Widely tunable radiation source based on second harmonic generation in lithium iodate

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Frequency tuning in a range 5000–6000 Å was observed to accompany intense noncollinear second-harmonic generation in an $LiIO_3$ crystal in which the second harmonic was excited by light pulses. Noncollinear second harmonic generation was observed also in KDP crystals. An explanation is offered.

We report here observation of frequency tuning by second harmonic generation (SHG) in a lithium-iodate crystal. The excitation was with a mode-locked neodymium-glass laser. The laser power was 40 GW. The duration was estimated by the two-photon luminescence method and amounted to $(3-5)\times10^{-12}$ sec.

The lithium-iodate crystal was cut at an angle 30° to the optical axis; the crystal length was 15.5 mm.

It should be noted that the second-harmonic generation had a clearly pronounced nonstationary character, and its emission spectrum consisted of a set of narrow bands with gaps of 10.5 cm^{-1} between them, as is typical of nonstationary SHG.[1-3]

When the crystal deviated from the position of exact phase synchronism for SHG, an additional spectral component was radiated, and its frequency could be smoothly tuned by rotating the crystal[4] (see Fig. 1).

The tuning band ranged from 10 to 40 cm^{-1}. The con-

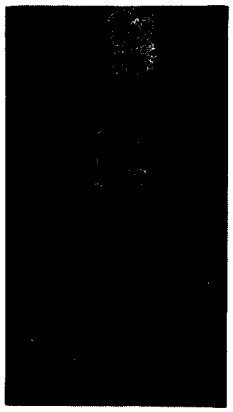

FIG. 1. Appearance of additional frequency-tunable component upon inclination of the crystal.

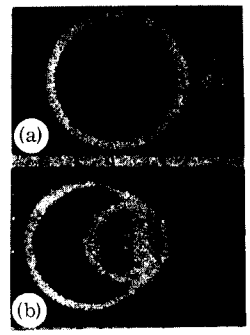

FIG. 2a) Angular pattern of noncollinear SHG in lithium iodate in the focal plane of the apparatus. The angular diameter of the ring is 8°20′ inside the crystal. b) Noncollinear SHG in KDP crystal. The angular diameters of the rings are 3°30′ and 4°55′ inside the crystal.

version coefficient was estimated photographically and amounted to $\eta = 10^{-4}$; the total conversion amounted to 2%.

Spectrum and angle measurements have shown that the additional line is radiated strictly in the forward direction, but it was observed that the second harmonic is radiated also at a certain angle with the direction of the exciting beam.[4,6]

Measurement of the angular dependence has shown that the noncollinear SHG occurs in a cone with angle diameter at the vertex 8°20′ inside the crystal (see Fig. 2a). The angle between the axis of the exciting beam and the axis of the cone of the noncollinear SHG varied with the crystal orientation.

When the crystal is rotated about the exciting-beam axis, the plane in which the axis of the second-harmonic cone is also rotated relative to the beam axis.

It should be noted that this rotation of the crystal about the beam direction changed the total second-harmonic intensity very insignificantly, owing to the large value and strong dispersion of the natural activity of lithium iodate.[5]

The maximum intensity of the tunable component was observed with the crystal oriented in such a way that the polarization plane at the entrance to the crystal coincided with the plane in which the optical axis of the crystal is located (e-polarization).

The polarization plane of the transformed radiation was rotated through a certain angle relative to the direction of the polarization of the principal radiation and varied with the orientation and length of the crystal.

Spectrum and angle measurements were also made[6] with the radiation focused into the crystal by a cylindrical lens; these measurements have shown that the intensity variation is smooth over the entire tuning band, without dips or maxima.

A plot of the wavelength against the rotation angle is shown in Fig. 3. The character of the plot, and in particular the presence of radiation with wavelength shorter than 0.53 μ, suggests that the change of frequency is connected with an interaction in accordance with the scheme $\omega_1 + \omega_1 \pm \Omega_{IR} = \omega_2$, where ω_1 and ω_2 are the frequencies of the principal radiation and of the additional component, while Ω_{IR} is the frequency of the infrared photons produced in the medium either as a result of beats or as a result of absorption.[7,8] The calculated plot of the interaction $k_1^0 + k_1^0 \pm k_{IR} = k_2^e$, where $k_1 = \omega_1 n_i/c$ and $k_{IR} = \Omega_{IR} n_{IR}/c$, is represented by the solid line in the figure. A certain difference between the curves is due apparently to the need for taking into account the natural activity.

The formation of the noncollinear-second-harmonic cone shown in Fig. 2 is due to scattering of the exciting beam inside the crystal and the subsequent interaction of the scattered radiation with the main beam.

A detailed account of such an effect was given in[9]. Since the direct calculation of the behavior of the harmonic cone entails great difficulties, the comparison with theory was made by substituting the experimental data in the equation obtained in[9]. Agreement with the equation was obtained with accuracy 10^{-3}. A similar effect is observed also in KDP crystals, but the picture is more complicated and consists of two rings (see Fig. 2b) with angular diameters 3°30′ and 4°55′. The explanation for the ring that is displaced relative to the beam axis is the same as in lithium iodate. The undisplaced ring must apparently be attributed to a similar interaction in accordance with the scheme $o + e \rightarrow e$, since the polarizations of both rings coincide on leaving the crystal.

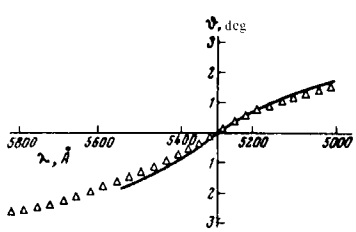

FIG. 3. Plot of spectrum against angle. Solid curve—calculation, triangles—experimental data.

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