and $\sigma_0 = 1.6 \times 10^{-9}$ Ω^{-1}cm^{-1}, $L_D = 230$ nm along the [010] axis.

The amplitude of the nonstationary holographic current can be incresed by application of the external dc voltage (Fig. 2,a). The signal enhancement is not the only change: the frequency dependence becomes resonant. The appearance of the resonance is due to the excitation of space-charge waves, which are the eigenmodes of space-charge evolution in semiconductors [1].

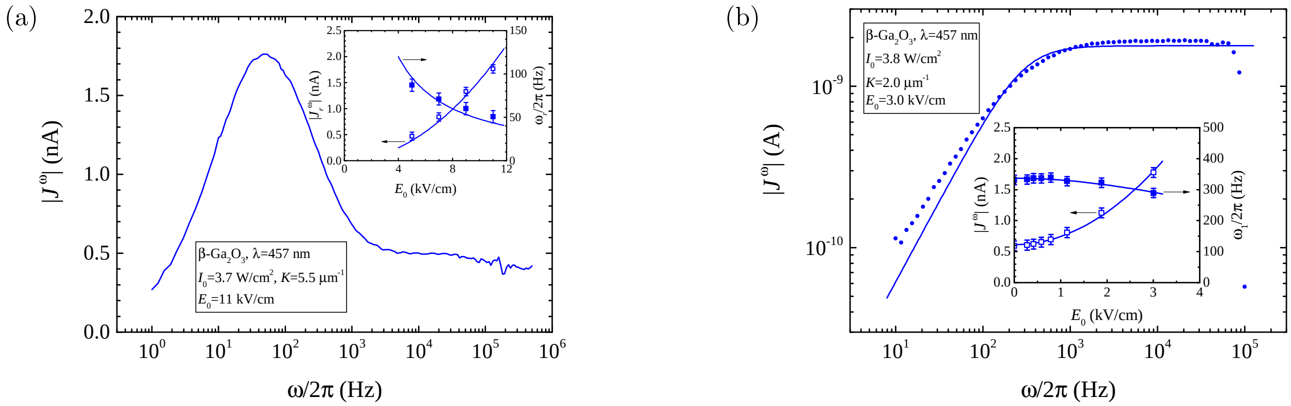

Figure 2: Frequency dependencies of the nonstationary holographic current excited in external dc (a) and ac (b) fields. The insets show dependencies of the signal amplitude, resonant and cut-off frequencies versus applied field value.

The nonresonant enhancement of the signal can be realized by application of the ac electric field (Fig. 2,b). The enhancement of the signal is associated with the more intensive charge transfer from bright to dark interference fringes, which results in a higher amplitude of the recorded electric field grating [1]. The application of an ac external field decreases the cut-off frequency, while the frequency response maintains the form inherent to the diffusion mode of signal excitation.

Conclusion

To summarize, we have studied the nonstationary holographic currents in monoclinic β-Ga_2O_3 crystal at $\lambda = 457$ nm. This material allows the signal excitation without any applied voltage as well as the signal enhancement in the presence of dc electric field. The noticeable signal level and flatness of the frequency response in β-Ga_2O_3 crystal can advance its utilization as a material for adaptive sensors of phase- and frequency-modulated optical signals.

References

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