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Study on the optical properties of rapidly grown KDP crystals

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Abstract

KDP crystals were grown at growth rates from 5.0 to 19.0 mm/d. Transmittance, laser damage threshold and light scatter were detected. It has been shown that laser damage thresholds of KDP crystals decrease with the increase of the absorption coefficients. Large-scale impurity is an important factor that causes light absorption in UV range and reduces the damage threshold.

Keywords: KDP; Rapid growth; Absorption coefficient; Damage threshold; Light scatter

1. Introduction

The inertial confinement fusion (ICF) program needs large plates of KDP crystals of high optical qualities as Q-switches and laser radiation converters [1]. The invention of the rapid growth method decreases the cost and growth period greatly. Zaitseva et al. in LLNL grew large-scale (40–55 cm) KDP crystals at rates of 10–20 mm/d by the method of "point seed" [2]. Nakatsuka grew 60 mm KDP crystals of at rates of excess 50 mm/d by using external energy [3].

It has been demonstrated that the main optical properties of rapidly grown KDP crystals can be as good as those grown by traditional method [4,5]. But their growth demands high pure raw materials and strict growth conditions. So it is still necessary to study the optical properties of fast growth KDP crystals.

Optical transmittance and laser damage threshold are two primary properties of the KDP crystals. In this paper, we present the results of our experiments on the optical transmittance and damage thresholds at different growth rates. The purpose of the experiments was to find out the relationship between the optical absorption coefficient and laser damage threshold and factors that influence both of them.

2. Experimental procedure

In our experiment, KDP reagents (A.R.) were used as solutes and twice distilled water was used as solvents. Crystals were grown on a point seed by temperature reduction method in 5 L standard glass crystallizers. The final sizes of the crystals varied from 5 to 7 cm. The temperature region of the growth was about 62.5–50 °C. And the reversible rotation rate of the platform holding crystals was about 30 rpm. In all the experiments, the saturations of the solutions were 62.5 °C.

The solution was filtered through filters with pores with the diameters of 0.10 μm and then was overheated at 75 °C for 36 h. After overheating, the temperature of solution was reduced to the point of 7 °C higher than the saturation point and then the seeds which were z-cut with the size of $1 \times 1 \times 0.5\ cm^3$ was put into the solution. Then we went on reducing the temperature of the solution to make seed crystals grow.

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3. Results and discussion

3.1. Transmittance

KDP plates with the thickness of 1.0 cm were cut from the pyramidal and prismatic sectors (see Fig. 1) of the crystals in [0 0 1] direction and then were well polished in (0 0 1) faces for measurement. The transmittance spectra shown in Figs. 2 and 3 were obtained by PE-lamda350 spectrometer. In prismatic sector (Fig. 2), the transmittances of KDP crystals grown at different rates are rather close to each other in visible region, while in UV region, transmittances decrease sharply with the rise of growth rates. In pyramidal sector (Fig. 3), the transmittances of crystals grown at different rates have far less differences than in the prismatic sector. Only in the range from 250 nm to 190 nm, there are apparent differences among them.

The absorption coefficients at 1064 nm and 355 nm were listed in Table 1. From the table, one can find that at the wavelength of 1064 nm, the absorption coefficients do not have observable increase or decrease with the rise of growth rates. But the absorption coefficients of rapidly grown KDP crystals are a little higher than those grown from traditional method, which is the same as Fujioka et al.'s result [6]. At the wavelength of 355 nm, the absorption coefficients reduce greatly with the rise of growth rates in the prismatic sectors, but in the pyramidal sectors, the absorption coefficients do not have observable increase or decrease with the rise of growth rates.

The laser damage thresholds of the crystals were measured by a Nd:YAG laser delivering a 1 ns single pulse. The laser damage which occurred in the interior of crystals was observed by a differential interference microscope. The results are summarized in Table 1. From the table, we can find that in both prismatic and pyramidal sectors, laser damage thresholds at both 1064 nm and 355 nm decreases with the increase of the growth rates.

