

# Polarisation Modulation in Cryogenic Lithium Niobate Waveguides

Frederik Thiele<sup>1</sup>, Jan Philipp Höpker<sup>1</sup>, Patrick Bartowiak<sup>1</sup>, Felix vom Bruch<sup>1</sup>, Harald Herrmann<sup>1</sup>, Raimund Ricken<sup>1</sup>, Viktor Quiring<sup>1</sup>, Christine Silberhorn<sup>1</sup>, and Tim Bartley<sup>1</sup>

<sup>1</sup> Universität Paderborn, Warburger Straße 100, 33098 Paderborn, Germany

## Abstract

We report on the theory and first results of a polarisation modulator in lithium niobate at cryogenic temperatures. In particular, we demonstrate switching contrasts over 90% at a temperature of 0.9 K, using a fibre-pigtailed plug-and-play device.

Lithium niobate is an important platform for integrated quantum optics given its high second-order nonlinearity and electro-optic properties [1]. Superconducting detectors and other quantum optic devices are operated at cryogenic temperatures [2]. It is therefore advantageous to develop optical components [3],[4] that are functional under these conditions.

In this work a polarisation modulator with periodically-poled titanium in-diffused lithium niobate waveguides was realised. The wavelength for polarisation switching is determined by the quasi-phases-matching of the periodically poled lithium niobate waveguide. The phases-matching wavelength is dependent on the birefringence, which in turn depends on temperature. At room temperature the polarisation modulator operated with a phases-matching wavelength of 1470 nm and at a temperature of 0.9 K with a phases-matching wavelength of 1580 nm. The behaviour of the birefringence and the related phases-matching wavelength was previously estimated by extrapolating the refractive index [5], however we see significant deviations from this extrapolation. To successfully characterise the device at 0.9 K, the modulator was pigtailed with single mode fibres. We achieved spatial mode overlap of up to 75% at room temperature and 55% at cryogenic temperatures, compared to theoretical maximum of 93%.

We characterised the switching behaviour of the polarisation modulator at different wavelengths around the phases-matching wavelength at 0.9 K. The switching of a modulator was determined by the input of a TE-polarised beam into the modulator and changing the bias voltage of the electrodes of the waveguides. The contrast was then determined by the minimum and maximum for every wavelength in the TE-channel behind a polarising beam splitter. Contrasts of over 92% were achieved at cryogenic temperatures.

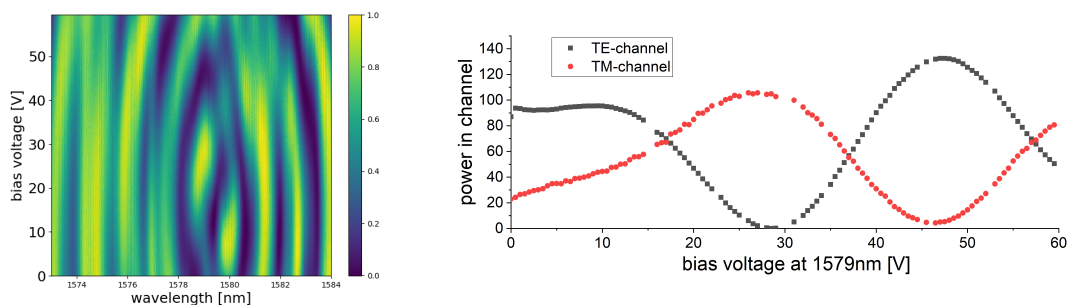


Figure 1: bias voltage vs. wavelength. Around the phases-matching wavelength was the bias voltage varied. The input light was TE-polarised and the output channel of the TE-polarisation of the PBS was acquired.

- [1] P. Sharapova et.al., *Toolbox for the design of LiNbO<sub>3</sub>-based passive and active integrated quantum circuits*, New Journal of Physics **19**, 123009 (2017).
- [2] M. Migdall et.al., *Single Photon Generation and Detection*, Elsevier 45 (2013).
- [3] N. Montaut et.al., *High efficiency ‘plug & play’ source of heralded single photons*, Phys. Rev. Applied, **8** 024021 (2017).
- [4] C. Y. Huang et.al., *Electro-optic Ti:PPLN waveguide as efficient optical wavelength filter and polarization mode converter*, Optics Express **15** 5 (2007).
- [5] S.C. Abrahams et.al., *Properties of lithium niobate*, The Institution of Electrical Engineers (1989).