Wigner 121 Scientific Symposium

Wigner Research Centre for Physics
Institute for Solid State Physics and Optics
Applied and Nonlinear Optics Department
Crystal Physics Research Group

History

The Research Laboratory for Crystal Physics (RLCP) was established in 1976 to continue existing tradition of the "Gyulai-Tarján school" in crystal growth and characterization. In 1998 the RLCP became part of the Institute for Solid State Physics and Optics now incorporated in the Wigner Research Centre. Oxide crystals with melting point up to 1300 °C have been grown in our laboratories such as $LiNbO_3$ (LN), $K_3Li_2Nb_5O_{15}$, TeO_2, Bi_2TeO_5, $Bi_{12}SiO_{20}$, $Bi_4Ge_3O_{12}$, ß-$Ba_2B_2O_4$, $Li_2B_4O_7$, $CsLiB_6O_{10}$, Y/Gd$Al_3(BO_3)_4$, Li_6Y/Gd$(BO_3)_3$, etc. They are widely used in classical and laser optics and scintillation detectors. Nowadays our interest turned to the preparation of rare earth (RE) doped oxide materials in nanocrystalline form (e.g. LN:Yb/Er, Y_2SiO_5:Tm) which are perspective materials in quantum optics and quantum technologies.

Pure and RE doped nanoLN

Preparation

Bottom up

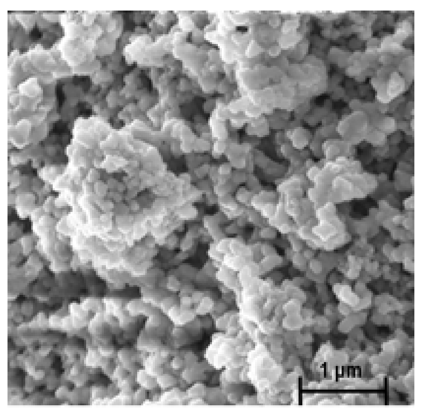
Solvothermal method

Considering various factors (quality of polyol medium, reaction time, heat treatment temperature, Li/Nb ratio), a simple method was developed, and LN nanocrystals with a homogeneous size and composition distribution in the size range below 100 nm were produced [1].

Two-step reaction mechanism

$$Nb_2O_5 + 6\,LiOH \rightarrow 2\,Li_3NbO_4 + 3H_2O$$

$$Li_3NbO_4 + Nb_2O_5 \rightarrow 3\,LiNbO_3$$

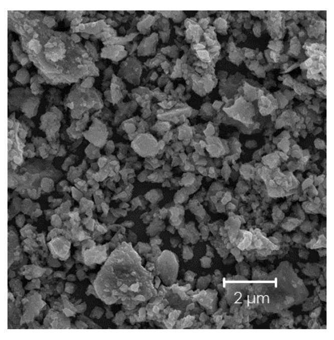


Top down

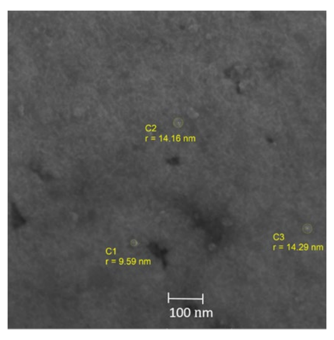
Ball milling method

Pure and rare earth doped $LiNbO_3$ crystals were milled by ball-milling technique [2]. The sizes of the particles were decreased with increasing the milling time and decreasing the size of the grinding balls.

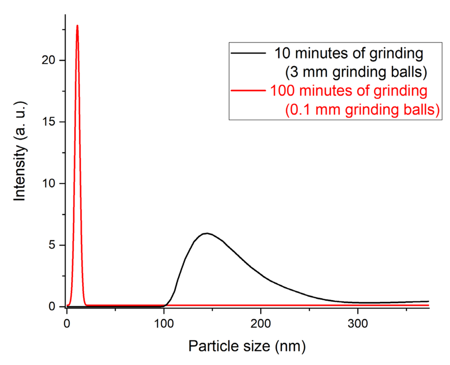
10 minutes of grinding (3mm grinding balls)



100 minutes of grinding (0.1 mm grinding balls)