3.2. Relationship between absorption coefficient and laser damage threshold

Fig. 4a–c present the relationship between absorption coefficient and laser damage threshold of KDP crystals. From these figures, one can find that in prismatic sector at 1064 nm (Fig. 4a) and in pyramidal sector at 355 nm (Fig. 4c), there is no definite relationship between absorption coefficient and laser damage threshold, but in prismatic sector at 355 nm (Fig. 4b), laser damage thresholds

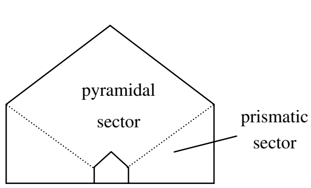

Fig. 1. Scheme of the growth sectors in a rapidly grown KDP crystal.

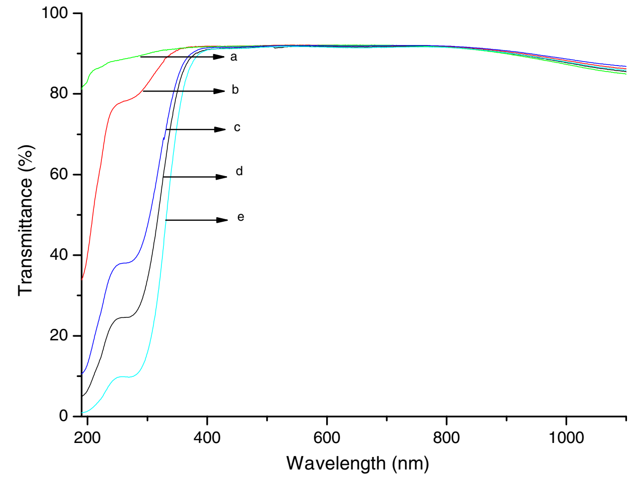

Fig. 2. Spectral transmittance of the prismatic sector of KDP crystals: (a) 1# grown by traditional method; (b) 2# with the average rate of 5.0 mm/d; (c) 3# 14.2 mm/d; (d) 4# 19.0 mm/d in [1 0 0] direction; (e) 5# grown at the same conditions as 4#, but the diameter of the pores of filters (0.15 μm) is larger than that of 4# (0.10 μm).

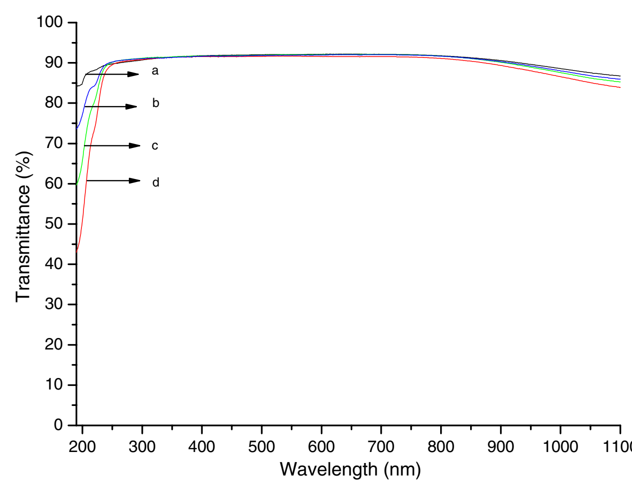

Fig. 3. Spectral transmittance of the pyramidal sector of KDP crystals: (a) 1# grown by traditional method; (b) 2# with the average rate of 5.0 mm/d; (c) 3# 14.2 mm/d; (d) 4# 19.0 mm/d in [1 0 0] direction.

decrease with the increase of absorption coefficients. When we analyze the values of the absorption coefficients carefully, we can find that in the former two conditions (Fig. 4a and c), the differences between every two absorption coefficients are small. The largest of them are 0.68%/cm in the first condition (the difference between 5.06%/cm and 4.38%/cm) and 0.148%/cm in the second condition (the difference between 0.573%/cm and 0.389%/cm). However, in the third condition (Fig. 4b), the differences between every two absorption coefficients are larger than in the former two conditions. The smallest of them are 1.14%/cm (the difference between 7.53%/cm and 6.39%/cm). That is to say, when the differences between every two absorption coefficients are large enough (larger than 1%/cm in our experiment), the laser damage thresholds of KDP crystals decrease with the increase of the absorption coefficients.