[1] N.G. Basov, IEEE J., QE-2, 354 (1966).
[2] A.G. Molchanov, I.A. Poluektov, and Yu.M. Popov, Fiz. Tverd. Tela 9, 3363 (1967) [Sov. Phys.-Solid State 9, 2655 (1968)].
[3] N.G. Basov, B.M. Balashov, O.V. Bogdankevitch, V.A. Danilychev, G.N. Kashnikov, N.P. Lantzov, and D.D. Khodkevitch, Journal of Luminescence 12, 834 (1970).
[4] N.G. Basov, O.V. Bogdankevich, V.A. Danilychev, A.G. Devyatkov, G.N. Kashnikov, and N.P. Lantsov, ZhETF Pis. Red. 7, 404 (1968) [JETP Lett. 7, 317 (1968)].
[5] N.G. Basov, O.V. Bogdankevich, V.O. Danilychev, G.N. Kashnikov, and O.M. Kerimov, Kratkie soobshcheniya po fizike (Brief Communications in Physics), No. 7, 68 (1970); O.V. Bogdankevich, V.A. Dani ychev, G.N. Kashnikov, O.M. Kerimov, and N.P. Lantsov, FIAN Preprint No. 9, 1970.

PARAMETRIC GENERATION OF LIGHT IN HIGH-EFFICIENCY NONLINEAR LiIO$_3$ AND α-HIO$_3$ CRYSTALS

A.I. Izrailenko, A.I. Kovrigin, and P.V. Nikles
Physics Department of the Moscow State University
Submitted 16 October 1970
ZhETF Pis. Red. 12, No. 10, 475 - 478 (20 November 1970)

The present paper is devoted to the results of an investigation of tunable parametric light generators (PLG) for the near infrared and visible bands, using new nonlinear crystals of the iodate group. These crystals were used earlier in frequency doublers [1, 2] and in experiments on parametric luminescence [3]. We used these crystals for the first time to develop effective parametric generators (energy efficiency $\sim$10%). Investigations of the nonlinear properties and optical strength of the grown crystals have shown that the limiting coefficient of modulation of the dielectric constant in LiIO$_3$ and α-HIO$_3$ crystals exceed by one order of magnitude the values for LiNbO$_3$ and KDP, respectively. Both crystals are grown from solutions and crystals measuring several centimeters and having good optical quality have been obtained by now. The LiIO$_3$ crystals were grown on z-cut primers by the method of evaporation from the solution at 40 and 60°C at pH $\sim$ 1.5. The crystal growth rate did not exceed 0.5 mm per day. The raw materials for the growing of LiIO$_3$ were HIO$_3$ of ChDA (analytic) grade and specially purified Li$_2$CO$_3$.

The PLG pump source used in the experiment was the second harmonic of a neodymium-glass laser operating in the single-mode regime. The second-harmonic power density reached 250 MW/cm^2 and the beam diameter was 2.5 mm.

LiIO$_3$ crystal. The working element was cut at an angle $\theta = 30°$ to the z axis. The crystal length was 1.6 cm. The effective nonlinear coefficient for the oo-e interaction was in this case $d_{eff} = 2\sin\theta d_{31}$.[1] The PLG resonator was made up of flat dielectric mirrors of high reflectivity for the signal wave only, $R_s > 99\%$.

The reflection coefficient for the idling pump wave was less than 20% (single-resonator PLG) [5, 6]. The tuning range was determined by the transparency of the crystal (Fig. 1), and the absorption band of the sample started near 2.7 μ.

The tuning was by rotating the crystal inside the PLG resonator (Fig. 2), whereby the signal wavelength changed from the degenerate value $\lambda_s = 1.06$ μ to $\lambda_s = 0.68$ μ, and the idling wave changed accordingly from 1.06 to 2.4 μ.

