# The growth of laser quality (Nd, La)$P_5O_{14}$ large crystals

*Chen Fusheng* *Chen Huanchu* *Liu Yaogang*
*Lu Baosheng* *Han Jianru*

(Institute of Crystal Materials, Shantong University, Jinan)

In this paper, the theoretical and technical researches on the growth of laser quality (Nd, La)$P_5O_{14}$ large crystals are reported.

The $Nd^{3+}$ concentration of (Nd, La) $P_5O_{14}$ crystals can be up to $4 \times 10^{21}$ $cm^{-3}$, which is thirty times as high as that of the common Nd: doped YAG crystals, yet with quite small concentration quenching effect. Thus small samples are needed to obtain larger laser gain, which is very advantageous for the miniaturation of laser device.

We have designed a new growth apparatus which has a small-free-space. The advantages of this apparatus are: simple, convenient, homogeneous heat field and efficient control of amount of evaporated solution. The optimum technical conditions for growth of large (Nd, La)$P_5O_{14}$ crystals presented. With the above apparatus and conditions, the number of nucleation was controlled successfully. Large transparent crystals with beautiful shape were obtained. The crystals grown by spontaneous nucleation are larger than 1.5 cm, $3.7 \times 2.7 \times 1.5$ cm by seeded growth, the largest one even up to 4 cm.

Laser output has been obtained from these crystals pumped by a pulse dye laser or a small xenon lamp at room temperature with an energy convesion efficiency of up to 10% and a threshold energy for monomode operation of 40 $\mu$J. Pulse and cw laser operations were obtained using the above mentioned crystals at room temperature by different ways of pumping.

physical-chemical process during crystal growth was investigated. The effect of evaporation rate on nucleation and growth, the curves of components in solution—evaporation amount and the isothermal solubility of (Nd, La)$P_5O_{14}$ in pyrophosphoric acid were determined. There was no effect on the species of polyacids in solution when the rare-earth oxides were added. The relative content of polyacids is only the function of $P_2O_5/H_2O$ ratio and has nothing to do with the preparation. The role of pyrophosphoric acid in dissolving (Nd, La)$P_5O_{14}$ was studied. The kinetic process was further analyzed from the curves of time vs the amount of water produced, the phosphoric acid components and the weight of crystals deposited during the crystal growth process. It is shown that the crux of obtaining high quality crystals is to control the evaporation rate of water at constant temperature growth. This conclusion has extensive significance for rare-earth phosphate growth from the phosphoric acid.

# 优质大尺寸 $(Nd, La)P_5O_{14}$ 激光晶体的生长

陈福生　陈焕矗　刘耀岗　陆宝生　韩建儒

（山东大学晶体材料研究所）

本文论述优质大尺寸$(Nd,La)P_5O_{14}$激光晶体的生长过程和工艺条件的研究。

$(Nd,La)P_5O_{14}$晶体的$Nd^{3+}$浓度可高达$4\times10^{21}$厘米$^{-3}$，比常用的掺Nd的YAG晶体大30倍，而浓度猝灭效应却很小，因而只需很小的工作样品就可以获得较大的激光增益，极有利于器件小型化。

我们找出了生长$(Nd,La)P_5O_{14}$大晶体的最佳工艺条件，设计了晶体生长装置，即小自由空间体系。该装置设备简单，使用方便，温场均匀，能有效地控制溶液的蒸发量。采用本装置和工艺条件，能成功地控制成核。长出外形完整透明的大晶体。自发成核生长的晶体大于1.5厘米。籽晶法生长的晶体为$3.7\times2.7\times1.5$厘米，最大达4厘米。

利用这些晶体，采用脉冲染料激光或小型脉冲氙灯激发，在室温条件下都已获得激光输出，激光能量转换效率达到10%，单横模运转的阈值能量约为40微焦耳。这些晶体在室温下用不同泵浦方式都实现了脉冲和连续激光运转。

我们较全面地研究了晶体生长的物理化学过程。测定了蒸发速率对晶体成核与生长的影响，生长溶液组份—水蒸发量曲线以及$(Nd,La)P_5O_{14}$晶体在焦磷酸中的溶解度曲线。阐明了在生长溶液中，高温下磷酸的聚合不因加入稀土氧化物而受到影响。各种多聚酸的相对含量仅仅是五氧化二磷与水比值的函数，与制备方法无关。弄清了焦磷酸对$(Nd,La)P_5O_{14}$晶体溶解起主导作用。通过时间—出水量，焦磷酸含量，晶体沉积量等曲线，进一步分析了晶体生长的动力学过程，指出在恒温生长时，控制水的蒸发速率是生长优质大晶体的关键。这一结论对于在磷酸体系中生长其他稀土五磷酸盐也具有普遍意义。这些研究结果为生长优质大晶体和改革工艺提供了理论依据。