# SPECTRAL-TIME STUDIES OF THE LASING OF A CaF$_2$:Sm$^{2+}$ CRYSTAL UNDER EXCITATION BY A RUBY LASER

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## Abstract

## Full Text

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**PHYSICS**

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# SPECTRAL-TIME STUDIES OF THE LASING OF A $CaF_2$:$Sm^{2+}$ CRYSTAL UNDER EXCITATION BY A RUBY LASER

In paper ($^1$) it was reported that, upon excitation by radiation from a ruby laser, components appear in the lasing spectrum of a $CaF_2$:$Sm^{2+}$ crystal at a temperature of ~ 77° K which coincide with the maxima of the long-wavelength continuum of luminescence. Since transitions from the metastable state $^1\Gamma_1$ ($^2$) to the ground state $^1\Gamma_1(^7F_0)$ are forbidden, their nature is apparently determined by electron-vibrational transitions to the level $^3\Gamma_4(^7F_1)$.

In the present work, spectral-time studies were made of the lasing of a laser sample 70 mm long and 8 mm in diameter. Dielectric mirrors with reflection coefficients of 99 and 65% were deposited on the ends. The lateral surface was matted so that internal types of oscillations would not be excited. The lasing spectrum, obtained on a prism spectrograph ISP-51 with a dispersion of ~ 50 Å/mm in this region, at 65° K (Fig. 1) consisted of a narrow line at 7082 Å, which at a temperature of ~ 77° K shifted by several angstroms to the long-wavelength side. Raising the temperature of the crystal, which was slowly heated in nitrogen vapor, at an unchanged excitation level first leads to the appearance of the 721 mμ line, then of the 729 mμ line, which broadens into a wide, ~ 70 Å structured band; the 708 mμ line then disappears. Finally, at the highest temperature at which the study was carried out, a broad structured band appeared in the lasing spectrum in the region of 741 mμ.

**Fig. 1.** Lasing spectrum of a $CaF_2$:$Sm^{2+}$ crystal under excitation by a ruby laser at temperatures ~ 65° K (**a**), ~ 77° K (**b**), and > 77° K (**c**).

From an analysis of the spectra it may be concluded that, with increasing lasing temperature, starting from the purely electronic 708 mμ line, lasing spreads

Fig. 2. Oscillograms of the processes. I $-T = 77$°K: a —pump pulse from a ruby laser;  —integral lasing pulse of the $CaF_2 : Sm^{2+}$ crystal;  —lasing pulse at $\lambda 708$ m ;  —lasing pulse at $\lambda 721$ m . II $-T > 77$°K: a —pump pulse from a ruby laser;  —integral lasing pulse of the $CaF_2 : Sm^{2+}$ crystal;  —lasing pulse at $\lambda 721$ m ;  —lasing pulse at $\lambda 729$ m . Synchronization period 10 nsec.

Figure 2: Fig. 2. Oscillograms of the processes. I $-T = 77$°K: a —pump pulse from a ruby laser;  —integral lasing pulse of the $CaF_2 : Sm^{2+}$ crystal;  —lasing pulse at $\lambda 708$ m ;  —lasing pulse at $\lambda 721$ m . II $-T > 77$°K: a —pump pulse from a ruby laser;  —integral lasing pulse of the $CaF_2 : Sm^{2+}$ crystal;  —lasing pulse at $\lambda 721$ m ;  —lasing pulse at $\lambda 729$ m . Synchronization period 10 nsec.

toward the long-wavelength side, while the intensity of the long-wavelength components increases; this is described by the gain function

$$g(\omega) = \sigma_e(\omega)\{N_2 - N_1 \exp[\hbar(\omega - \omega_0)/kT]\}.$$

In the general case this function also depends on the polarization of the light radiation at frequency $\omega$ and on the wave vectors of the corresponding vibrations; $\sigma_e(\omega)$ is the stimulated-emission cross section; $N_2$ and $N_1$ are the populations

of the initial and final laser levels, and $\omega_0$ is the frequency of the purely electronic transition.

The difference between this laser and a similar one based on $MgF_2 : Ni^{2+}$ ($^{3-5}$) is that the final lasing level is not the ground level and is separated from it by $\sim 260$ cm$^{-1}$.

To determine the temporal behavior of the lasing intensity, spatial separation of individual spectral regions was carried out on a DFS-13 spectrograph with a dispersion of 4 Å/mm. Synchronous recording of individual spectral components was performed on a six-channel 6LOR-02 oscilloscope with a bandwidth of $1.5 \cdot 10^9$ Hz, which was somewhat degraded by the path, to approximately $0.8 \cdot 10^9$ Hz.

