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Novel coercive field engineering technique for improved periodic poling of $KTiOPO_4$ isomorphs

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Coercive field engineering of periodically poled $KTiOPO_4$ (PPKTP) for quasi-phase matching (QPM) applications has successfully been done with Rb^+-ion indiffusion (Rb-exchange) in $KTiOPO_4$ (KTP) isomorphs [1]. To date, Rb-exchange is the only viable technique for periodic poling of bulk QPM structures with sub-µm periodicities in KTP [2]. Rb-exchange is also used to form waveguides in KTP isomorphs as it creates a refractive index increase in the exchanged layer [3]. However, for bulk QPM applications this feature is undesirable since it induces a shift in the phase-matching wavelength, which may cause unwanted spectral broadening of the generated light. Due to the large Rb^+-ion there is also a significant stress imposed in the crystal, which results in a higher fragility and lower PPKTP yield. Until now, barium has been used as an addition to the Rb-exchange recipe to increase the depth of the Rb^+ indiffusion [4]. Here we show the use of standalone Ba^{2+}-ion indiffusion as an effective method for coercive field engineering for creating short period PPKTP for QPM applications, which avoids the introduction of stress and the unwanted phase-matching wavelength shift. With this method we have poled 3.77 µm periods in flux grown KTP and Rb-doped KTP (RKTP) with record high second harmonic generation (SHG) efficiencies of 2 %/Wcm and 3.4 %/Wcm, respectively.

Similarly to Rb-exchange, Ba-exchange involves photolithographic patterning of the polar surface of the KTP crystal. A stop layer for ion-exchange is created on the crystal by O_2 plasma etching, and it is subsequently submerged for 4 hours into an exchange melt consisting of 7 At. % $Ba(NO_3)_2$ and 93 At. % KNO_3, which is kept at 375°C for the exchange duration. The crystal is then poled with 5 ms triangular voltage pulses. Figure 1(a) shows an example of how multiple voltage pulses can be used for poling a Ba-exchanged crystal, while measuring the SHG output after each pulse. The same crystal is poled with multiple pulses and then poled back to single domain in three cycles during the measurement. The results show no degradation in SHG output when re-poling the crystal in the second and third cycles. The demonstrated poling method together with possibilities for re-poling samples is useful for increasing both the quality and the yield of PPKTP.

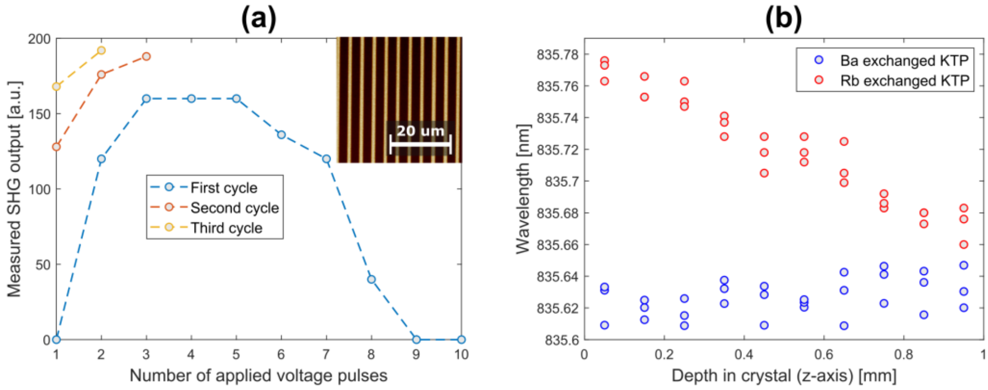

Fig. 1 (a) The measured SHG output when successive 6 kV 5 ms triangular pulses are used for poling a periodically Ba-exchanged RKTP crystal. After the first cycle the crystal is poled back to the original polarisation and the second cycle is measured, similarly the third. The inset shows a PFM image of the poled structure. (b) SHG wavelength variation as a function of the depth in Rb- and Ba-exchanged KTP crystals, where z=0 is the exchanged surface.

Figure 1(b) shows the SHG wavelength shift in KTP crystals poled using Rb- and Ba-exchange. For Rb-exchange there is a 0.1 nm wavelength shift across the thickness of the crystal, which is not seen for the Ba-exchange. These results show that Ba-exchange is more suitable than Rb-exchange in experiments where the full aperture is needed, i.e., for high power frequency conversion, where a large diameter beam is required in the PPKTP. The technique may also be used in conjunction with, or complementary to Rb-exchange, for further development of sub-µm QPM structures for applications such as slow-light [5], ultra-bright biphotons [6], or squeezed-states generation [7].

References

[1] C. Liljestrand, F. Laurell, and C. Canalias, "Periodic poling of Rb-doped $KTiOPO_4$ by coercive field engineering", Opt. Express **24**, 14682-9 (2016).
[2] A. Zukauskas, A.-L. Viotti, C. Liljestrand, V. Pasiskevicius, and C. Canalias", Cascaded counter-propagating nonlinear interactions in highly-efficient sub-µm periodically poled crystals," Scientific Reports, **7**, 8037 (2017).
[3] P. Mutter, C. C. Kores, M. Widarsson, A. Zukauskas, F. Laurell, and C. Canalias**,** "Ion-exchanged waveguides in periodically poled Rb-doped $KTiOPO_4$ for efficient second harmonic generation", Opt. Express **28** (2020).
[4] K. Daneshvar, E. A. Giess, D. Kang, J. R. Williams, and D. Dawes, " Rb ion-exchange profile in potassium titanyl phosphate (KTP)", Opt. Mat. **12**, 453-457 (1999).
[5] J. B. Khurgin, "Slowing and stopping photons using backward frequency conversion in quasi-phase-matched waveguides," Phys. Rev. A **72**, 1–5 (2005).
[6] C. Chuu, and S. E. Harris, "Ultrabright backward-wave biphoton source," Phys. Rev. A **83**, 061803(R) (2011).
[7] L.-A. Wu, M. Xiao, and H. J. Kimble, "Squeezed states of light from an optical parametric oscillator", J. Opt. Soc. Am. B **4**, 1465 (1987).