CARACTERISATIONS OPTIQUES NONLINEAIRES DE GUIDES D'ONDES NON HOMOGENES SUR PPLN

I. Krasnokutska, O. Stepanenko, E. Quillier, H. Tronche, P. Aschieri, M. De Micheli, P. Baldi

Laboratoire de Physique de la Matière Condensée, Université Nice Sophia Antipolis, UMR CNRS 7336, Parc Valrose, 06108 NICE CEDEX, France

Pascal.Baldi@unice.fr

RÉSUMÉ

Les guides d'ondes à quasi-accord de phase sont largement employés de nos jours pour leur forte efficacité nonlinéaire, leur compacité et leur versatilité. Cependant, des problèmes de fabrication ou d'utilisation peuvent entraîner une dégradation importante de leurs performances comme une efficacité réduite ou des spectres distordus. Sur un jeu de guides d'ondes inhomogènes fabriqués par échange protonique sur niobate de lithium, nous avons utilisé la génération de fluorescence paramétrique et la génération de second harmonique afin de remonter aux paramètres d'inhomogénéité des guides.

MOTS-CLEFS : *guides d'ondes ; PPLN ; optique nonlinéaire.*

1. INTRODUCTION

Nonlinear interactions, such as Spontaneous Parametric Down Conversion (SPDC) and Second Harmonic Generation (SHG) in Periodically Poled Lithium Niobate (PPLN) waveguides are nowadays widely employed, for example in quantum telecommunications.[1] However, many teams have reported non standard behavior for the generated power spectrum, with shifted main peak and pronounced side lobes compared to the expected perfect sinc^2 form.[2-3] Main reasons of this behavior are inhomogeneity of the waveguide or of the poling. Knowing the origin of these distortions is of great importance as it allows improving the fabrication process and increasing the interaction efficiency. It is thus interesting to have precise nonlinear characterization tools and accurate numerical simulation methods. For our demonstration, we have fabricated a set of on-purpose distorted PPLN waveguides and used SPDC and SHG as characterization methods. We compared both nonlinear processes together and with numerical simulations and concluded that the distortions of spectrum and reduced efficiencies appear from a nonuniform effective index along the waveguides.

2. FABRICATION OF PPLN WAVEGUIDES

Sample fabrication started by poling a 3" wafer using the e-field technique. Periods range from 15.6 to 16.6μm by 0.1μm step. Soft Proton Exchange (SPE) at 300°C for 3 days was then used to fabricate the waveguides.[4] One part of the sample was covered by a standard photolithographic mask with uniform openings of widths ranging from 4 to 8μm by 1μm step, while the other part was covered by a mask with non-uniform widths. The width was linearly increased from w at the input face to w+4 at the middle of the waveguide, and then linearly decreased back to w at the output face (waveguides were thus symmetric). The initial value w was ranging from 4 to 8μm by 1μm step. Sample was then end-faces polished and all waveguides were 4.5cm long.

3. NONLINEAR CHARACTERIZATIONS OF THE HOMOGENEOUS WAVEGUIDES

The homogeneous waveguides were first characterized using SPDC and SHG. The SPDC experimental set-up is described elsewhere.[5] The SHG set-up used a Tunics-Plus 10 tunable laser, delivering 5mW from 1500 to 1620nm as the fundamental wavelength. A polarization maintaining fiber allows the light injection into the PPLN waveguide. Light was coupled out from the waveguide using a microscope objective. A system of dichroic mirrors, filters and flip-flap metallic mirrors allowed to measure both fundamental and second-harmonic spectra and to observe on cameras the excited modes. Figs. 1 and 2 show typical spectra with no deviation from the expected forms as it should be in uniform waveguides

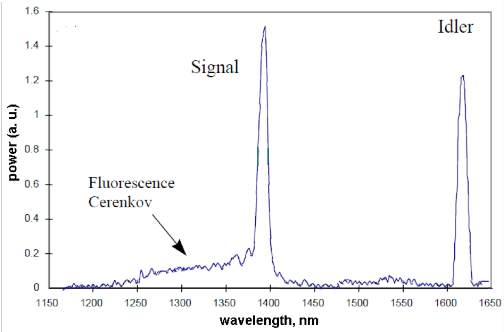

Fig. 1 : SPDC spectrum in an homogeneous waveguide.

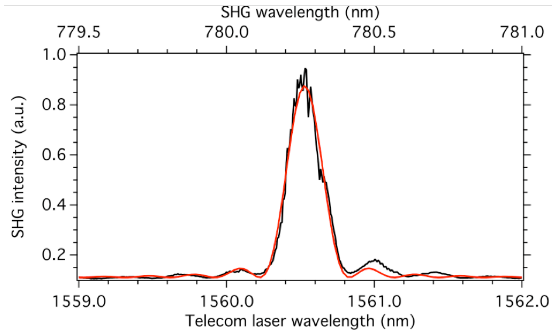

Fig. 2 : sinc^2 form for the SHG spectrum in an homogeneous waveguide.

We also performed SPDC in the bulk to check the quality of the poling. Figures 3 show that we obtained the expected spectrum shape characteristic of non-collinear SPDC. We did not observed any distortions into the sharp break between the signal and idler peaks, confirming that the poling was uniform.

