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Backswitch poling of 0.5-mm-thick lithium niobate for 6.4%/W-efficient cw second harmonic generation of 460 nm light

Robert G. Batchko, Martin M. Fejer, Robert L. Byer
Ginzton Laboratory, Stanford University, Stanford, CA 94305-4085

V. Ya. Shur
Institute of Physics and Applied Mathematics,
Ural State University, Ekaterinburg 620083, Russia

Levent Erman
Coherent®, Laser Group, 5100 Patrick Henry Dr., Santa Clara, CA 95054

Abstract

We report a periodic poling technique, utilizing controlled domain flip-back, for high-fidelity patterning of ferroelectric materials. 6.4%/W-efficient cw second harmonic generation of 38 mW at 460 nm is demonstrated in 4- μ m-period, 50-mm-length, 0.5-mm-thick periodically-poled lithium niobate.

Key Words

Nonlinear optics, devices; Nonlinear optical materials; Lithium niobate; Frequency conversion

In nonlinear optics applications employing quasi-phasematching (QPM), short pitch domain gratings are generally required for the generation of visible and ultraviolet light. In lithium niobate, domain periods smaller than 6 microns are generally useful for first order QPM generation of green, blue and ultraviolet wavelengths.¹ While conventional electric-field poling techniques are well established for the fabrication of long pitch periodically-poled lithium niobate (PPLN)², these methods have been limited in achieving uniform domains with QPM periods under 6 microns in 0.5-mm-thick commercial grade substrates. We introduce an enhanced electric-field poling technique that incorporates spontaneous backswitching as the means for achieving increased domain pattern resolution and yield in 0.5-mm-thick lithium niobate substrates.

In backswitch poling, the sample is lithographically patterned with stripe electrodes overcoated with an insulator, similar to conventional poling methods.² The sample is then forward poled in the common fashion using liquid electrolyte for electrical contact with the patterned electrodes and unpatterned surface, and a high

voltage source for providing the external field necessary to nucleate and grow domains. A typical voltage waveform is shown in Figure 1a. During this forward stage, poling is allowed to continue through to completion. Forward poling is completed when the domains have spread beneath the insulator and generally merged in the bulk. As soon as forward poling has reached completion, the external field is removed. In this fashion, the external field is removed before the depolarization field has been screened by bulk and external charges. Therefore, the depolarization field, having switched sign due to the process of forward domain inversion, is momentarily large enough to cause the erasure, or backswitching, of the forward switched domains. Depending on the speed of the screening processes, backswitching can continue until the domains have returned to the original state. However, as shown in Figure 1b, backswitching can be terminated by re-applying the external voltage. The ability to selectively enable and terminate backswitching allows for the formation of domain patterns with small feature sizes and high uniformity through large volumes of material.

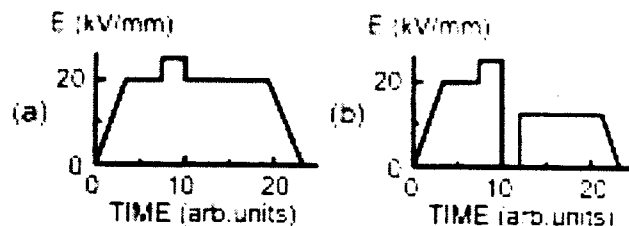


Figure 1. (a) Conventional poling voltage waveform; and (b) backswitch poling.

To demonstrate backswitch poling, we patterned 3-inch-diameter, 0.5-mm-thick lithium niobate wafers with 4- μ m-period, 0.5- μ m-wide NiCr electrodes on the +z face. The wafers were forward poled for 145 ms and then

allowed to backswitch for 39.2 ms. The wafers were etched in hydrofluoric acid in order to reveal the domain structures. Figure 2a,b shows y face and -z face views of the domains. Samples up to 50 mm in length were taken from the backswitched wafers.

