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Nonlinear properties of RTP for second harmonic generation at 1030nm

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Abstract: We demonstrate that around 1030 nm, RbTiOPO4 (RTP) realizes the second harmonic generation of Yb-doped lasers in non-critically phase-matched configuration at ambient temperature, with efficiencies comparable to LBO and wide thermal acceptance.

Frequency doubled lasers are widely used in today's industry, from micromachining to solid state pumping or spectrometry applications. While it is a nonlinear process fully mastered today, with conversion efficiencies routinely reaching more than 60%, it is still a technique sensitive to many outside parameters such as angular misalignments or temperature operation. In order to increase the robustness of a frequency conversion scheme, one needs to reduce the dephasing between the fundamental and the second harmonic cause by either an angle misalignment (angular sensitivity) or a temperature change (thermal sensitivity).

$RbTiOPO_4$ (RTP) is an isomorph of KTP, used mainly for high repetition rate electro-optic modulators [1]. Since its discovery, its optical and nonlinear properties have been widely studied : among them, one very interesting feature is its large thermal acceptance centered at 100°C for SHG at 1064 nm [2], and simultaneous temperature non-sensitive and angular non-critical SHG at 1030 nm at room-temperature [3]. In addition to its non-linear properties comparable to KTP, it should be a good candidate for highly stable, frequency doubled lasers.

The refractive indexes of RTP have been precisely characterized in previous works [3], and show that type-II non-critical phase matching (NCPM) at room temperature is possible in the y-z plane for a wavelength around 1030 nm. Its d_{eff} in this direction has been previously determined to be d_{eff} = 2.04 pm/V [4]. Usually with standard frequency doubling crystals, the NCPM wavelength can be adjusted with temperature: as an example, the NCPM wavelength of the well-known LBO crystal can easily tuned from 1 µm to 1.25 µm by adjusting the operating temperature from 200°C to -20 °C [5]. For RTP crystals, this is a bit more complicated: as RTP shows very wide thermal acceptance, the NCPM wavelength cannot be tuned with temperature. Thus, in RTP, the laser wavelength needs to be tuned to be exactly at (or slightly above) the NCPM wavelength. To verify the NCPM wavelength of RTP at room temperature, we first used a broadband fluorescence source based on Amplified Spontaneous Emission (ASE) from an Yb-doped fiber amplifier that delivered an output of 5 W at 30 kHz with pulse width of 15ns with a spectrum ranging from 1020 to 1045 nm. This source was focused in the RTP crystal and the green output was monitored with a spectrometer that had a resolution of 0.2 nm (See Figure 1).

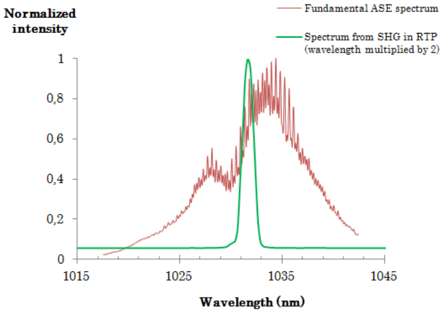

Figure 1: Frequency doubled wavelength by YZ-cut RTP at room temperature and normal incidence

The random distribution of the ASE power and the low resolution of our spectrometer can't give an exact value of the SHG efficiency or the exact phase matching wavelength, but it is enough to know at what wavelength the fundamental laser should be tuned. The green spectrum was centered on 1031.6 nm.

Having the accurate NCPM wavelength for SHG in RTP, the frequency doubling experimental setup is very straightforward, and is detailed in Figure 2. The fundamental laser is a Master Oscillator Power Amplifier (MOPA) [6] emitting at a wavelength centered at 1031,6 nm by tuning the seed diode wavelength. It emits 4W of average power at a repetition rate of 30 kHz, with pulse width of 15 ns and a diffraction-limited beam profile ($M^2<1.1$). The output spectral linewidth is Fourier-transform limited ($\Delta\nu$=40MHz). Then the laser is focused into the nonlinear crystal at a focal spot size of 120 µm.

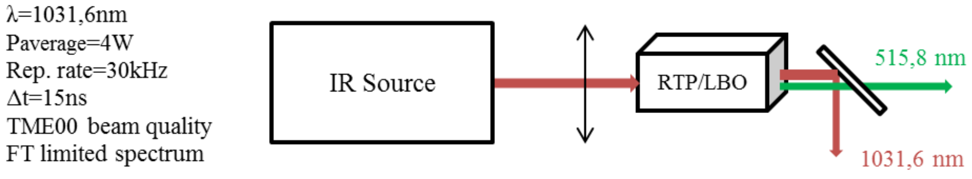

Figure 2: Experimental setup

The nonlinear crystal is a Y-cut RTP of dimensions 4x4x10mm. It is AR coated for 1030 and 515 nm. The AR coatings on the RTP crystal had an unsually low damage threshold so loose focusing had to be used. To show the advantage of a large thermal acceptance, no thermal regulation system is implemented. The performances of the RTP crystal is compared with a 3x3x20 mm3 LBO cut for Type-I SHG at 1030nm, with AR coatings at 1030 and 515 nm, and operated in NCPM configuration at 188°C. As shown in Figure 3, in the same focusing conditions both crystals yield comparable results: we obtained 1.4W of green average power with LBO and 1.35W with the RTP crystal.
At the highest pump power we were very close of the damage threshold of the RTP AR coating (evaluated at about 2.5 J/cm^2), so we lowered the output green power to about 1.2 W. After operating the RTP for 1h, no grey-tracking damages were observed and the output power was very stable with calculated RMS fluctuations of 2%. (Figure 4)