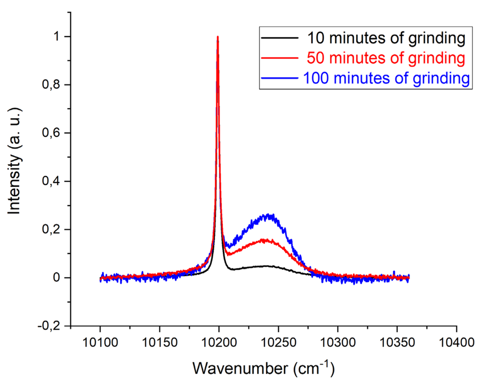
Size distribution



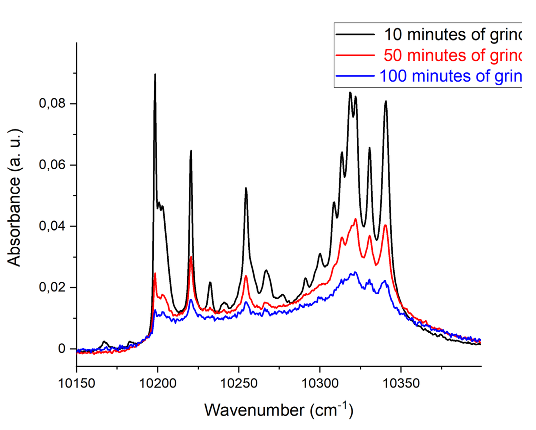
Investigations

During the grinding process, the structure of the crystal may change, either as a result of the mechanical force or that of the size reduction. This phenomenon can investigate by following the changes of RE bands appearing in the infrared absorption spectrum, as a function of the grinding time and the phases formed during grinding.

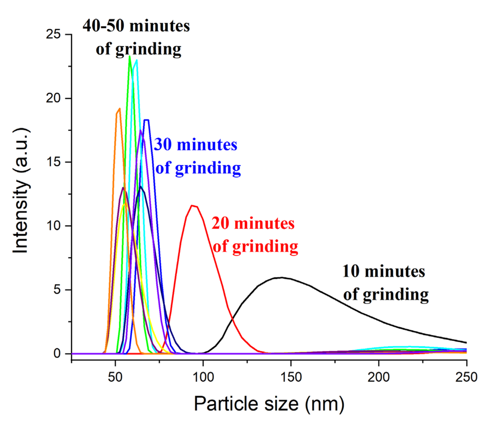
$^2F_{7/2} - ^2F_{5/2}$ transition of the Yb-doped $LiNbO_3$



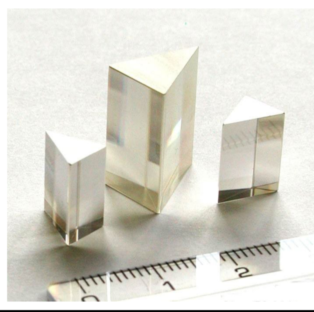
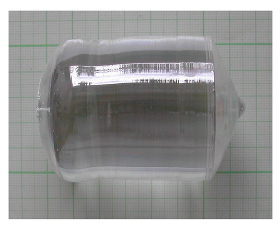
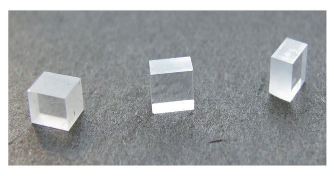
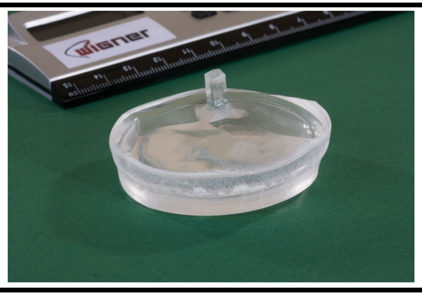
$^4I_{15/2} - ^4I_{11/2}$ transition of Er-doped $LiNbO_3$



Size distribution in both cases

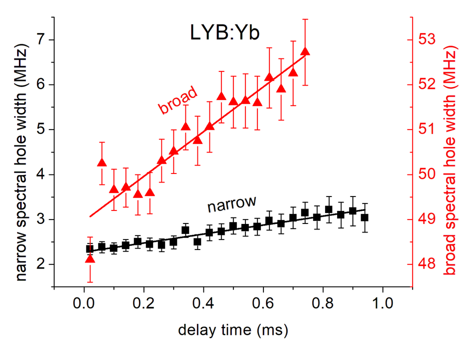


Crystals for applications

Material	Crystal sample	Application
$LiNbO_3$:Mg		**Medical diagnostics and nonlinear spectroscopy** High-energy THz pulses by optical rectification in $LiNbO_3$:Mg crystal can be generated in tilted-pulse-front-excitation geometry.
TeO_2	 	**3D AO scanning in the Femto3D-AO two-photon microscope** Acousto-optic deflectors produced from TeO_2 and $LiNbO_3$ crystals are used to control the optical beam spatially.
β-BaB_2O_4		**Measuring and manipulating femtosecond pulses** The excellent non-linear optical properties of BBO crystals allow their usage for high intensity laser applications.

