Kyropoulos Growth and Characterisation of Titanium doped Sapphire

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Amphitheater Jean Besson

Jury:

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Abstract: There is a huge interest in construction of solid state lasers capable of reaching petawatt (PW) levels and beyond. In order to achieve this level of power, Ti:Al2O3 amplifiers up to 20 cm in diameter or larger are required and hence there is the need for the growth of large diameter Ti:Al2O3 crystal boules. The Kyropoulos growth process has been identified by the company RSA le Rubis SA as the most productive technique because it allows growing massive crystals under a low temperature gradient and hence of good quality.

Growing crystals weighing about 30 kg comes with its share of complications which gravely affect the crystal morphology and hence its crystalline quality. To address the issues of morphology, a detailed study of the growth parameters effect was carried out by analysing the process of crystals grown in the industrial setup. The factors for the critical issues of a flat plate formation and re-melted zones in the crystal were identified and an ideal set of parameters for the pulling rate and mass growth rate was proposed. These led to marked improvements in the productive volume of the crystal and enabled growth of crystals with predictable morphologies.

To take a step further, a completely autonomous crystal growth system was envisioned which would allow the operator live monitoring of the crystal shape and give control over its radial growth parameters. This is based on the simultaneous in situ measurement of crystal weight and remaining liquid level. A mathematical study is presented to explain the relationship between all the weighing forces acting on the growing crystal and to study the feasibility of this control system. It is shown that it could be useful for the diameter regulation during the Kyropoulos growth process.

Crystals were characterised and checked for defects which would affect their optical properties. One such defect was the presence of a translucent band in the otherwise transparent crystal, called “milky defect”. The crystalline quality in terms of dislocation density due to induced strain was analysed using X-ray diffraction techniques, along with optical characterisation and chemical analyses. Aided with heat transfer and thermo-mechanical numerical simulations of the growth system, an explanation for the origin of this defect in terms of acting thermal stress and associated crystal growth dynamics is proposed.

Titanium doping in the sapphire crystal is needed for the Laser application, but there is segregation of the dopant during growth and this leads to an inhomogeneous distribution in the grown crystals, as

shown by optical characterisation of the distribution of titanium in its Ti3+ and Ti4+ states. Ideas in order to improve the laser sample homogeneities are proposed.