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# Influence of amaranth dye on the growth and properties of KDP single crystal

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ABSTRACT

Amaranth dye doped KDP single crystals were grown by slow cooling seed rotation method with the vision to improve the properties of the crystal. The grown crystals were of size up to 53 × 20 × 50 mm$^3$. The grown crystals were subjected to FTIR, UV–vis photoluminescence, microhardness and laser damage threshold studies. The addition of dye improves the growth rate of the crystals. Photoluminescence (PL) emission spectra of amaranth doped KDP crystals are practically identical. Amaranth increases the mechanical strength and laser damage threshold of the grown crystals compared to pure KDP crystals.


## 1. Introduction

Potassium dihydrogen phosphate (KDP) has been extensively studied for many years (since 1930) due to its important applications in science and technology. Extremely high optical and structural perfection of KDP makes it possible to produce elements for various non-linear optical and electro-optical properties such as frequency multipliers, optical parametric oscillators, electro-optical modulators, 3D optical data storage and pockels cells for mega-joule laser systems of the new generation [1–6]. The technology of large size KDP single crystal growing on the point seed by the method of slow cooling is having great practical importance because such crystals are widely used in very high-energy Nd-glass lasers used for inertial confinement fusion research. Large plates of nonlinear crystals are needed for electro-optic switches and frequency converters. In the last three decades, many research efforts have been made to promote the high quality single crystal and increase the growth rate to meet the requirements of inertial confinement fusion [3,7–10]. From this point of view various rapid new growth techniques are developed worldwide [6–8,10]. Zaitseva et al. used "point seed" temperature reduction method to grow dye doped KDP crystal with the growth rates from 0.5 to 25 mm/day in 1999 [8]. In 2008, Pritula et al. grew urea doped KDP crystals by "point seed" temperature reduction technique [10]. The amount of impurities in the raw materials is an important factor for the rapid growth of crystals. For pure KDP crystals, the degree of structural imperfection is determined by the content of inorganic impurities that are necessarily present in initial salt solutions. KDP crystals can absorb different types of inorganic and organic molecules: the high valence cationic ions $Cu^{2+}$, $Cr^{3+}$, $Al^{3+}$, $Bi^{3+}$ and $Fe^{3+}$, organic molecules such as phenols, fatty acids, amaranth, sunset yellow, ethanol, 1-propanol and so on [3,5,10–13]. Some of the parameters are generally affecting the growth habits of KDP crystals, such as the super saturation of the solution, the absorption of foreign particles, temperature and pH value [3,10]. It is experimentally proved that the cationic ions are easily absorbed on the prismatic faces and inhabit their growth but the effects of anionic ions are rarely seen in these faces [12]. Different kinds of inorganic lattices can encapsulate organic dye molecules and dyes inclusion in crystal promises spectroscopic, optical and photonic applications [14]. The incorporation of the dye molecules in KDP crystal is determined by the molecular electrostatic potential (MESP) and the charge state of the growing crystal face. The chemical bonds of KDP crystals are formed by cations ($K^+$), anions ($H_2PO_4^-$) and the hydrogen bonds of the

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adjacent ($H_2PO_4^-$) groups. The morphology of KDP crystals are constituted by prism and pyramidal faces [15]. The prismatic faces (1 0 0) of KDP crystals are framed of ($H_2PO_4^-$) and $K^+$ successively, whereas the pyramidal faces (1 0 1) end with $K^+$ in growth solution [16]. The surface of pyramidal face of KDP crystal has a positive charge, while the electrostatic potential (ESP) distribution of the anion impurity is totally negative. Therefore, amaranth dye is easily occupying the lattices of the pyramidal sector (1 0 1) [17]. Asakuma et al. reported that dyes can be absorbed onto the different faces of KDP crystals. For example sunset yellow, amaranth, sky blue are absorbed on the pyramidal sector (1 0 1), methylene blue, crystal violet are absorbed onto the prismatic sector (1 0 0) and brilliant blue, acid fuchsin are captured onto both sectors [18]. In our investigation, anionic amaranth dye is preferably absorbed onto the pyramidal face (1 0 1) of KDP crystal. Concentration of impurity surface assimilation is assigned to the alternating control of the cation ($K^+$) or anion ($H_2PO_4^-$) on various crystal facets in the case of KDP crystal. The organic dye molecules tend to be absorbed by a positively charged face of the pyramidal facet [19,20].

The present paper describes and discusses the experimental results concerning the influence of amaranth organic dye on the crystal growth, FTIR, UV–vis photoluminescence, mechanical stability and bulk laser damage resistance of the KDP single crystals.

