Ion-exchanged Waveguides in Periodically Poled Rb-doped KTiOPO₄ for Efficient Second Harmonic Generation

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Introduction
Waveguides offer a high level of robustness, stability and compactness compared to traditional optical setups. Furthermore, they enable integration of optical components. Bulk Rb-doped KTiOPO₄ (RKTP), due to its decreased ionic conductivity compared to ordinary flux grown KTP, is a superior material for periodic poling and enables quasi-phase matching structures with very short periods. However, in contrast to conventional grown KTP, ion exchanged waveguides present a low refractive index contrast between the waveguide region and the substrate. This is attributed to the fact that RKTP already contains a small amount of Rb, which partially blocks diffusion and slows down the ion-exchange. The ion exchange process can be accelerated by adding Ba²⁺ ions into the exchange melt which creates additional vacancies available for the Rb⁺ ions and hence should result in higher refractive index contrast. However, it has been observed that the addition of Ba²⁺ into the melt sometimes causes domain reversal during the ion exchange.

Fabrication
Goal: develop a process where the refractive index and the QPM structure can be engineered independently.
Our approach: periodic poling, followed by ion exchange with Rb⁺ and Ba⁺ in order to form waveguides.
Question: is the PP structure stable and maintained during the ion exchange.

Ion exchange and domain stability
Experiment: 1. Selective etching after periodic poling. 2. Ion exchange with different recipes. 3. Selective etching again in order to observe changes in domain structure.
Note: Some crystals were subjected only to temperature treatment in order to determine whether domain instability is a purely thermal process.
Domain stability: We did not observe any domain reversal caused by the ion exchange itself. However, some domains that had not propagated through the entire crystal appeared to be unstable during the heat treatment and merged into larger domains. This behavior was observed regardless of the melt composition, and even if the samples were only exposed to a high temperature treatment without the ion exchange process. Consequently, the domain alterations are solely attributed to the thermal stability of the RKTP domain walls. Therefore, high quality domain gratings are necessary for efficient waveguide fabrication.

Second Harmonic Generation (SHG) experiments
Substrate: PPRKTP with straight domain walls
Ion exchange: 20% KNO₃, 75%, RbNO₃, 5% Ba(NO₃)₂ for 2h at 340 °C
Waveguide width: 8 μm
Waveguide length: 10.9 mm
Poling period: 5.82 μm
Phase-matching wavelength: 939.7 nm
Normalized conversion efficiency: 119 %
Loss: 0.51 cm⁻¹ @ 940 nm

Conclusion and outlook
In conclusion, we have fabricated channel waveguides in periodically poled RKTP and used them for efficient SHG with a normalized conversion efficiency of 119 %/Wcm². Waveguides in RKTP open the possibility for stable operation at high optical powers and enable the investigation of novel nonlinear processes such as counter-propagating interactions in a waveguide format. Moreover, we have investigated the domain stability of RKTP during ion exchange and concluded that it was the heat treatment, rather than the ion-diffusion process, that could alter the domain structure. In the future, we plan to fabricate longer waveguides up to a length of 30 mm.