**Fig. 2.** Oscillograms of the processes. *I* $-T = 77$°K: *a* —pump pulse from a ruby laser; *b* —integral lasing pulse of the $CaF_2 : Sm^{2+}$ crystal; *c* —lasing pulse at $\lambda 708$ m ; *d* —lasing pulse at $\lambda 721$ m . *II* $-T > 77$°K: *a* —pump pulse from a ruby laser; *b* —integral lasing pulse of the $CaF_2 : Sm^{2+}$ crystal; *c* —lasing pulse at $\lambda 721$ m ; *d* —lasing pulse at $\lambda 729$ m . Synchronization period 10 nsec.

Because of the low sensitivity of the oscillograph receivers, $\sim 20$ V/mm, coaxial photodetectors with an oxygen-silver-cesium photocathode FEK-14 ($^6$) were chosen as receivers; in them the linear portion of the light characteristic $i = f(I)$, where $i$ is the current as a function of the intensity $I$ of the light incident on the photocathode, reaches 6.5 A. The load resistance was 75 Ω, and the time resolution was 0.9 nsec.

During each flash, the lasing pulse of the Q-switched ruby laser serving as the pump for the $CaF_2 : Sm^{2+}$ crystal was recorded, as was the spectrally integrated lasing pulse of the crystal under study, and also two pulses from two spectral components of the lasing at wavelengths of 708 and 721 m , or 721 and 729 m ; in the region of 729 m  the band at 741 m  was included. The time delays in the cables and in open space were selected so that the pulses coincided on the oscilloscope screens with an accuracy of up to 5 nsec.

Characteristic oscillograms of the processes are presented in Fig. 2. Analyzing them, one may conclude that the lasing pulse at $\lambda$708 m  is smooth and is delayed relative to the pump pulse by the time necessary to reach the lasing threshold. Measurements of the time integral of the pump intensity from the beginning of the pump pulse to the beginning of the $CaF_2 : Sm^{2+}$ lasing pulse showed that it is constant to within 20%.

The lasing pulses at $\lambda$721 and 729 m  coincide in time and are delayed relative to the beginning of the pump pulse by $40 \div 80$ nsec. A gradual increase of the temperature above 77°K at unchanged pumping leads to the disappearance of the pulse at $\lambda$708 m , and then also at $\lambda$721 m . Only the pulses at $\lambda$729 m  remain. The second peak in Fig. 2 (IIa) possibly belongs to the lasing band at 741 m . The disappearance at high temperature of the lasing line at $\lambda$708 m , as well as the lack of coincidence in time of the pulses at this wavelength and at $\lambda$721 and 729 m , indicates that the latter cannot be lines of forced combinational scattering.

Since the final laser level lies 260 $cm^{-1}$ from the ground level, at the initial moment of generation one may assume that a four-level scheme is realized. However, the disruption of generation at $\lambda$ 708 m$\mu$ and the subsequent excitation on the electronic-vibrational components apparently indicate the existence of a "narrow throat" in the relaxation channel of the $\Gamma_4(^7F_1)$ level ($^{7-9}$).

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## REFERENCES

1. V. K. Konokhov, V. M. Marchenko, A. M. Prokhorov, *Optics and Spectroscopy*, **20**, 531 (1966).

2. G. A. Zvereva, V. P. Makarov, FTT, **9**, issue 10 (1967).

3. L. F. Johnson, R. E. Ditz, H. J. Guggenheim, *Phys. Rev. Lett.*, **11**, 318 (1963); *Appl. Phys. Lett.*, **5**, 275 (1964).

4. D. E. McCumber, *Phys. Rev.*, **134**, A299 (1964).

5. L. F. Johnson, H. J. Guggenheim, R. A. Thomas, *Phys. Rev.*, **149**, 179 (1966).

6. L. I. Andreeva, B. M. Stepanov, *Measurement Techniques*, **8**, 38 (1965).

7. B. Z. Malkin, FTT, **5**, 1062 (1963).

8. J. D. Axe, P. P. Sorokin, *Phys. Rev.*, **130**, 945 (1963).

9. R. R. Orbach, *Phys. Rev.*, **133**, A34 (1964).

10. Z. A. Al' bikov, V. V. Vorob' ev, R. S. Shuvalov, *Measurement Techniques*, **8**, 89 (1966).

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