# Crystal Growth and Spectroscopic Investigation of Yb,Er:$YCa_4O(BO_3)_3$ for 1.55 μm Laser

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**Abstract**

Single crystals of Yttrium Calcium Oxyborate (YCOB) doped with different concentrations of $Er^{3+}$ and $Yb^{3+}$ ions were grown by Czochralski method. High qualities of crystals in morphology and transparency were obtained. Analysis on crystal structure and lattice parameters were performed by X-ray diffraction method. It was found that congruent melting composition is $YCa_{4.2}O_{1.2}(BO_3)_3$. Absorption and fluorescence properties of grown crystals were also reported.

## 1. Introduction

The search for new laser materials emitting 1.55 μm of wavelength has a lot of interest because of numerous applications in eye safe range finding and optical communication. Laser action with 1.55 μm of wavelength could be obtained in some laser mediums such as LSB(1) and glasses(2). Emission in 1.55 μm range can be obtained with $Er^{3+}$ ions through $^4I_{13/2} \rightarrow {}^4I_{15/2}$ transition. The weak absorption of $Er^{3+}$ in the emission range of InGaAs laser diode and reabsorption process, which prevent high doping of active ions, have led to consider co-doping of $Yb^{3+}$ has high absorption around 980 nm. $Yb^{3+}$ itself has been proved to be interesting sensitizer for emission at 1.55 μm(3).

In this work, we will present the growth and spectroscopic properties of YCOB crystals substituted $Y^{3+}$ by $Er^{3+}$ and $Yb^{3+}$ as a new promising candidate of laser material 1.55 μm.

## 2. Structure of YCOB

About ReCOB (where Re = Rare Earth) structure it was reported by S. Lei et al(3) for the first time and determined to be $Ca_5(BO_3)_3F$ structure assigned to the Cm space group. This structure is monoclinic and asymmetric. The $Y^{3+}$ ions occupied a deformed octahedron. There are two types of Calcium sites, $Ca^{2+}$(I) and $Ca^{2+}$(II). They are six-coordinated with Oxygen atoms. The $B^{3+}$ ions have two different forms of triangle planes; $B^{3+}$(I) and $B^{3+}$(II). YCOB has two natural sets cleavage planes, (010) and (201), and cracks easily.

The phase identification and crystallographic axis of grown YCOB crystals were determined by X-ray diffraction method. The parameters of unit cell constants were analyzed a=8.043Å, b=16.180Å and c=3.505Å with $\beta$=101.01.

## 3. Crystal Growth

We had grown these crystals to study spectroscopic properties with high optical quality. Single crystals were grown by Czochralski method from the several kinds of melt compositions contained in a Iridium crucible under the $N_2$. atmosphere. Before crystal growth proceeded, a series of polycrystalline charges were synthesized to grow Yb:YCOB and Er,Yb:YCOB crystals. For that, powders of $Y_2O_3$, $Er_2O_3$, $Yb_2O_3$, $B_2O_3$ and $CaCO_3$ (>99.99% purity) were mixed and then sintered to stoichiometric compositions by following chemical reaction: $Y_2O_3 + 8CaCO_3 + 3B_2O_3 \rightarrow 2YCa_4O(BO_3)_3 + 8CO_2$. The pulling rate was 1-2.5 mm/h and rotation rate was 15-20rpm. The melting point of YCOB is 1510℃. The <010> oriented seed crystal was used after seed preparation by Pt wire. We found congruent melting composition of melt is $YCa_{4.2}O_{1.2}(BO_3)_3$,. It was melted without decomposition. Also it was found $Yb^{3+}$ ions can be substituted up to 25% in $Y^{3+}$ sites.

## 4. Absorption and fluorescence spectra of Yb:YCOB and Er,Yb:YCOB

Absorption spectra were obtained using a MB150 FT-IR spectrophotometer. Fluorescence spectra were measured by optical pumping of InGaAs laser diode at the wavelength of 976.4nm. The detection of the luminescence was carried out with a HR320 monochromator and Ge-detector. Spectra measured along the *b*-axis from the optically polished wafers of 20%Yb:YCOB, 1%Er,20%Yb:YCOB and 2%Er,20%Yb:YCOB crystals (2.0mm in thickness) were shown in Fig. 1 and Fig. 2. The absorption cross section of the main peak at 976 nm was calculated from the absorption coefficient. By the emission spectra of 1%Er,20%Yb:YCOB and 2%Er,20%Yb:YCOB, the luminescence in 1450 - 1600nm region with maximum at 1537nm was observed.

## 5. Conclusions

As results, we developed new technology of crystal growth for high quality of YCOB single crystals doped with high concentration of Yb and Er ions for the first time in the world. We analysed crystal structure of YCOB. The broad $Yb^{3+}$ absorption lines in 2%Er,20%Yb:YCOB are well suited for laser diode pumping near 976nm. This new crystal is promising for diode pumped laser materials at 1.55 $\mu$m.

## References


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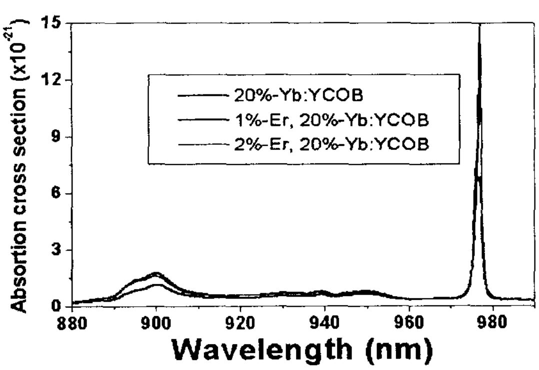


Fig. 1 Absorption spectrum of Yb:YCOB and Er,Yb:YCOB crystals.

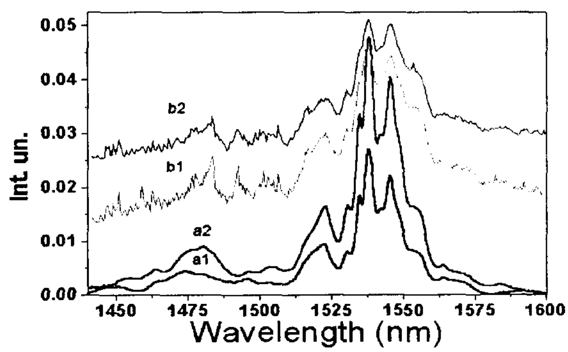


Fig. 2. Absorption (a1, a2) and fluorescence (b1, b2) spectrum of Yb, Er:YCOB crystals; a1, b1 for 1%Er,20%Yb:YCOB, a2, b2 for 2%Er,20%Yb:YCOB.