Parametric emission generation in cubic noncentrosymmetrical crystals

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Abstract. The physics of polariton radiation generation in cube noncentrosymmetrical crystals is discussed. Theoretical values of polariton radiation frequencies in GaP, ZnSe, ZnTe and GaAs crystals were found. The basic circuit of parametrical terahertz radiation generator is introduced.

1. Introduction and background
The possibilities of spectroscopy in the terahertz (THz) frequency range have been increased with appearance of the novel techniques for generation and detection of THz waves. Spectroscopy of the polaritonic Raman scattering is the known method for studying of the collective excitations (phonons, magnons and others) in crystals [1]. The researching of the polaritonic Raman scattering spectrum has been performed for different kinds of the cubic noncentrosymmetrical crystals by using of different lasers. These technique allows the full characterization of the complex dielectric constant for many types of dielectric crystals [2]-[4]. Moreover, studying of the polaritonic Raman scattering is an important problem for development of novel coherent infrared radiation sources with tunable frequency (for example, THz- radiation source) [3],[5].

In the present paper the conditions of the polaritonic generation in cubic noncentrosymmetrical crystal for collinear geometry of Raman scattering were discussed.

2. Results
We are using the dispersion equation $\omega(k)$ for a monochromatic polariton wave, propagating in a dielectric crystal [3]:

$$\omega^2 = \frac{c^2 k^2}{\varepsilon(\omega) \mu(\omega)}$$  (1)

where $\varepsilon(\omega)$ is a dielectric permittivity , $\mu(\omega)$ is a magnetic permeability (in the subsequent calculation we introduced $\mu(\omega)=1$), $k$ is a wave vector, $\omega$ is a frequency. The dispersion of the dielectric permittivity is assumed as the well-known Kurosawa ratio [1] for the isotropic dielectric medium with the one resonance:
where the constant $\varepsilon_\infty = n_0^2$ is a dielectric permittivity of the medium corresponding to the high frequency range, $\omega_L$, $\omega_T$ are zeroes of the frequency and the pole of the dielectric function. Taking into account the laws of conservation of momentum and energy in the elementary process of the Raman scattering by polaritons the following equation could be written [3]:

$$\omega = \omega_0 - \omega_1,$$

$$k = k_0 - k_1.$$  \hspace{1cm} (3)

Here $\omega, \omega_0, \omega_1$ are the frequencies of polariton, exciting and scattered radiation, respectively, and $k, k_0, k_1$ are appropriate wave vectors. Note, the equation (3) corresponds to the collinear scattering geometry. An expression for the polariton frequency could be obtained after elementary conversions:

$$\nu = \sqrt{\left(n_0 + \nu_0 \left(\frac{\partial n}{\partial \nu}\right)_{\nu_0}\right)^2 v_T^2 - \varepsilon_n v_x^2 - \varepsilon_n} - \varepsilon_n$$  \hspace{1cm} (4)

where $n_0$ is a refractive index of the crystal corresponding to the exciting radiation with frequency $\nu_0$, $\nu = \omega / 2\pi c_0$ is a frequency in cm$^{-1}$. Using [6]-[8] we could find the frequency of THz radiation generation in the cube noncentrosymmetrical crystals corresponding to the collinear Raman scattering geometry. These frequencies are listed in the table 1.

**Table 1.** Polariton frequency for different cube nonsentrosimmetrical crystals at collinear geometry of the Raman scattering: the first column shows the crystal type, the second column shows the pump frequency, the third column shows the refractive index at the pump frequency, and the fourth column gives the frequency of generated radiation.

| Type of crystal | $V_0, CM^{-1}$ | $n_0$ | $V_x, CM^{-1}$ |
|-----------------|----------------|-------|-----------------|
| GaP             | 15803          | 3.315 | 302.4           |
| ZnSe            | 18797          | 2.6797| 139             |
| ZnTe            | 15803          | 2.9625| 171.7           |
| GaAs            | 9434           | 3.4851| 175             |

For instance in the figure 1 the polariton curves for GaP crystal are presented. Point A corresponds to the frequency of the THz radiation generation in the case of the collinear geometry of polariton light scattering.
Monochromatic THz-radiation generation in considered cubic noncentrosymmetrical crystals may be carried out according to the scheme presented in figure 2.

The silicon flat 5 presented in the figure 2 is used both as a filter cutting the part of the optical pumping light which could partially transmit through the crystal sample 3 and as an additional Fabry-Perot resonator enhancing the efficiency of THz lasing on a certain frequencies.

Thus, polariton frequencies (or parametric radiation frequencies) were calculated for GaP, ZnSe, ZnTe and GaAs crystals in the cases of pumping by ultra short optical pulses of different types of lasers with high average and peak power. Conventional scheme of THz radiation generator based on these results was introduced.

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