Study of picosecond tunable-frequency lasing at F_2^+ color centers in LiF crystal

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This paper reports the achievement of picosecond lasing with forced-mode locking in a LiF crystal with stable neutral F_2^+ color centers.1)

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The action of pumping radiation with $\lambda = 0.53$ μm in these crystals causes a two-step photoionization $F_2 + h\nu \rightarrow F_2^* + h\nu \rightarrow F_2^* + \bar{e}$ to F_2^* centers. Subsequent absorption of the pumping energy by the formed centers (F_2^+) leads to population inversion in them and the generation of wide-band or frequency-tunable radiation at room temperature.[1]

The pumping source was the second harmonic of the radiation of a neodymium-garnet laser that operated in the self-mode-locking condition with a repetition frequency of 10 Hz.[2] A nitrobenzene solution of polymethine dye No. 3955 was used as the saturable filter; a nonlinear SDA crystal was used to double the frequency of the fundamental laser radiation. The pumping radiation had the following parameters: $\lambda = 0.532$ μm, train duration of about 60 nsec, axial interval of ~7 nsec, and average duration ~45 psec at a total train energy of ~15 mJ.

The scheme for obtaining lasing is shown in Fig. 1. The pumping radiation was focused by a lens with a focal length $f = 200$ mm onto the crystal (30–40 mm long) that was oriented close to the Brewster angle. The mirrors R_1 and R_2, transparent to the pumping radiation, had a reflection coefficient of 99.9% within the wavelength band from 0.8 to 1.1 μm. Three 60° glass prisms were used as the dispersion elements. The cavity wavelength was varied by rotating the mirror R_2. Radiation escaped from the cavity as a result of Fresnel reflection from the operating faces of the active crystal,

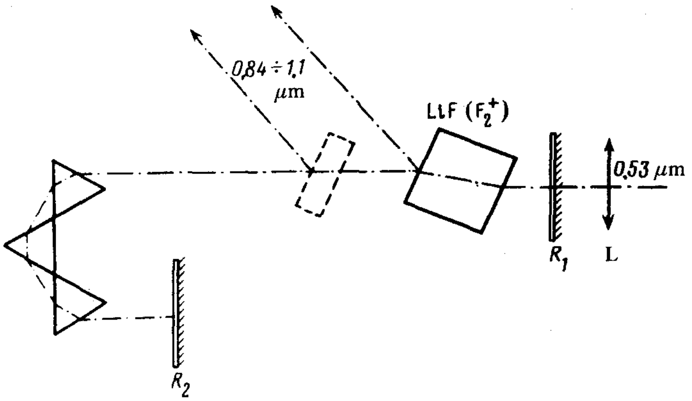

FIG. 1. Scheme for obtaining lasing in LiF (F_2^*) crystal.

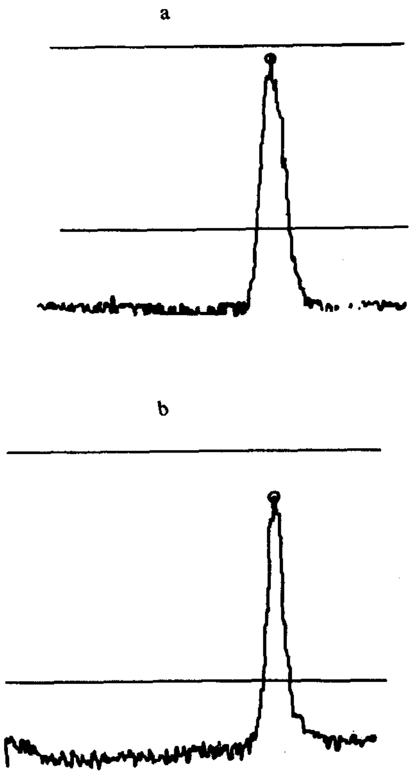

FIG. 2. Time dependence of the intensity of pumping pulse (a) and the intensity of the tunable lasing pulse (b).

or by inserting a glass plate into the cavity oriented at a large angle with respect to the optical axis.

Time measurements of the parameters of the pumping pulses and tunable lasing were made by means of a picosecond, electron-optical system consisting of an EOK-3 electron-optical camera (developed at FIAN) and a Hamamatsu (Japan) time analyzer.[3] The EOK-3 operated in the linear sweep condition with a maximum time resolution of 1–2 psec.

In the three-prism dispersion cavity, matched to the pumping cavity in terms of length, we obtained picosecond pulses of tunable lasing with a duration of about 30 psec at half-height, which is somewhat shorter than the duration of the pumping pulses (45 psec). Figure 2 shows the shape of a typical pumping pulse (Fig. 2a) and a tunable lasing pulse (Fig. 2b), which were obtained by photographing the television screen of the electron-optical system. The distance between the two horizontal lines corresponds to 3 psec. In addition to the smooth pulses in Fig. 2b, a clearly defined internal structure of several peaks with a duration of 10–15 psec was observed for some lasing pulses; this approximately corresponds to the lasing spectrum of a tunable laser with $\Delta\nu \approx 3$ cm^{-1}.

