GROWTH AND PROPERTIES OF BERYLLIUM HEXALUMINATE CRYSTALS ACTIVATED BY CHROMIUM AND TITANIUM IONS

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During last years, spectral luminescence properties of crystalline matrices activated by transition element ions are extensively investigated to make, on this basis, new effective tunable lasers operating by electronic-vibrational transitions of the doping ions. Crystalline media providing effective lasing within near-IR region at room temperatures are especially interesting in this respect. Such media include beryllium hexaluminate.

This paper considers synthesis, growth, and some properties of the said compound.

Analytically pure BeO and chemically pure Al_2O_3 taken in the stoichiometric ratio were thoroughly mixed, field-heated at 1200 ^{0}C, and exposed during 12 to 72 hours to synthesize the compound. The X-rays phase analysis showed that chrysoberyl was the first substance to be formed after 12 hours. First peaks of beryllium hexaluminate began to appear only after 24 hours. The complete reaction to form the compound proceeds at 1000 ^{0}C and the exposition during two weeks, but a week is enough at 1500 ^{0}C-temperature [1].

The crystals have the orthorhombic lattice with the following parameters, *a*=9.55, *b*=13.757, *c*=8.909 A. A possible space group is Pcar or Pcam, estimated density *d*=3.75 g/cm^3, and calculated density *d*=3.74 g/cm^3 [1].

$BeAl_6O_{10}$ crystals activated by Cr^{3+} and Ti^{3+} were grown by the Czochralski method from iridium crucibles of 60-mm diameter with using the induction heating. A neutral atmosphere was utilized for the Cr^{3+} activation, but a reducing medium was used for the growth with Ti^{3+}. The growth rate was 1 to 1.5 mm/hour, the rotational speed varied from 40 to 60 rev/min. Crystals of high quality were obtained at temperature gradients 15 to 20 ^{0}C/cm and axial gradients 40 to 60 ^{0}C/cm. The crystals have the following dimensions, diameter of 10 to 15 mm, and length of 90 mm. The concentrations of Cr_2O_3 and Ti_2O_3 in the mixture were 0.1 to 0.15 and 0.25 wt. %, respectively. The coefficient of Cr^{3+} distribution in the crystal was much higher than unity to provide good conditions for its homogeneous penetration along the boule length and prevent from a problem of impurity bands.

The total optical losses in the maximum of the lased line, λ=830 nm, were 0.01 cm^{-1}.

A crystal of 0.5-cm length pumped coherently by the second harmonic of a YAG-Nd^{3+} laser with acousto-optical Q-switching was used to study the lasing characteristics of $BeAl_6O_{10}$: Cr^{3+}. Radiation tunable over 0.79 to 0.92 mkm was lased by the way of a Lio filter [2].

Stimulated radiation over 0.78 to 0.92 mkm was also lased by lamp pumping of the elements with 0.4-cm diameter and 2.5-cm length in a line resonator containing a dispersion prism. The efficiency of the $BeAl_6O_{10}$ laser with a single-lamp pump (NPP-5/45) was similar to that of an alexandrite laser with the element of 3-cm length.

Ti^{3+} ions in $BeAl_6O_{10}$ can acquire two different positions C_1 and C_2. Analysis of the absorption, luminescence and EPR spectra shows that Ti^{3+} ions in this crystal form pair centers Ti^{3+} - Ti^{3+}, which have the strong absorption band in the range of 0.6 to 0.9 mkm to overlap the electronic-vibrational luminescence band. The presence of this band hardly provides an opportunity to lase stimulated radiation by Ti^{3+} ions in $BeAl_6O_{10}$.

The Table below shows some properties of $BeAl_6O_{10}$ and $BeAl_2O_4$ crystals.

Table

Crystal	Mohs' hardness	Heat conduction, W/mkm	Density, g/cm^3	Heat capacity, J/kg K	Young's modulus, 10^9 N/m^2	Poisson modulus	Fluorescence range, mkm	Fluorescence peak, mkm	Lifetime, mks	Transition cross-section, 10^{-20} cm^2	Lasing maximum, mkm
$BeAl_6O_{10}$	8	12.5	3.7	0.8	381	0.24	0.7-1.1	0.77	13.5	6.0	0.83
$BeAl_2O_4$	7.5	23	3.74	0.83	469	0.3	0.7-0.82	0.71	260	0.7	0.75

The absorption spectra of $BeAl_6O_{10}$ are shifted towards the IR range as compared with the alexandrite spectra to be, consequently, prospective for using the former crystal in lasers with diode pumping. $BeAl_6O_{10}$ absorbs 70 % at λ=0.65 mkm of the maximum, whereas alexandrite does near 35 % at the same wavelength.

Since the luminescence spectra of $BeAl_6O_{10}:Cr^{3+}$ and $BeAl_2O4:Cr^{3+}$ overlap each other, it is possible to create a hybrid laser having two crystals in a single resonator. The output here is tunable radiation, which is equal to the total lasing range of the crystals. In this case, the lasing will be within 0.71 to 1.0 mkm. The similar lasers can find a wide application for scientific and practical objectives.

Therefore, here is obtained the new compound that can effectively operate in tunable lasers with lamp and diode pumping.

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References

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