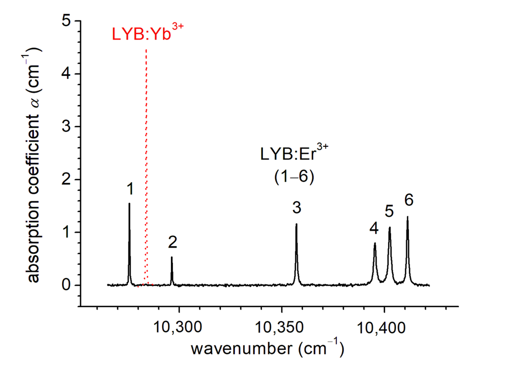
Spectroscopy of crystals

$^2F_{7/2} - ^2F_{5/2}$ transition of Yb^{3+} and $^4I_{15/2}$–$^4I_{11/2}$ transition of Er^{3+} in $Li_6Y(BO_3)_3$ (LYB)



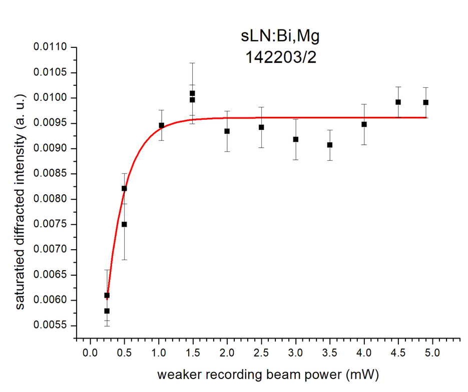
Spectral diffusion in LYB:Yb^{3+}

Saturation spectroscopic studies were performed in Yb^{3+} or Er^{3+} ions doped in LYB single crystals, in order to determine the characteristic times and other related properties, e.g. spectral diffusion (see left figure) of the studied transitons of theYb^{3+} and Er^{3+} ions [3].

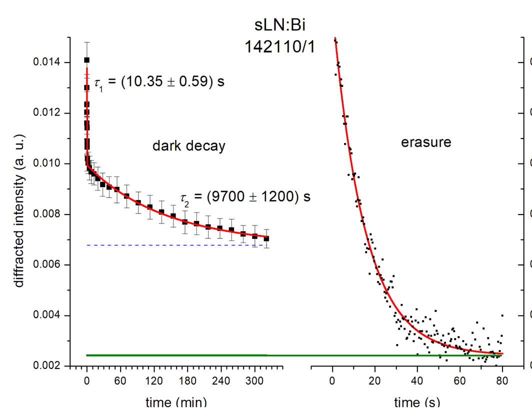


Absorption spectra of the transitions

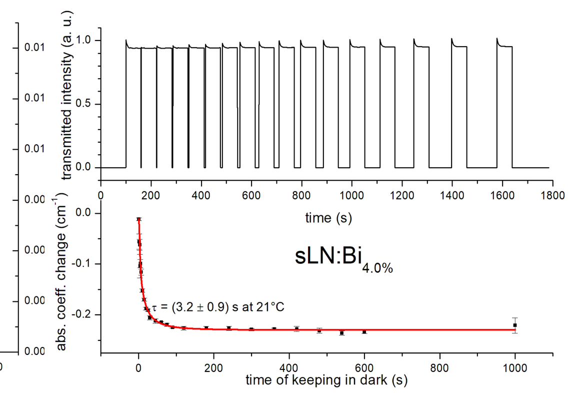
Photorefractive and photochromic effect in stoichiometric $LiNbO_3$:Bi and $LiNbO_3$:Bi,Mg



Saturation of photorefractive diffraction efficiency in LN:$Mg_{2.0\%}$,$Bi_{2.0\%}$ sample