## 2. Experimental procedure

### 2.1. Crystal growth

The starting material was pure KDP, which was bought from MERK-GR. Millipore ultrapure water with resistivity of 18.2 MΩ cm was used as the solvent. Amaranth dye was used as additive in different mole percentage 0.2, 0.3 and 0.4 respectively. Pure KDP seed crystals were first obtained in the supersaturated KDP solution by slow evaporation. The crystals were grown by the slow cooling method on a point seed from an aqueous solution containing 0.2, 0.3 and 0.4 mol% of the dye and pure KDP salt. Seed crystals with perfect morphology and free from macro defects were used for growth experiments. This experimental setup consists of a seed rotation controller coupled with a stepper motor, which is controlled using a microcontroller supported drive. This controller rotates the seed holder in the crystallizer. The seed crystal is mounted on the center of the platform made up of acrylic

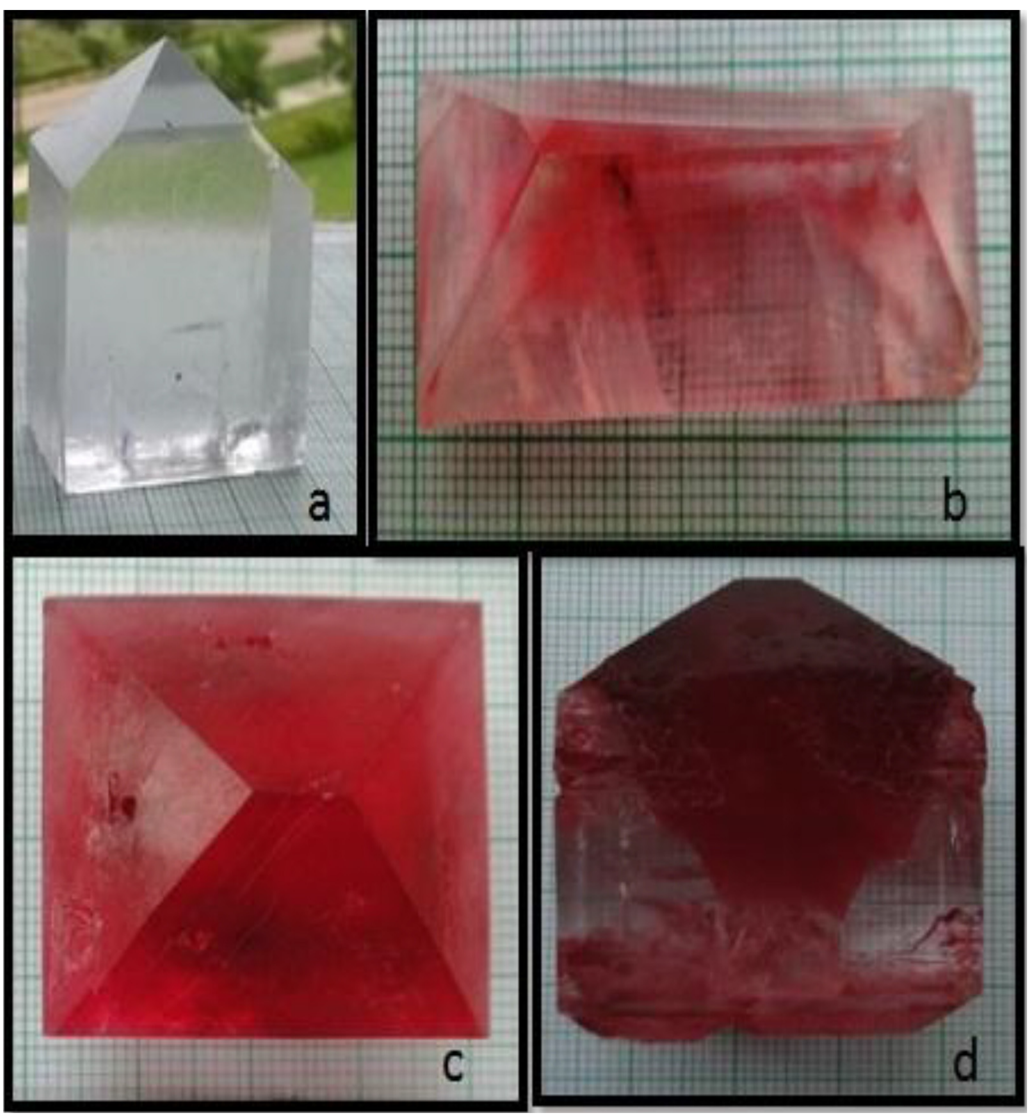


**Fig. 1.** (a) Pure KDP crystal, (b) 0.2 mol% amaranth doped KDP crystal, (c) 0.3 mol% amaranth doped KDP crystal and (d) 0.4 mol% amaranth doped KDP crystal.