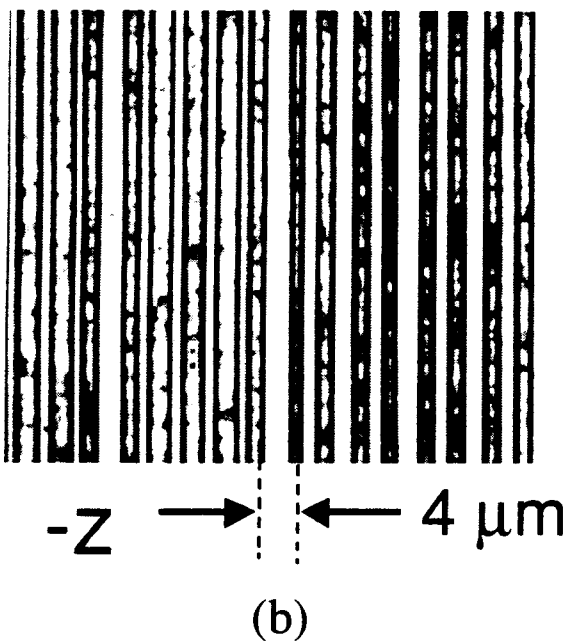
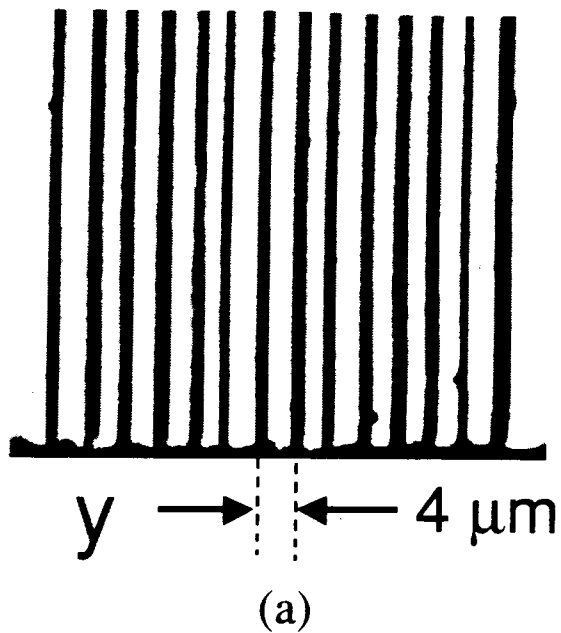


Figure 2. Images of backswitch-poled 4- μ m-period domains in 0.5-mm-thick PPLN: (a) y face, and (b) -z face. Uniform domains were formed throughout 3-inch-diameter wafers, yielding devices up to 50 mm long.

To characterize the backswitched PPLN samples for nonlinear conversion efficiency, we chose single-pass

frequency doubling of a 1 W cw Ti:S pump laser operating at 920 nm. An uncoated 50-mm-long sample was heated to ~ 220 °C and the pump beam was near-confocally focused to a 44 μ m waist radius in the center of the crystal. With 766 mW of pump power internal to the PPLN, 38 mW of 460 nm light was generated internally. This corresponds to 4.9 % conversion of the pump radiation, or 6.4 %/W conversion efficiency. A temperature tuning curve for the sample is shown in Figure 3.

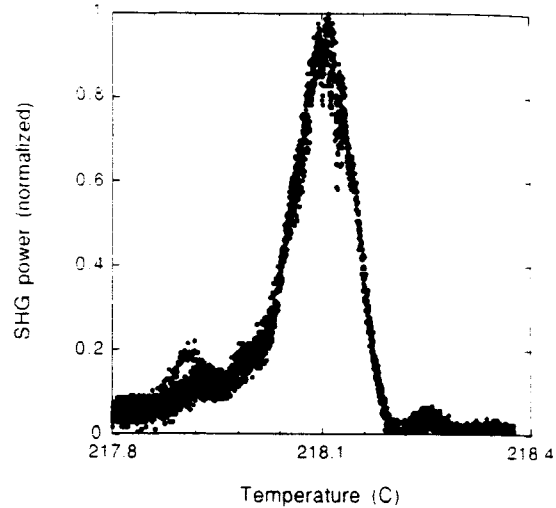


Figure 3. Temperature tuning curve for SHG of 460 nm light in backswitch poled PPLN. The pump source was a 1 W cw single frequency Ti:S laser and was tightly focused to a 44 μ m waist radius in the 50-mm-long PPLN. With 766 mW of internal pump power, 38 mW of 460 nm light was generated internally.

Acknowledgements

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