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NEW CLASS OF TUNABLE $Al_2O_3 : Ti^{3+}$ - LASERS WITH LASER AND ELECTRON BEAMS PUMPING AS A LIDARS TRANSMITTERS

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Generation capacities of tunable $Al_2O_3:Ti^{3+}$ - crystals lasers with optical excitation by lasers (in the whole by $YAG:Nd^{3+}$ -laser) or flash lamps are demonstrated at present in considerable detail.

Various and, in many cases, unique characteristics and, also, an application's wide range of these lasers have drawn much attention to them and served as a stimulus for search of another excitation methods to expand the continuous tuning wavelength range, to increase the pulse repetition frequencies and some another characteristics of these lasers.

One of the interesting methods of Ti-sapphire crystals excitation is excitation by copper-vapor laser radiation (CVL) [1]. First, the CVL emission at wavelength λ=510.6 nm is well within the $Ti^{3+}:Al_2O_3$ absorption band, and thus it can be used efficiency to excite the active medium. Second, at present, a mean power of more than hundreds of watts has been achieved with the CVL's. Finally, the efficiency of a powerful CVL reaches 1.5% and, hence, a high end-to-end efficiency of such a laser system is obtained. This paper examines some new results, obtained by us at $Al_2O_3:Ti^{3+}$ - laser's excitation by copper-vapor laser radiation.

However, in our opinion, one of the most perspective ways of Ti-sapphire crystals excitation is excitation by high energy electrons [2,3]. The validity of such supposition is supported by Al_2O_3 matrix high radiation resistance and effective energy transmission from electron-hole pairs to ions of activator.

Main spectral, kinetic and spatial characteristics of excitation and laser generation of Ti-sapphire crystals pumped by CVL's radiation or by high energy electron beams are studied in this paper.

New class of laser sources on activated crystals is proposed, which use ionized and radiation pumping, in particular, by high energy electrons beam and, also, simultaneous optical and electron beam pumping for laser generation in one crystal with wide continuous tuning wavelength range in the visible and near-IR regions of spectrum.

Quasilongitudinal scheme for optical excitation and transverse scheme for electron beam excitation are used in experiments.

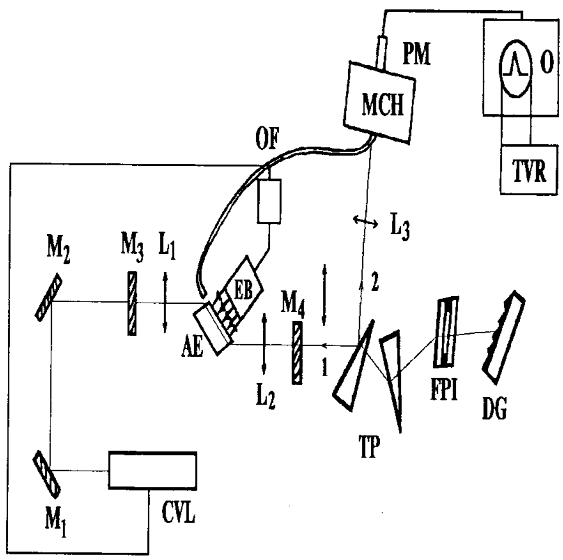

Fig. 1. Arrangment of $Ti^{3+} : Al_2O_3$ laser investigations: CVL - copper vapor pumping laser; L_1, L_2, L_3 - lenses; M_1, M_2 - beam-deflecting morrors; M_3, M_4- cavity mirrors; TP - two-prism achromatic telescope; FPI - Fabry-Perot interferometer; DG - diffraction grating; AE - active element ($Al_2O_3:Ti^{3+}$ crystal); EB - electron beam gun; MCH - monochromator; PM - photoelectric multiplyer; O - oscilloscope; TVR - television registrator of signals; OF - fiber optic guide; 1 - nonselective cavity output; 2 - selective cavity output.

The structural scheme of experiment is given in Fig. 1.

The copper-vapor laser had the unstable resonator with beam divergence ~ 0.4 mrad and average output power up to 20 W at a pulse repetition frequency from 5 to 10 kHz (production of firm "Laser Spectrum LTD", Russia, Tomsk). The electron beam is generated either by standard gun based on vacuum diode [3] or by new type of electron beam generator, proposed and designed by us [4,5], which allows to receive the high energy electrons beams directly in the air and another gases. The electrons energy used for excitation of Ti-sapphire crystals reached 650 keV; current density in beam up to 500 A/cm^2, impulse duration of 10-60 ns. The active elements of different forms and dimensions cut out from crystals with activator concentration from 0.02 to 0.1 % by weight. The C_{3v} crystal axis is oriented perpendicularly to the most dimension of active element. The study of crystal luminescence characteristics carried out at a mirrors absence or at detuned resonator (see Fig. 1).