---

[1] The values of d_{31} measured in different laboratories differ somewhat, with $d_{31}(\text{LiIO}_3) = (31 \pm 3)d_{36}(\text{KDP})$ in [2] and $(16 \pm 2)d_{36}(\text{KDP})$ in [4].

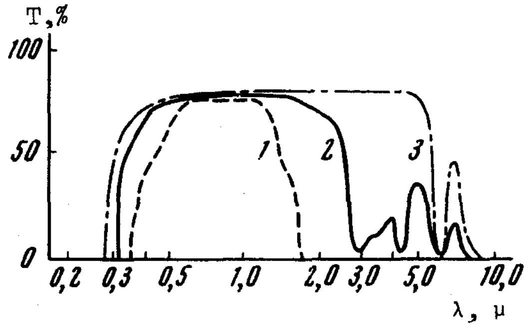

Fig. 1. Transparency region in α-HIO_3 and $LiIO_3$. Light polarization E ‖ z. 1) α-HIO_3, ℓ = 20.1 mm; 2) $LiIO_3$, ℓ = 16.05 mm, 3) $LiIO_3$, ℓ = 2.72 mm from [5].

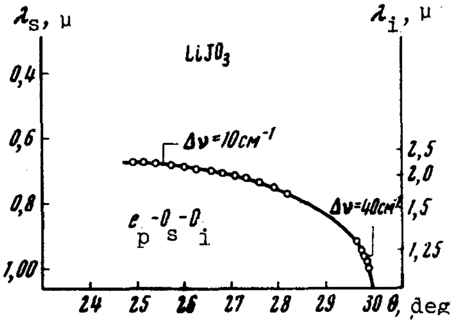

Fig. 2. Tuning curve of $LiIO_3$ crystal. Δν - half-width of parametric liminescence line (ℓ = 16.05 mm).

Further tuning was impossible because of the increase in the generation threshold owing to the growth of the absorption and the idling frequency.

The spectral characteristics of the PLG radiation were investigated with the DFS-8 spectrograph (only the signal-wave radiation was registered). The spectral width of the output radiation near the degenerate regime was 40 - 60 Å and narrowed down to 1 - 2 Å at λ_s = 0.68 μ. The corresponding calculated halfwidth of the parametric lines were 40 and 5 Å.

The theoretical generation threshold of our system was $\sim$1 MW/cm^2. Owing to the use of relatively short pumping pulses (τ_p = 15 nsec), however, there was no time for establishment of a stationary regime. The experimental threshold, determined by the growth of the PLG power and the apparatus sensitivity, was 10 MW/cm^2. At a pump power P_p = 45 MW/cm^2 the energy conversion coefficient was W_i/W_p = 8%.

The investigations have shown that the $LiIO_3$ crystal was much more resistant to the radiation than the $LiNbO_3$ crystal. The damage thresholds were 40 - 50 and 10 MW/cm^2, respectively. If the nonlinear efficiency of the crystal at an equal length is characterized as the product of $P_{\text{breakdown}}$ by d^2_{eff}/n^2, then the $LiIO_3$ crystal turns out to be $\sim$9.4 times more effective than the $LiNbO_3$ crystal. Thus, although $LiIO_3$ crystals have no 90° synchronism and can therefore not be used for continuous PLG, they should be regarded as the most promising for powerful pulsed PLG in the visible and infrared bands.

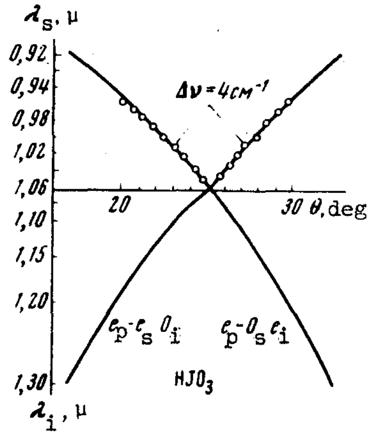

Fig. 3. Tuning region in α-HIO_3 (the solid curves are theoretical, ℓ = 20.1 mm).

