ESRF	**Experiment title:** Lattice parameter determination of structured Zn:$LiNbO_3$ thin films epitaxially grown on $LiNbO_3$ substrates	**Experiment number**: SI-1518
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Report:

Due to its outstanding optical and electro-optical properties, $LiNbO_3$ is a suitable material to optical waveguide devices (such as modulators and switches) and to second-harmonic generation devices for integrated optical applications (see for example [1, 2, 3, 4]). Optical waveguides demand a well-defined modification of the local refractive index. For this purpose, Zn-doped $LiNbO_3$ thin films with a thickness up to 4 µm were grown on standard x-cut $LiNbO_3$ single crystal substrates by means of the liquid phase epitaxy (LPE) method [5, 6]. Zinc-substituted stoichiometric Zn:$LiNbO_3$ shows an increased refraction index and also an enhanced damage threshold. However, a lattice mismatch of the epitaxial films to the substrate is the consequence of the Zn-substitution. It was assumed and also with the recently taken measurements experimentally verified [7, 8] that this lattice mismatch causes an additional inherent strain in the grown films with influence on the required refraction index.

The aim of the current experiment was to characterize epitaxially grown Zn:$LiNbO_3$ thin films which were subsequently laterally structured (Fig. 1) in view to the generation of optical wave guide strips. These strips were microfabricated by reactive ion etching (RIE) using an inductively coupled plasma (ICP) source [9], recently described ba Ren et a. [10].

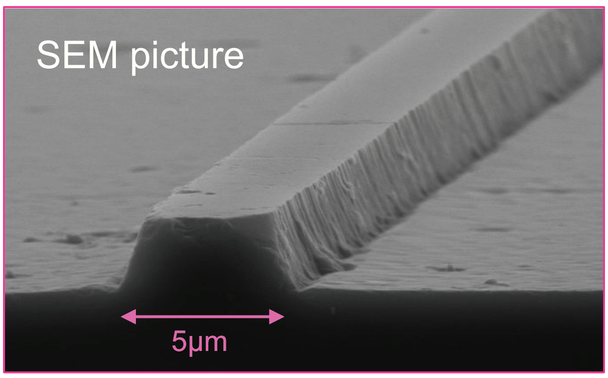

Fig. 1: Zn:$LiNbO_3$ rib waveguide, produced by ICP-RIE etching technique [9]

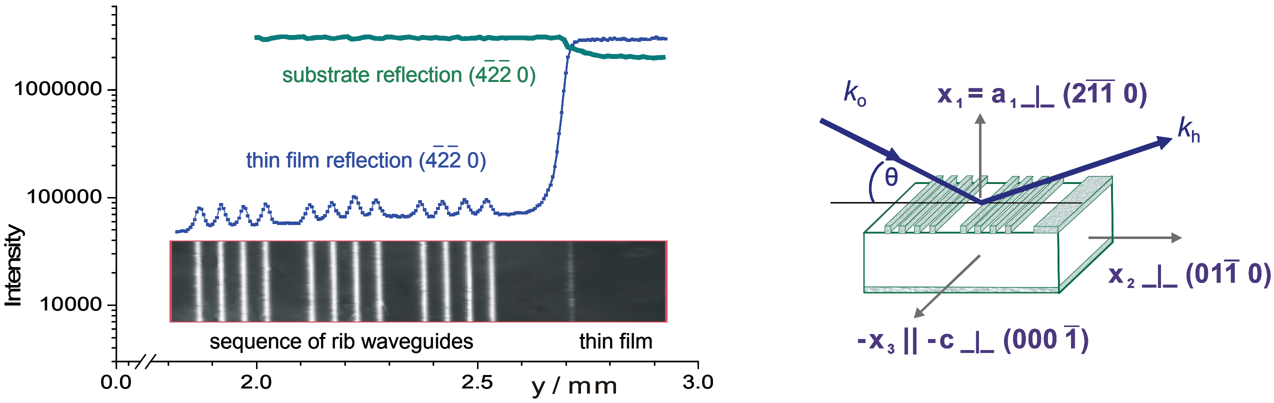

Fig. 2: Lateral y-scan taken with the symmetric 4-2-2 0 thin film and substrate reflection, respectively. A photographic real dimension detail of the sample is shown in the insert. On the left side a sequences of rib waveguides are visible whereas on the right side still the homogeneous thin film is presented .

Using high-resolution x-ray diffraction measurements (HRXRD) with symmetric reflections thin film lattice parameters perpendicular to the sample surface can be won, in reference to the x-cut LiNbO3 substrate with a relative accuracy of $(\Delta d/d)_\perp < 10^{-5}$ (Fig. 2, 3).

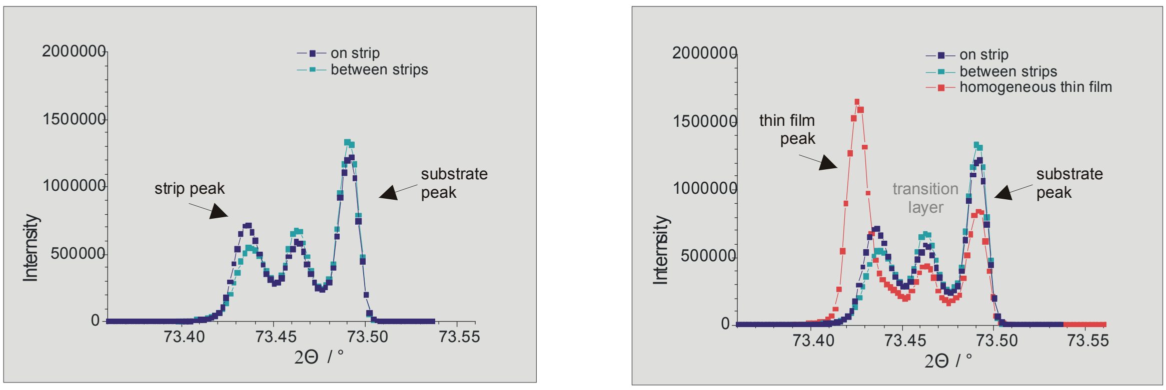

Fig. 3: θ/2θ scan taken up with the symmetric (4-2-2 0)-reflection on and between the ribs, respectively (on the left side), and of the homogeneous thin film to the comparison (on the right side).