The typical space distributions of Ti-sapphire crystal luminescence intensity, excited by electron beam, are given in Figures 2, 3. In this case, the crystal represents parallelepiped with square sections of side 5 mm, length 10 mm.

Fig.2 shows the oscillograms of crystal luminescence intensity, obtained for its five 1 mm crystal layers starting with the nearest to electron gun.

For observation of these oscillograms, the screen with slot of width 1 mm and height 5 mm was installed on the crystal end in front of the input of the measuring system fiber optic guide (*OF*, Fig. 1) .

Fig. 2 illustrates the fact that the most crystal effective excitation by electron beam takes place in the nearest to the electron gun ~ 100...250 μm thick layer (in accordance with parameters of electron beam) and the more deep layers excitation is connected with optical radiation from the nearest to the electron gun layers and with secondary particles.

Space-temporary characteristics of radiation indicates to its superluminescence nature. Except for superluminescence impulse with time constant τ_L tens ns (see Figure 4, curve 4), there are also two stages with time constants at 3.5 μm and 0.1 - 0.5 μm. The first stage is determined by Ti^{3+} ions general luminescence, the second is connected with traps radiating disintegration followed by excitation transmission to activator ion. De-inversion at the expense of amplification in directions non-parallel to resonator axis is an essential factor in crystals more than 1 mm thick.

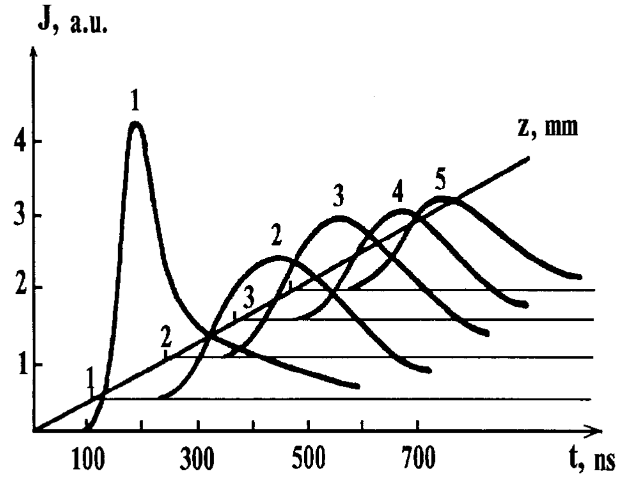

Fig. 2. Oscillograms of luminescence intensity pulses from five 1-mm crystal layers, numbered starting with the nearest to electron gun. Crystal dimensions - 5 × 5 × 10 mm. Electron energy in the beam - 400 keV, electron current duration - 50 ns, λ = 850 nm.

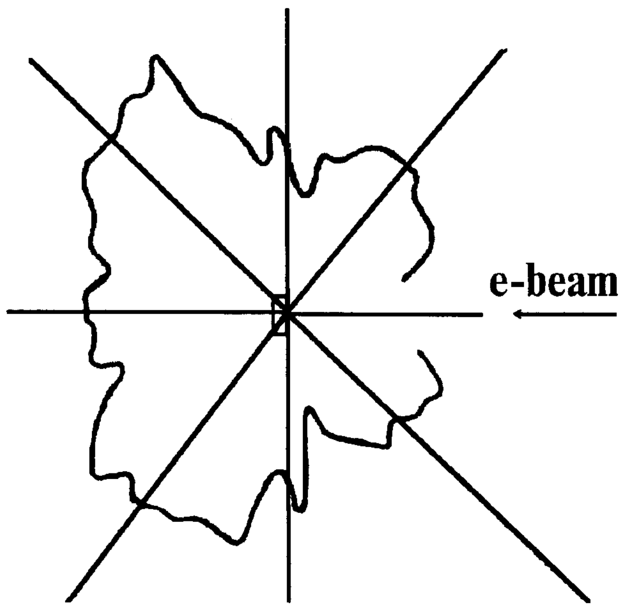

Fig. 3. Space distribution (in horizontal plane) of luminescence intensity pulses amplitude for conditions of Fig. 1.

