Vacuum ultraviolet luminescence of LaF_3 single crystals

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The ultraviolet and vacuum-ultraviolet luminescence of LaF_3 single crystals activated with rare earths was investigated. A vacuum-ultraviolet emission band was observed, for the first time ever, at 740 Å; it is ascribed to $5d\rightarrow 4f$ transitions of the Nd^{3+} ion and is characterized by a high quantum yield (more than 50%).

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Lasers for the ultraviolet and vacuum ultraviolet bands, which are needed for laser photochemistry, biology, isotope separation, and laser thermonuclear fusion, are presently diligently investigated.

Solid active media for such lasers, which offer many potential advantages, such as large specific energies, have been least studied, owing to the difficulty of their production and investigation.

Possible active solid media for ultraviolet and vacuum ultraviolet lasers are LaF_3 single crystals activated with rare earths, since the first absorption peak of the host lies at 11.5 eV. The transitions of many triply charged rare-earth ions lie in the ultraviolet and vacuum ultraviolet regions. In addition, the activator concentration in LaF_3 crystals can be varied in a wide range, thereby permitting variation of the properties of the active media.

The luminescence was investigated with a setup[1] consisting of a high-power hydrogen laser[2] operating at a pulse repetition frequency on the order of 30 Hz, a cryostat, and a monochromator. After passing through the monochromator, the crystal radiation was incident on a luminor (sodium salycilate) having a constant quantum yield in the investigated spectral region. The luminor emission was registered with a

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photomultiplier and recorded with an automatic plotter. In the measurement of the emission time we used a special photomultiplier. In the investigation of the vacuum ultraviolet and ultraviolet luminescence of LaF_3 activated with various rare earths at wavelengths $\lambda \leqslant 3000$ Å, we observed for LaF_3 single crystals activated with Nd a heretofore unknown vacuum-ultraviolet emission band. The observed vacuum ultraviolet band has, according to our estimates, a quantum yield larger than 50%. The emission spectrum of the $LaF_3:Nd^{3+}$ in the investigated wavelength region is shown in Fig. 1. In addition to the intense vacuum ultraviolet band, there are weak ultraviolet

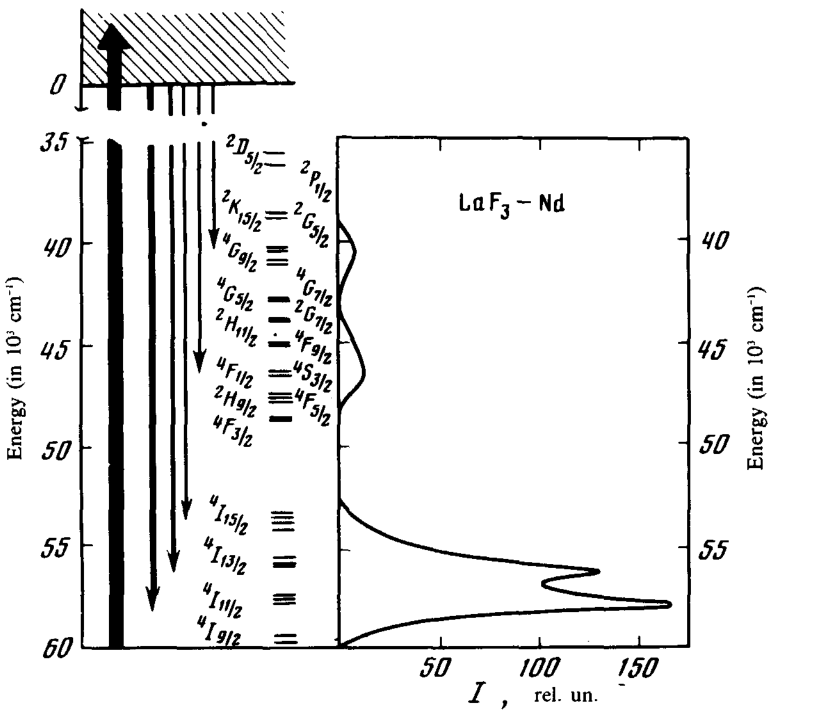

FIG. 1.

