Polarisation Modulation in Cryogenic Lithium Niobate Waveguides

Frederik Thiele¹, Jan Philipp Höpker¹, Patrick Bartowiak¹, Felix vom Bruch¹, Harald Herrmann¹, Raimund Ricken¹, Viktor Quiring¹, Christine Silberhorn¹, and Tim Bartley¹

¹ 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-phasematching of the periodically poled lithium niobate waveguide. The phasematching wavelength is dependent on the birefringence, which in turn depends on temperature. At room temperature the polarisation modulator operated with a phasematching wavelength of 1470 nm and at a temperature of 0.9 K with a phasematching wavelength of 1580 nm.

The behaviour of the birefringence and the related phasematching 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 phasematching 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 phasematching 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.