This fact is supported also by space distribution of J_m luminescence amplitude, is given in Figure 3 for the same crystal.

The space distribution shows that the most luminescence intensity amplitudes are observed in directions, having geometrical (and, probably, optical) length.

The space dependence of duration of a pulse or time-constant τ_L of luminescence intensity relaxation anticorrelates very well with intensities amplitude space distribution, analogously to its spectral dependencies anticorrelation (see curves 2, 4; Figure 4) (for general luminescence τ_L = const ≈ 3.5 μm)

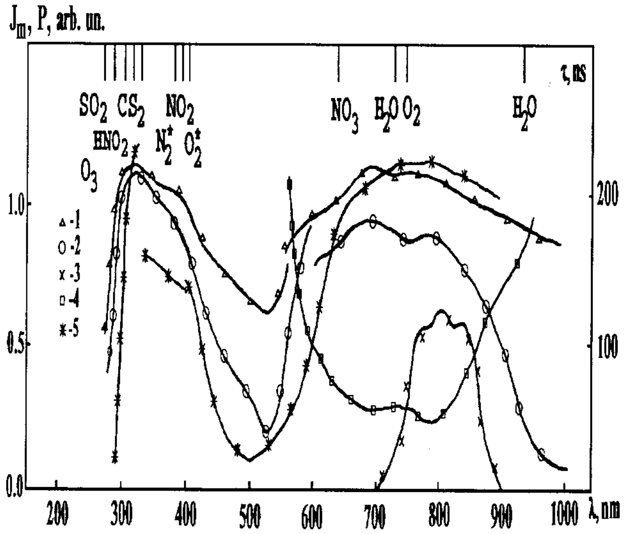

Fig. 4. Spectral behaviour of luminescence intensity amplitude J_m for electron energy 430 keV (1) and 600 keV (2), time constant τ_L of emission relaxation (3), average laser power P by copper vapor laser pumping (4), and transparency of $Al_2O_3:Ti^{3+}$ crystal (5).

They fail to explain in non contradictory form the above mentioned totality of luminescence spectral, space and kinetic characteristics by thermal and other effects, but succeed to explain — under the assumption about amplification existence in active medium. This clearly demonstrates the superluminescence nature of emission.

Figures 4 gives luminescence amplitude spectral behaviour at different energies of exciting electrons (1, 2), crystal spectral transparency (3), τ_L in radiation long wave band (4), the respective to curve (1) and, also, laser tunable curve on Ti-sapphire crystal excited by copper-vapor laser radiation.

The space-temporary characteristics of crystal radiation short-wave band (with center at 0.32 μm ... 0.4 μm) are analogous to the same characteristics for long-wave band (with center at 0.7 μm ... 0.8 μm), that is, we deal with superluminescence , also, in short-wave band, and probably — with perspective laser UV source. With a rise of electrons energy in beam, crystal excitation efficiency increases both in range 0.4...0.55 μm and into longer wave direction, producing powerful superluminescence and with wavelengths more than 1 μm.

The totality of characteristics and regularities stated above in this paper, shows to fundamental possibility of Ti-sapphire crystal laser creation in continuous tuning range from 0.27 μm to 2 μm and at frequencies mixing or doubling — in more wide range.

Specifically, our experiments have shown that crystal electron beam excitation can be used for considerable widening of lasers continuous tuning on Ti-sapphire with pumping by copper-vapor lasers and, also, by another optical sources.

The new types of lasers, indicated above, could be find wide use as lidars transmitters for multi-frequency sounding of aerosols parameters, gas analysis and so on.

In particular, some good lines for a series of components and atmospheric pollutants analysis falling in both crystal luminescence ranges is given in the upper part of Figure 4.

For example, the multifrequency laser sensing of aerosols and atmospheric water vapor with the use of the H_2O resonance absorption effect centered at 0.72 and 0.94 μm, as well as monitoring the atmospheric thermodynamic parameters in the O_2 absorption band centered at 0.76 μm should be mentioned.

Also, this spectral range involve resonance absorption lines of more than 10 atomic components and their ions, and of excited N_2 and O_2 molecules that make this laser promising for use in sensing the upper atmosphere.

Besides, the deterioration of crystals optical quality and their generation aspects up to fluence 10^{17} in our experiments on Ti-sapphire crystals electron excitation is not found.

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