L.2: Growth of large size KDP single crystal using indigenously developed setup for high power laser application

Potassium dihydrogen orthophosphate (KDP) is one of the important nonlinear optical crystals suitable for Q-switching and frequency multiplication of high power Nd-doped glass or YAG lasers working at ~1.0 µm wavelength. As one increases the energy of the laser pulse, the demand of KDP crystal element size also increases. Design and development of crystal growth systems and related growth technology for KDP crystal is being pursued from its inception. It comprises of mainly design and fabrication of water baths, crystallizers, seed mounting platforms associated with their rotation mechanism and so on. Development of water bath and crystallizer of capacity up to 200 L and 20 L, respectively and grown KDP crystals of dimensions up to ~100 x 100 x 100 mm^3 have already been performed. Second harmonic generating elements have been prepared from these crystals and provided to various users groups at RRCAT, BARC, SGSITS and DAVV, Indore, etc. Currently the high energy solid-state laser program at RRCAT is being scaled up to achieve high energy laser of the order of 500 J per beam. There are various subsystems required for its development, among which large size KDP crystals are needed for making large aperture Q-switches having cross-section of 150 mm x 150 mm. For this purpose, large size KDP single crystals with good optical homogeneity and without any visible defects are required. KDP elements of this size are not readily available in the international market due to their requirement in strategic applications. KDP crystal is normally grown using low temperature solution growth technique based on slow cooling of saturated solution, where water is used as solvent. KDP belongs to tetragonal crystal structure having four-fold symmetry about c-axis. The growth morphology acquires tetragonal bipyramidal shape composed of prismatic {100} and pyramidal face {101}. Growth of large size KDP crystal is a challenging task because it requires firstly the design, fabrication and testing of large size components for making crystal growth system, then handling and processing of large amount of hot solution and finally optimization of growth parameters to control nucleation and defects. Most of the components are not available in the market and hence developed indigenously. Some of the important items are large size wash basin for cleaning 50 L capacity glass beakers, 350 L capacity water bath with high order temperature stability as shown in Figure L.2.1(a), 50 L capacity hermetically sealed glass crystallizer along with large size acrylic make platform with ball bearing assembly for smooth rotation and stepper motor controller. The temperature stability of the water bath is ± 0.1 °C with a small axial temperature gradient of 0.02 °C/cm. Recently, a special purpose crane is also developed with the help of Design & Manufacturing Technology Division, RRCAT for movement of large size and heavy glass crystallizer containing hot solution.

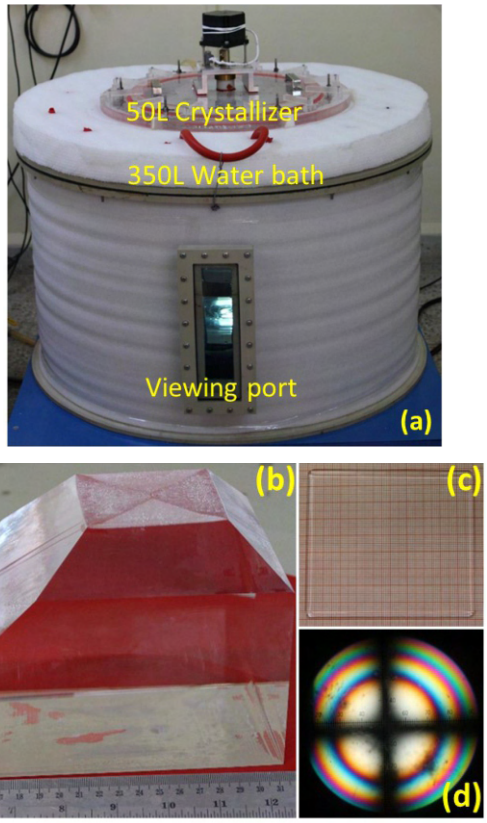

Fig. L.2.1: (a) A 350 L capacity water bath containing 50 L capacity glass crystallizer, (b) as-grown KDP crystal, (c) c-cut plate prepared from the top part of the KDP crystal and (d) characteristic conoscopic pattern confirming angular accuracy of the plate.

For crystal growth, ~ 39 kg KDP solution was prepared in high purity water and subsequently filtered through 0.2 µm porosity membrane filter. Initially, saturation temperature was determined gravimetrically and subsequently growth was initiated from a point size KDP seed mounted at the center of the acrylic platform. Growth parameters were optimized, which continued up to 50 days and resulted into successful growth of 160 mm × 155 mm × 120 mm (L x W x H) size and 5.5 kg mass of KDP crystal as shown in Figure L.2.1(b). This is the largest size KDP crystal grown so far in our country and is suitable for fabrication of 150 mm x 150 mm cross-section element for Q-switch fabrication for our laser program. The crystal is visibly transparent except some localized inclusions at lower portion only. The grown crystal has been cut using a diamond coated wire saw. Figure L.2.1(c) shows a c-cut plate prepared from the crystal for assessment of its orientation for Q-switch application. Fig. L.2.1(d) shows characteristic conoscopic interference pattern confirming the good orientation accuracy of the plate for the purpose. Further plates are being prepared from the crystal and their characterization for optical quality and defect density will be carried out for the intended purpose.

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