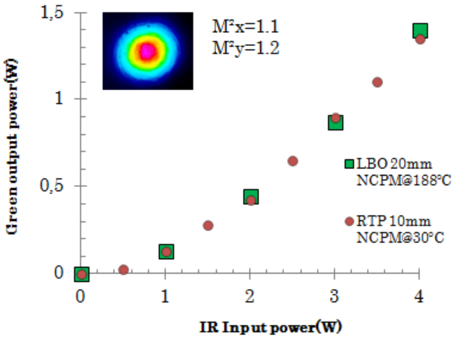

Figure 3: Output green average power with LBO (green squares) and RTP (red circles). Inset beam profile and measured beam quality with RTP

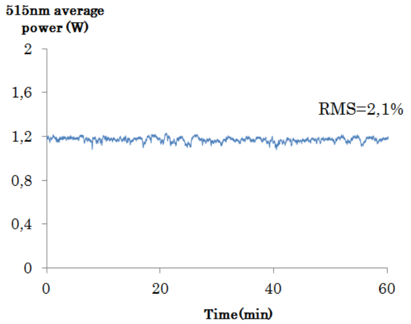

Figure 4: 515nm output stability

We then characterized the two interesting properties of SHG in the RTP crystal, namely the NCPM behavior and wide thermal acceptance. Inset in Fig.2a is the angular acceptance measurement, done by detuning the crystal until significant power drop was observed.

An acceptance angle of about 300 mrad was measured, showing the NCPM behavior (by comparison, the angular tolerance for a standard KTP in critical phase matching and with the same length is about 8 mrad) (See Figure 5).

The thermal acceptance was measured by heating the crystal from 20 to 90°C: the power dropped to half of its initial value when the temperature was raised by 60°C, leading to an estimated thermal acceptance of 120°C. (Fig 6) A more detailed characterization of the thermal acceptance can be found in [3].

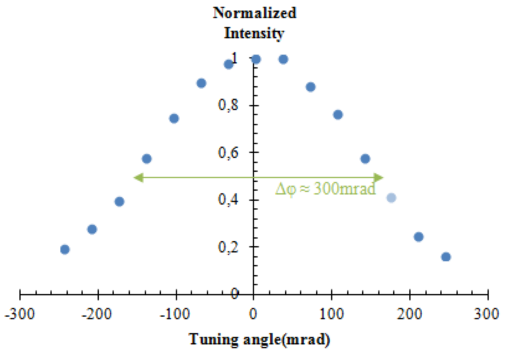

Figure 5: Angular acceptance of SHG in RTP crystal

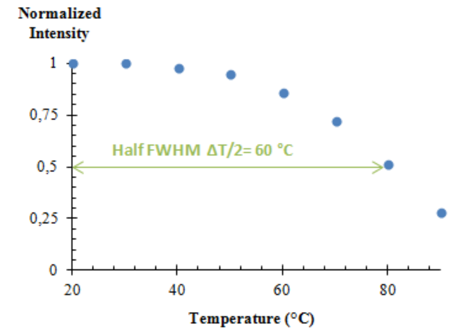

Figure 6: Thermal acceptance of SHG in RTP crystal

In summary, we designed a frequency doubled 515 nm source based on a 1030 nm ns pulsed Yb-based laser and a 10 mm RTP crystal. At 1030 nm, RTP combines for SHG a large d_{eff}, NCPM behavior at room temperature and wide thermal acceptance, a combination never demonstrated before to the best of our knowledge. For these reasons, it will be an excellent solution for applications requiring a simple and robust frequency doubling scheme such as intracavity frequency doubling or military laser systems.

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References

[1] H. Albrecht, P. Villeval, and C. Bonnin, “Study of RTP crystal used as Electro-Optic modulator,” *Advanced Solid-State Photonics*, pp. 3–5, 2006.

[2] J. Mangin, G. Mennerat, and P. Villeval, “Thermal expansion, normalized thermo-optic coefficients, and condition for second harmonic generation of a Nd:YAG laser with wide temperature bandwith in RbTiOPO4,” *Journal of the Optical Society of America B*, vol. 28, no. 4, 2011.

[3] G. Mennerat, B. Trophème, P. Villeval, L. Deyra, X. Délen, F. Balembois, and P. Georges, “Simultaneous temperature and angular non-critical frequency doubling at 1030 nm in RTP,” *Submitted to Optic Express*, 2013.

[4] Y. S. Oseledchik, A. I. Pisarevsky, A. L. Prosvirnin, V. V. Starshenko, and N. V. Svitanko, “Nonlinear optical properties of the flux grown RbTiOPO4 crystal,” *Optical Materials*, vol. 3, no. 4, pp. 237–242, Oct. 1994.

[5] T. Ukachi, R. J. Lane, W. R. Bosenberg, and C. L. Tang, “Measurements of non-critically phase-matched second-harmonic generation in a LBO crystal,” *Applied Physics Letters*, vol. 57, no. 10, 1990.

[6] X. Délen, L. Deyra, A. Benoit, M. Hanna, F. Balembois, B. Cocquelin, D. Sangla, F. Salin, J. Didierjean, and P. Georges, “Hybrid master oscillator power amplifier nanosecond laser source at 257 nm,” *Optics Letters*, vol. 38, no. 6, pp. 995–997, 2013.