Perturbational estimation of sidewall-roughness induced losses in thin-film lithium niobate channel waveguides

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Given a few measurements of losses attributed to sidewall-roughness in TFLN / LNOI rib and strip waveguides, attenuation levels for waveguides of the same class, but with different cross section geometry, can be predicted reliably through a simple perturbational procedure.

TFLN / LNOI channel waveguides

Photonic circuitry based on thin-film lithium niobate (TFLN) or lithium niobate on insulator (LNOI) finds applications in current fields of quantum optics such as the processing of single photon states, where low propagation losses are of particular relevance. Common fabrication procedures lead to waveguides, where the losses can be attributed predominantly to the roughness of dielectric interfaces. With their slanted sidewalls, anisotropic core, and inhomogeneous layered exterior, the few established rigorous scattering models are not applicable to typical TFLN channels.

Perturbational loss estimates

As a pragmatic approach towards predicting loss levels, the surface roughness is modelled by thin layers at the waveguide sidewalls with a small imaginary contribution to the local permittivity [1]. Perturbational integrals then serve to calculate the effect of that layer on the modal attenuation. The expressions are consistent with the losses being driven by the squared local relative electric field. As shown in Fig. 1, our model can accurately estimate the change of the attenuation with the waveguide geometry, based on merely a single fit parameter [2]. Given a particular manufacturing process, respective data will be highly relevant for the the design of optimized photonic TFLN-based circuits.

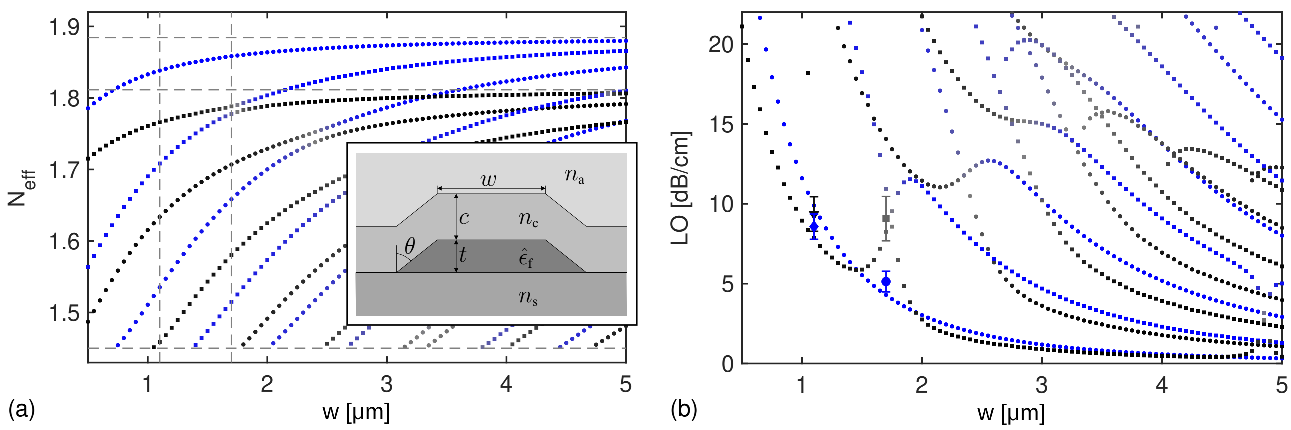

***Figure 1**: LNOI strip waveguides in X-cut, Y-propagation configuration with cross sections as shown in the inset, effective indices N_{eff} (a) and modal loss LO (b) as a function of waveguide top width w. Parameters: $t = 450$ nm, $c = 600$ nm, $\theta = 56°$, $n_s = n_c = 1.45$, $n_a = 1$, birefringent core with ordinary and extraordinary refractive indices $n_o = 2.1836$, $n_e = 2.1220$ at wavelength $\lambda = 1.55\,\mu$m. Bold markers show the measured loss data. Colors indicate the polarization, blue: TE-like, black: TM-like, gray: intermediate. Basis: rigorous finite-element calculations (JCMwave).*

References

[1] S. M. Lindecrantz, O. G. Hellesø. *IEEE Photonics Technology Letters*, 26(18):1836–1839, 2014.

[2] M. Hammer, S. Babel, H. Farheen, L. Padberg, J. C. Scheytt, C. Silberhorn, J. Förstner. Estimation of losses caused by sidewall roughness in thin-film lithium niobate rib and strip waveguides (submitted, 2024).