α-HIO_3 crystal. We used a crystal ℓ = 2.5 cm long, cut with the ab plane at an angle θ = 25° to the b axis for the e-eo interaction. In this case d_{eff} = 2 sin 2d_{14} and d_{14} = (1.5 ± 1)d_{31}($LiNbO_3$).

The working end surfaces of the crystal were protected with glass plates making optical contact with the aid of an immersion liquid.

Variation of the generator wavelength in the range 0.96 - 1.2 mm was also effected by rotating crystal. The experimental data agree with the calculated ones [3].

We investigated the spectral characteristics of the output radiation of the PLG with respect to the two parametric frequencies, but only with respect to the signal frequency in the case of the resonator. In the former case the spectrum consists of groups of lines determined by the mode-coincidence conditions [7]. The total width was ≤ 8 Å and the distance between line groups was $\Delta\lambda = 2.2$ Å. The corresponding luminescence line width is 4 Å, and $\Delta\lambda_{scat} = 1.9$ Å. In the scheme with the resonator, with only the signal frequency varied, the spectrum consisted of one line of width $\delta\lambda = 0.1$ Å, i.e., of one longitudinal mode, and the intermode distance for our resonator was 0.25 Å. The spectrum was recorded with a Fabry-Perot interferometer. At an appreciable excess of pump power P_p over the threshold power P_{thr}, several modes appeared, or even two groups of lines, with a spacing characteristic of a resonator having two frequencies. Apparently, the reflection of the mirrors at the idling frequency, $R_i \sim 20\%$, came into play. The power conversion coefficient was comparable with the efficiency for a generator using a KDP crystal.

The α-HIO_3 crystal is sufficiently resistant to radiation damage. Faults in the crystal, in the form of filaments, were produced at $P_{breakdown} \geq 55$ MW/cm^2 (in the case of the KDP crystal, $P_{breakdown} \simeq 500$ MW/cm^2). Thus, the limiting efficiency of α-HIO_3 crystal is 9 times higher than that of KDP.

[1] S.K. Kurtz, T.T. Perry, and J.G. Bergman, Appl. Phys. Lett. 12, 186 (1968).
[2] G. Nath and S. Haussühl, Appl. Phys. Lett. 14, 154 (1969).
[3] A.J. Campillo and C.L. Tang, Appl. Phys. Lett. 16, 242 (1970).
[4] F.R. Nash, J.G. Bergman, et al., J. Appl. Phys. 40, 5201 (1969).
[5] T.I. Freidman, Nonlinear Optics, Proc. 2nd All-union Symposium on Nonlinear Optics.
[6] J.E. Bjorkholm, Appl. Phys. Lett. 13, 53 (1968).
[7] A.I. Kovrigin and P.B. Nikles, et al., Vestnik, Moscow State Univ. 11, No. 5 (1970).

SPECTRUM OF THE FIELD OF MOVING FOCAL REGIONS [1]

V.N. Lugovoi and A.M. Prokhorov
P.N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 7 October 1970
ZhETF Pis. Red. 12, No. 10, 478 - 483 (20 November 1970)

1. Much attention is being paid in the current literature to theoretical and experimental investigations of an effect discovered by Shimizu [2], of broadening of the spectrum of intense beams that are not stationary in time and pass through a medium with a well-pronounced quadratic Kerr effect (cf., e.g., [3 - 6]). In the cited paper, the theoretical analysis of this question is based on the assumption that waveguide propagation in the form of thin filaments takes place in the light beam. A number of additional assumptions are also employed to explain the main features of the experimentally-observed spectral picture.

At the same time, theoretical investigations of the propagation process itself, reported in [7, 8, 1] (and subsequent experimental investigations [9 - 11]), have shown that the picture of this process differs greatly from that previously proposed. In the case of giant laser pulses, the light beam has a waveguide but a multifocus structure, accompanied by formation of a finite number of individual focal regions on the beam axis. The nonstationary