Dark decay and erasure of photorefractive grating in LN:$Bi_{2.0\%}$ sample

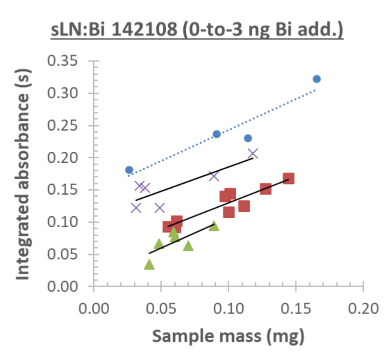


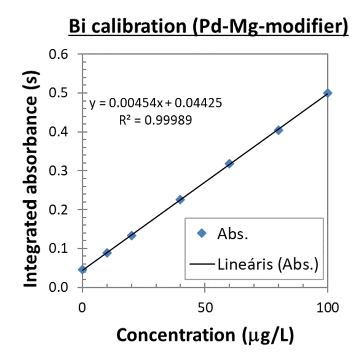
Transient photochromic effect in LN:$Bi_{4.0\%}$ sample

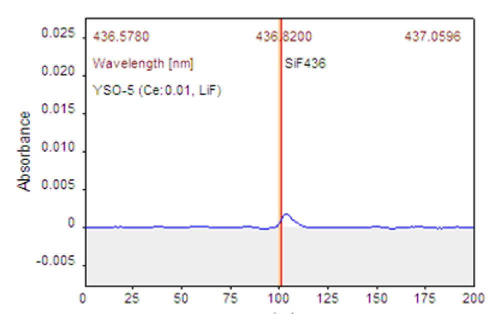
Analytical measurements

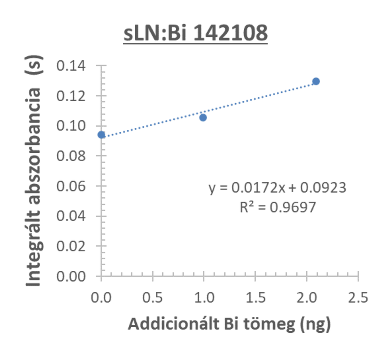
(1) Solid and solution introduction high-resolution continuum source atomic absorption spectrometry (HR-CS-AAS) were developed to quantitate metals in nano and bulk samples of optical lithium niobate (LN) crystals. An example is the quantitation of Bi from LN (Figs. below in right and mid columns).

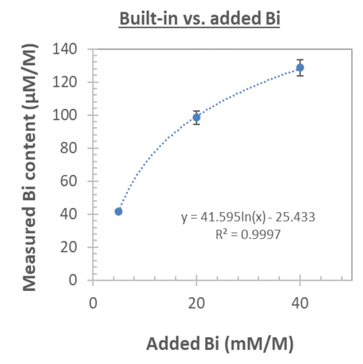
(2) F content of yttrium-orthosilicate (YSO) crystals was studied with HR-CS-AAS using molecular absorption of AlF at 227.47 nm, 227.49 nm, and a SiF band at 436.82 nm (see Figs., left column) [4].

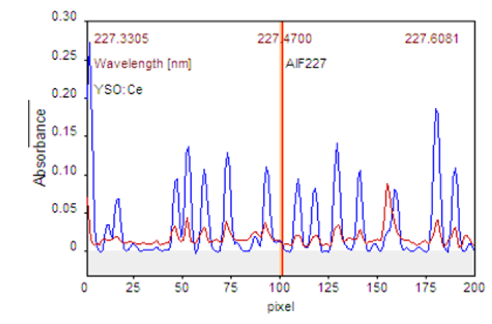












Publications of the group

[1] *Formation of $LiNbO_3$ Nanocrystals Using the Solvothermal Method,* G. Dravecz et. al., Crystals 13:1, 77 (2023) 10.
[2] *Lithium oxide loss of lithium niobate nanocrystals during high-energy ball-milling*, Laura Kocsor et. al., Journal of Alloys and Compounds 909 (2022) 164713.
[3] *Saturation spectroscopic studies on Yb^{3+} and Er^{3+} ions in $Li_6Y(BO_3)_3$ single crystals*, G. Mandula et al., Crystals, 12 (2022) 1151.
[4] *Influence of LiF additive and cerium doping on photoluminescence properties of polycrystalline YSO and LYSO*, N. Laczai et al., Materials Research Bulletin, 133 (2021) 111018.