Harmonic generation of blue light in backswitch-polled lithium niobate

Robert L. Batchko, Martin M. Fejer, Robert L. Byer, Vladimir Y. Shur,*
William S. Capinski, ** E. L. Gitzen Laboratory, Stanford University, Stanford,
California 94305-4085 USA; E-mail: rgi@oki.stanford.edu

Second harmonic generation (SHG) of mode-locked near-infrared lasers is useful, both as a source of visible ultrashort pulses, and as a means for increasing single-pass conversion efficiency. While LBO has proven to be efficient for SHG of femtosecond Ti:S lasers, crystals of sufficient length for picosecond applications are not available. Hence, alternative materials are of interest. Previously, 0.3-mm-thick samples of periodically-poled lithium niobate (PPLN) produced 52%-efficient SHG of green light when pumped by cw-mode-locked picosecond pulses. Recently, we reported on backswitch-poling, an electric-field poling technique for ferroelectrics which utilizes spontaneous flip-back for obtaining domain patterning with high resolution and high yield. Here we demonstrate cw-mode-locked second harmonic generation of blue light in 0.5-mm-thick backswitched PPLN.

We backswitch-poled 4-μm-period gratings in 76-mm-diameter 0.5-mm-thick congruent Z-cut LiNbO₃ wafer substrates. PPLN samples, ranging in length from 0.5 mm to 50 mm, were obtained from these wafers. Using a cw-mode-locked Ti:S pump laser, uncoated PPLN samples were characterized for single-pass SHG efficiency. The laser had a 76.32 MHz repetition rate, 1.65 ps pulsewidth and 0.8 nm bandwidth. The pump beam was tuned to 926.5 nm and focused to a 36 μm 1/e² waist radius inside the samples. The samples were heated to 270°C in order to achieve SHG of the IR pump beam and prevent photorefractive damage. Figures 1(a) and 1(b) show plots of 463 nm SHG conversion efficiency and blue internal average power vs. internal average IR power for 0.5-mm-length and 12-mm-length PPLN samples, respectively.

Conversion efficiencies of 43% and 59% were achieved from the 0.5-mm and 12-mm length samples, respectively. Blue internal average powers of 420 mW and 471 mW were reached in the 0.5-mm and 12-mm length samples, respectively. The 0.5-mm-length sample was approximately 0.4 walk-off lengths in the pump. The SHG efficiency data from the 0.5-mm-length sample corresponds to an effective nonlinear coefficient dₑ = 20 pm/V, in agreement with the ideal value.

SHG conversion efficiency was limited to 59%, presumably by thermal effects due to absorbed optical power. To elucidate the absorption mechanisms, we characterized two-photon absorption at 463 nm by separating the IR pump beam from the SHG output, and focusing the blue beam to a 6.2 μm waist. The power transmitted through a 0.5-mm-length PPLN test sample was measured as the sample was translated along the focused blue beam. From this z-scan taken at 177 mW average internal blue power in the test sample, we estimate the two-photon absorption coefficient as 3 × 10⁻⁶ cm/W.

The use of multi-grating PPLN devices, with periods around 4 μm, would enable efficient frequency doubling across the tuning range of picosecond Ti:S oscillators. Achieving even higher blue powers by optimizing the conversion efficiency in the presence of linear and nonlinear absorption, and comparison with alternative QPM materials such as lithium tantalate, which is expected to have a lower two-photon absorption coefficient, will be discussed.

*Institute of Physics and Applied Mathematics, Ural State University, Ekaterinburg 620083, Russia; E-mail: vladimir.shur@usu.ru
**Coherent®, Laser Group, 5100 Patrick Henry Drive, Santa Clara, California 95054 USA; E-mail: bill_capinski@coher.com

CThB2 Fig. 1. Conversion efficiency and internal average power at 463 nm SHG vs. internal average IR power for: a) 0.5-mm-length, and b) 12-mm-length PPLN samples.

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Single pass blue light generation in bulk periodically poled LiTaO₃ with a passively mode-locked Nd:YAlO₃ laser at 930 nm

T. Kellner, G. Huber, J.P. Meyn,* R. Wallenstein, * C. Hönninger,** F. Morier-Genoud,*** U. Keller,** Institut für Laser-Physik, Universität Hamburg, Jungfernstieg 9a, 20355 Hamburg, Germany; E-mail: kellner@physnet.uni-hamburg.de

Single pass frequency conversion in nonlinear optical crystals with a large nonlinear coefficient is a simple method to enlarge the spectral region already covered with all-solid-state laser sources into the visible spectral region. Periodically poled ferroelectric materials like LiNbO₃, KTiOPO₄ and LiTaO₃ were widely investigated in the last years. These nonlinear crystals exhibit a large nonlinearity and can be periodically poled with grating periods sufficient for green and blue light frequency generation. We investigated the single pass second harmonic generation of a passively mode-locked Nd:YAlO₃ laser operating at λ = 930 nm in a bulk periodically poled LiTaO₃ (PPLT) crystal. The Nd:YAlO₃ laser was passively mode-locked with a semiconductor saturable absorber mirror (SESAM) in a V-shaped cavity. A schematic picture of the experimental set-up is shown in Fig. 1.

The plane-brewster Nd:YAlO₃ laser crystal was pumped with a laser diode module at λ = 804 nm. The mirrors M1–M5 were high reflection coated at the laser wavelength and high transmitting at λ = 1.08 μm to avoid laser oscillation at this four level laser transition in Nd:YAlO₃. The transmission of the output coupling mirror M₅ was 73%. Details of the SESAM used in our experiments are described elsewhere. The design of the cavity was chosen to achieve passive mode-locking according to the theory of passively mode-locked laser with SESAMs. The passively mode-locked laser exhibited large Q-switched amplitude modulations of 40–60%. We have shown that these modulations can be avoided by introducing negative GDD in the cavity to obtain soliton formation. The pulse widths of the mode-locked laser pulses were measured to be in the range of ΔTwave = 7 ps–12 ps. The fundamental output power of the mode-locked Nd:YAlO₃ laser was 440 mW at an incident pump power of

CThB3 Fig. 1. Experimental set-up, LDM laser diode module, L1 = 14.3 cm, L2 = 174 cm, L3 = 15.7 cm, L4 = 12.9 cm, L5 = 42 cm, LC: Nd:YAlO₃ laser crystal, OD: optical diode, PM: power meter.