For homogeneous Zn:$LiNbO_3$ thin films with a Zn doping of 5.3 mol-% we get a relative lattice parameter increase of $7.8 \cdot 10^{-4}$ perpendicular to the sample surface. Such thin films show an experimentally determined change of refractive index of $\Delta n = 5 \cdot 10^{-3}$ [11].

In plane lattice parameters of the epitaxially grown Zn:$LiNbO_3$ thin films in respect to the substrate can be won from **r**eciprocal **s**pace **m**aps (**rsm**) recorded with asymmetric reflections [8]. In this case one obtains a precision of $(\Delta d/d)_{||} < 10^{-4}$ (Fig. 4). It is seen, that the in Zn:$LiNbO_3$ thin films grow pseudomorphously on the x-cut $LiNbO_3$ substrate, characterized by the fact that $\Delta d|| = 0$ but $\Delta d\perp \neq 0$ (Fig. 4 top right). Hence, the homogeneous Zn:$LiNbO_3$ thin films are laterally stressed. However after structuring, the waveguide strips appear laterally relaxed related to the homogenous thin film, how is to be seen in the rsm recorded in ´on-a-strip-position´ (Fig. 4 top left). In this case the lateral and normal change of lattice parameter related to the homogenous thin film are the same.

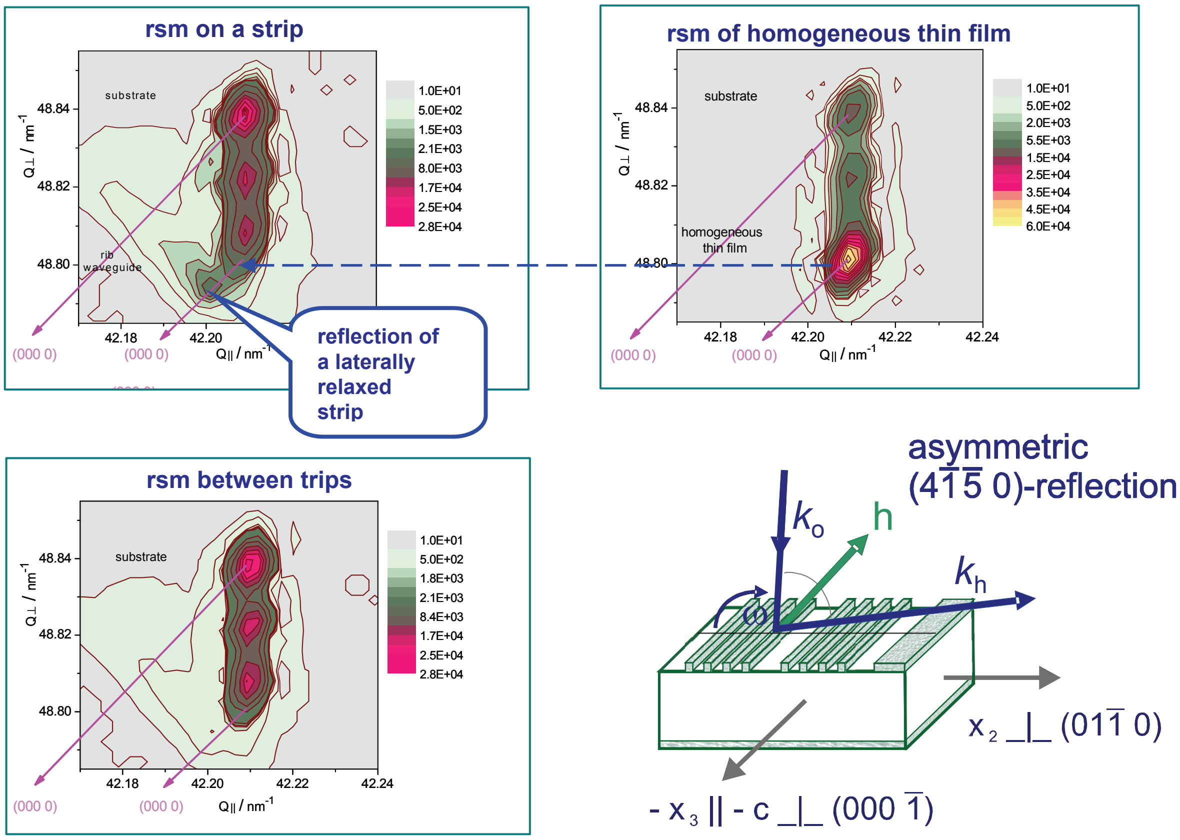

Fig. 4: Reciprocal space maps recorded with the asymmetric (4-1-5 0)-reflection on (top left) and between (down left) the strips, respectively, and of the homogeneous thin film to the comparison (top right).

Using the lattice parameters obtained from these rsm, it is now possible to calculate the inherent normal and lateral stress components [8] of the epitaxially grown homogeneous Zn:$LiNbO_3$ thin films and of the waveguide strips prepared from it.

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