

Local order around Erbium in ion-exchanged lithium niobate: an EXAFS study

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The exploding demand for Internet access, telecommunications and broadband service has led to a push for a greater lightwave transmission capacity since electrical technologies will not likely be able to comply with the increasing request of high-speed systems. In order to meet that demand, a number of sophisticated optical components are required: as far as device opportunities are concerned, several technologies are therefore contenders for implementation such as bulk-type, fiber-type and planar types devices respectively. As a consequence, an increasing impulse toward the development of new materials for generation, guiding, switching and amplification of light compatible with the planar geometry is constantly given. In this scenario, the combination of excellent electro-optical, acousto-optical and non linear optical properties makes lithium niobate (LiNbO_3) an attractive host material for application in integrated optics. More recently active components were also investigated, and in particular in the last decade the erbium ions has established a key role in the development of optical communication technology in optical signal amplification for the $1.55\mu\text{m}$ telecommunications wavelength.[1-5]

The aim of this proposed experiment is to determinate the local environment of the erbium ions embedded in the matrix. The ion-exchange was obtained by immersing the lithium niobate crystals (both X- and Z-cut) in a molten eutectic solution of Li_2SO_4 , Na_2SO_4 and K_2SO_4 , in the proportion of 70.7, 9.9 and 19.4 wt. %, respectively, with the addition of a small amount of $\text{Er}_2(\text{SO}_4)_3$, from 0.005 to 4.7 wt.%. In Tab.I we report a summary of the preparation conditions considered in the present work.

Sample	heating rate	exchange temperature	exchange time	$\text{Er}_2(\text{SO}_4)_3$ wt%
EU2X	300°C/h	560°C	24 h	4.7 %
EU4X		600°C	7 h	0.1 %
EU4Z		600°C	7 h	0.1 %
EC50Z	100°C/h	645°C	15 h	0.18 %
EC56Z		600°C	40 h	0.18 %
EC58Z		645°C	40 h	0.18 %

Table I. Ion exchange parameters for Er:LiNbO₃ crystals.

EXAFS measurements were performed on the Italian beamline GILDA, with a bending magnet device source. The sagittally focusing monochromator, used in the so-called dynamical focusing mode, was equipped with two Si(311) crystals. The flux on the sample was of the order of $1 \cdot 10^{10}$ photons s^{-1} . Spectra were recorded in fluorescence mode, at liquid nitrogen temperature, at the Er LIII-edge. The signal collection was achieved by a high-purity 13-element Ge detector, keeping the total count rate per single element below $2 \cdot 10^4$ cps, to assure linear response. The samples were also measured in Total Electron Yield (TEY) with a channeltron detector, since in this configuration EXAFS is more sensitive to the surface

(about 100 Å) owing to the short mean free path of electrons. Reference sample of Er_2O_3 was measured at 77 K in transmission mode.

In Fig.1 we compare the Fourier transform moduli at Er L_{III} -edge of the ion-exchanged. The experimental data of the ion-exchanged crystals, superimposed to their relative fit, all show a peak located at about 2 Å corresponding to a coordination with oxygen atoms. In all the samples Er coordinates 7-8 oxygens at a distance varying from 2.32 to 2.36 Å. The Debye-Waller factors are greater to respect the Er_2O_3 one. [6]

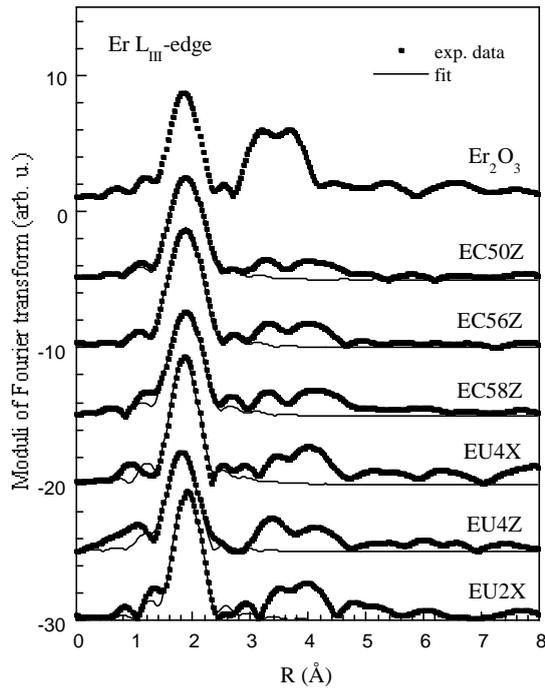


Fig. 1. Moduli of Fourier transform of EXAFS spectra (dots: experimental, solid line: fit), compared with the Er_2O_3 standard at Er L_{III} -edge, spectra are k^3 -weighted, and transformed in the 2-9 Å⁻¹ k-range.

In Fig. 2 we compare the absorption coefficients of EU4X sample observed in the fluorescence and TEY modes. In the insert we present the Fourier transform moduli, together with its relative fit. EXAFS results of the fit are the same of that found in the analysis of fluorescence spectrum.