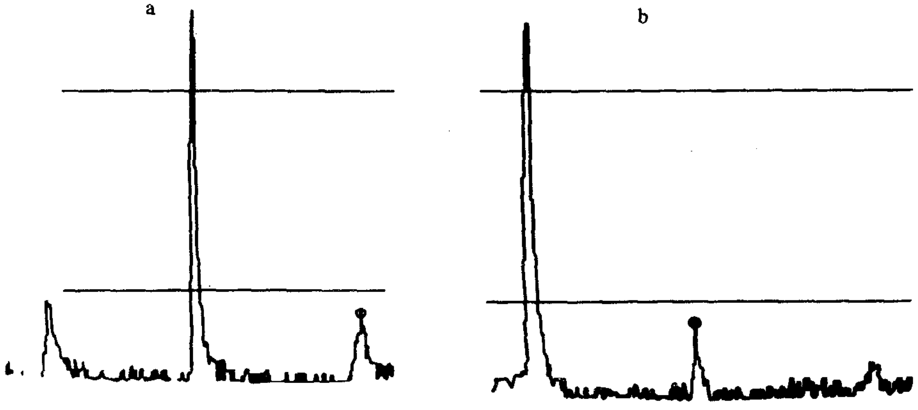

FIG. 3. Time dependence of generated pulse train: a) center part of train, b) decay of train.

The train of lasing pulses consisted of 5–7 pulses with an axial interval specified by the pumping laser. Choosing the pumping power made it possible to obtain lasing conditions in the LiF (F_2^+) laser that are close to one-spike. In this case the pulse train had the form shown in Fig. 3 (the distance between lines is 15 psec). Figure 3a depicts the central part of the train, while Fig. 3b illustrates its decay. It can be seen in the figures that the intensity of the side spikes is at least five times weaker than the central

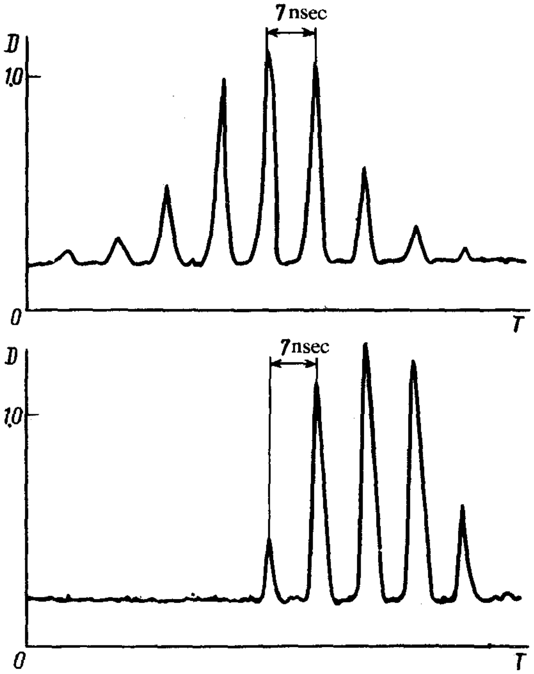

FIG. 4. Time development of wide-band lasing train with $\lambda = 0.93$ μm (lower train) relative to the pumping train with $\lambda = 0.53$ μm (upper train). D is the photographic film density and T is the time.

one. The possibility of generating single picosecond pulses having high contrast is of interest in itself for many applications.

Thus, the generation of picosecond pulses with a radiation wavelength that is tunable within the interval from 0.84 to 1.1 μm was obtained in a LiF (F_2^+) crystal with a three-prism dispersion cavity.

The use of a plane-parallel cavity, which was formed by the same mirrors R_1 and R_2 without using the dispersion elements, drastically broadened the spectrum of generated wavelengths; however, no shortening of the generated pulses was observed. The lasing pulse had a shape similar to that in Fig. 2b, with an unresolved internal structure (as in the dispersion cavity). The similar behavior of the tunable and wide-band lasing, as well as the inability to shorten the pulse drastically according to the generated spectrum, are due in all likelihood to an inadequately high degree of mode locking because of the small number of pulses in the pumping train.

The kinetics of lasing development in the LiF crystal with F_2^+ color centers was measured at a sweep rate of 2.5×10^7 cm/sec by means of a EOK-1 electron-optical camera developed at FIAN. Two trains of picosecond pulses were recorded simultaneously: the first was the pumping train with $\lambda = 0.532$ μm and the second was the wide-band lasing train with $\lambda_{\max} = 0.93$ μm. These two time sequences, obtained after photometric analysis, are shown in Fig. 4, in which it can be seen that the lasing train of the F_2^+ centers is delayed by about four axial intervals relative to the pumping train. This delay time agrees well with the lifetime of the upper lasing level of the F_2^+ centers $\tau = 29$ nsec.[4] This indicates the important role of the population inversion build-up processes in this material for the subsequent generation of ultrashort pulses.

In conclusion, the authors wish to thank V. F. Kamalov (Moscow State University) for informing them of the preliminary results on the generation of subnanosecond pulses in LiF crystals with F_2^+ centers.

[1)] The results of this work were reported at the 2nd All-Union conference "Laser Optics", Leningrad, January 3–7, 1980.

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