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INTRAMOLECULAR ENERGY TRANSFER
AND LASERS

Translation

AID Work Assignment No. 43
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INTRAMOLECULAR ENERGY TRANSFER AND LASERS

This translation was prepared in response to AID Work Assignment No. 43, Task 8. The article was originally published as follows:

Bykov, V. P. Vnutrimolekulyarnyy perenos energii i kvantovyye generatory. Zhurnal eksperimental'noy i teoreticheskoy fiziki, v. 43, no. 6, 1962, 2313-2315.

Although a number of different types of optical and infrared lasers has been created so far, the most effective is still the ruby laser.

The high effectiveness of the ruby laser is due primarily to the energy level configuration of the chromium ion. The energy spectrum of the trivalent chromium ion, which is an isomorphic replacement of the trivalent aluminum ion in the corundum lattice, consists of a system of broad and narrow excited levels. Two excited levels are of importance to laser action: the 3E level, a slightly higher, broad 4F level, and the 4A_2 ground level. The transition from the 3E level to the 4A_2 level is accompanied by luminescence. The transition from the ground state 4A_2 to the 4F level represents absorption of the pumping light within a wide spectral range from 5300 to 6000 Å. On the other hand, thanks to the narrow 3E level, the emission occurs in the form of a very narrow spectral line, making it easy to satisfy the oscillation conditions (Ref. 1). The proximity of the 4F and 3E levels provides for a high energy yield of luminescence and affords reason to hope that the laser may yet achieve a high efficiency.

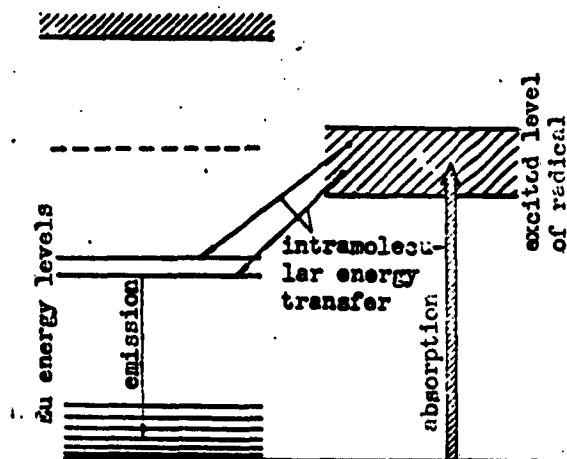
The energy level configuration is different in the majority of other types of luminescent materials. As a rule, materials with narrow luminescence lines have the wide absorption band situated at an excessive height. For example, the rare-earth ions possess the property of photoluminescence where the luminescence lines are fairly narrow. The luminescence of these ions is caused by transitions between excited levels of the internal 4f-shell of the ion. All these levels are very narrow, since the 4f-shell is well screened from external perturbations by the 5s- and 5p-shells. The broad levels of the excited 6s- and 6p-states lie at a great height. Thus, in the trivalent europium ion the luminescence levels lie below 20,000 cm^{-1} , while the broad absorption level lies at 40,000 cm^{-1} .

We should like to point out one possibility which has as yet not been exploited. As was shown by Weissman (Ref. 2) and confirmed by Sevchenko and Trofimov (Ref. 3), a transfer of energy from some atoms of a molecule to others has been observed in the molecules of certain complex compounds. This concerns compounds of europium and samarium of the type designated by EuR_3 and SmR_3 , where R is the organic radical. It has been shown that these compounds have wide absorption bands representing the excited states of the organic radical. In some cases these states lie in the vicinity of 25,000 cm^{-1} , which is fairly close to the luminescence levels of rare-earth ions.

The luminescence of the compounds investigated is caused by the 4f-shell of the rare-earth ions. This shows that the energy absorbed by the organic radical may be transferred to the rare-earth ion.

Consequently, the system of energy levels of this type of compound (see illustration) resembles the energy level system of the chromium ion in the ruby and is more suitable for utilization in lasers than a system of energy levels of the rare-earth ion itself. The advantage of such compounds is also due to the fact that the screening effect of the surrounding radicals tends to decrease strongly the probability of nonradiative transitions in the 4f-shell of the rare-earth ion and, consequently, to increase the quantum yield of luminescence, which in some cases may approach unity.

At this time there is no reason to think that the intramolecular energy transfer phenomenon is limited to rare-earth ions and organic radicals. It would seem that any ion capable of becoming luminescent could be matched with a molecule possessing a suitably placed



absorption level and in which an intramolecular energy transfer could occur.

The phenomenon of intramolecular energy transfer allows us to reconsider materials which previously have been thought to be unpromising for use in lasers. The utilization of this principle affords us the opportunity to create lasers more effective than the ruby laser and also to expand the range of generated wavelengths.

I would like to thank Academician P. L. Kapitsa for his attention to this problem.

Institute of Physical Problems
Academy of Sciences USSR

Submitted to the editor
26 September 1962

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3. A. N. Sevchenko, A. K. Trofimov. Zhurnal eksperimental'noy i teoreticheskoy fiziki, 21, 220, 1951.