emission bands. The bands are asymmetrical in shape and complex. When cooled to nitrogen temperatures, two strong maxima can be well resolved in the vacuum ultraviolet band. Figure 1 shows the lower terms of the $4f$ configuration of Nd^{3+} in an LaF_3 matrix.[3] The arrows show the observed transitions. The observed emission bands were identified by us with the $4S^2 5d^1 \rightarrow 4f^3$ transitions of the Nd^{3+} ion. Since these transitions are allowed, the lifetimes should be short. This agrees with the measured emission times, which turned out to be not longer than 20 nsec, this being the limit of the temporal resolution of the employed apparatus. The position of the edge of the $4f^2 5d^1$ state was obtained from the excitation spectrum in[4] and is equal to 60×10^3 cm^{-1}.

The pump sources, besides vacuum ultraviolet lasers, can be synchrotron radiation, gamma radiation of pulsed reactors, and plasma-focus radiation of a magnetoplasma compressor.

We have also investigated the luminescence of $LaF_3 : Pr^{3+}$. The obtained spectrum has two very strong groups of lines at 2500 and 2700 Å, as well as several much weaker short-wave bands; it is shown in Fig. 2. The same figure shows the lower terms

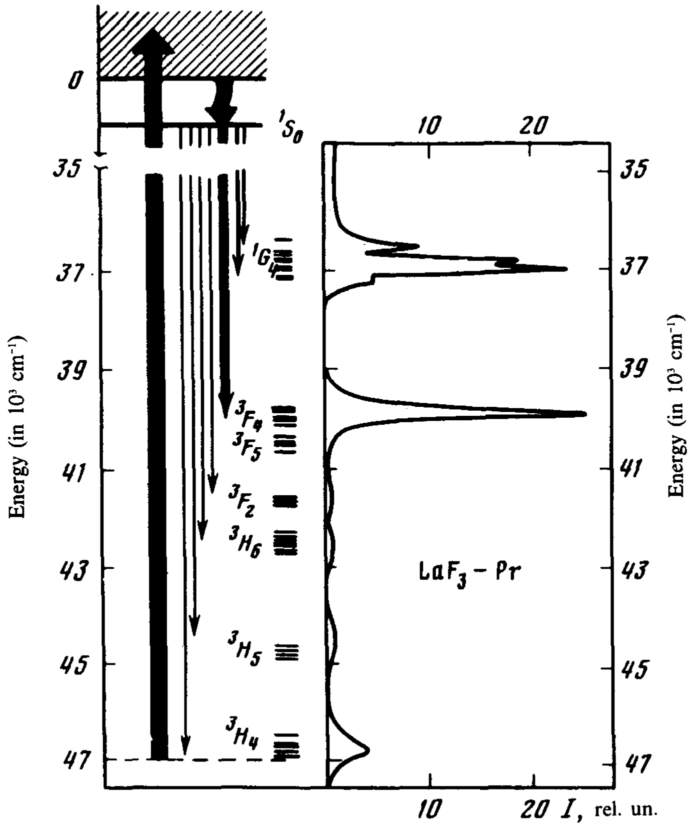

FIG. 2.

of the $4f^2$ configuration of the Pr^{3+} ion. The arrows show the observable transitions, which we identified as transitions from the state $^1S_0$ of the $4f^2$ configuration. The quantum yield for each line from the 2500 and 2700 Å groups is of the order of 10% and as a whole does not exceed 50%. The measured emission time is 0.7 μsec. Similar data were obtained for this crystal in[5] under laser excitation.

We note in conclusion that the presently available crystals, which were grown by us, have dimensions and lengths of the order of 10 cm and a diameter 1 cm, so that it is possible to obtain a very high value of the output power and lasing energy.

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