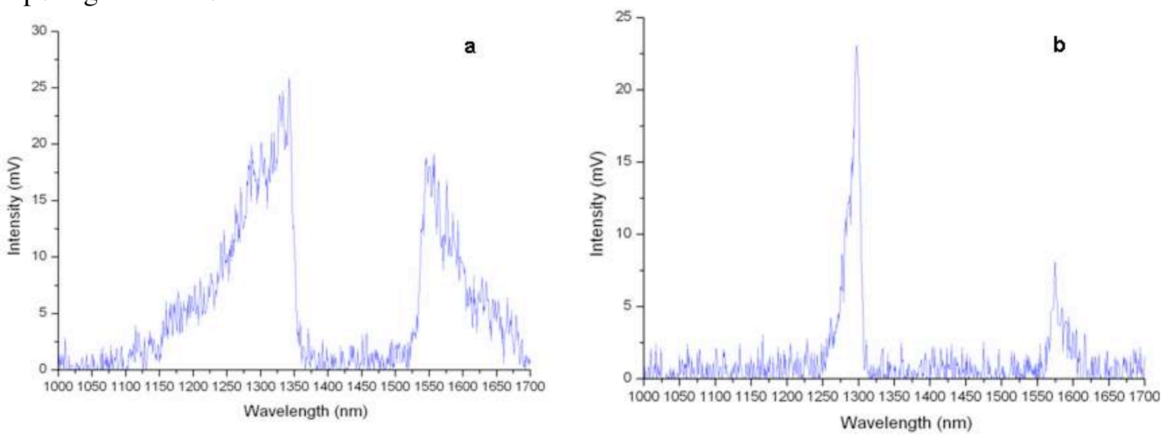

Fig. 3 : non-collinear SPDC in the bulk PPLN. Λ=15.6 μm, λ_p =712.6 nm. a - original spectrum. b – the emission cone is limited by a diaphragm.

4. SPDC AND SHG IN THE NON-HOMOGENEOUS WAVEGUIDES

Figures 4 and 5 report SPDC and SHG respectively for three different waveguide widths. The distortions in the spectra were in qualitative agreement with the simulated ones. For a given waveguide, the inversion of the side lobes compared to the main peak between SPDC and SHG is due to the phase mismatch term that appears in the governing equations. Because of the waveguide dispersion the side lobes are more pronounced on one side or the other of the main peak depending on w. For w=6μm the nonlinear spectra have almost perfect shape, even if the efficiency η is reduced compared to similar homogeneous waveguide. We obtained comparable values η_{SHG}=(7.9±1.4)%$W^{-1}cm^{-2}$ and η_{SPDC}=(5.9±0.9)%$W^{-1}cm^{-2}$, indicating that the two nonlinear characterizations are in good agreement. Furthermore the measured bandwidths were also shown to be in good agreement.

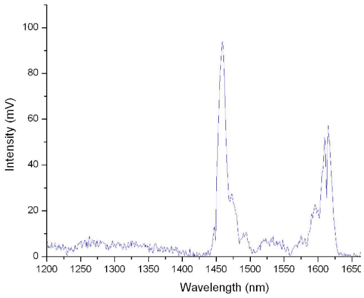

Fig. 4a: spectrum of generated SPDC in a w=4μm width waveguide for Λ=15.6μm and λ_p=763.6nm.

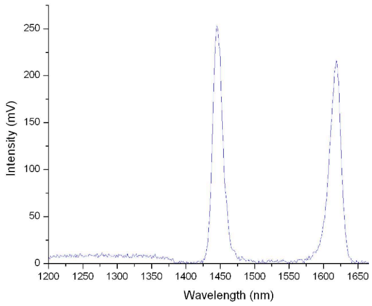

Fig. 4b: spectrum of generated SPDC in a w=6μm width waveguide for Λ=15.6μm and λ_p=764.2nm.

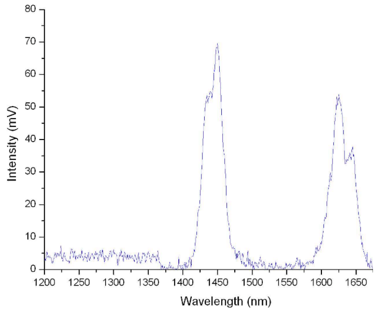

Fig. 4c: spectrum of generated SPDC in a w=8μm width waveguide for Λ=15.6μm and λ_p=766.2nm.

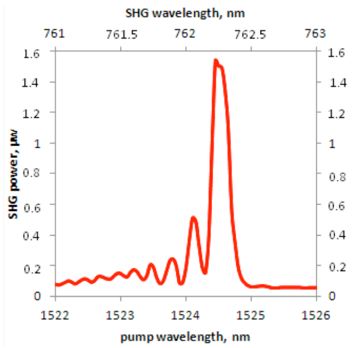

Fig. 5a: SHG in the same than Fig. 4a waveguide.

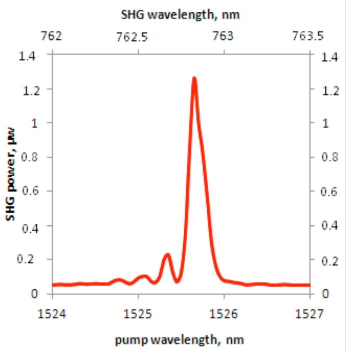

Fig. 5b: SHG in the same than Fig. 4b waveguide.

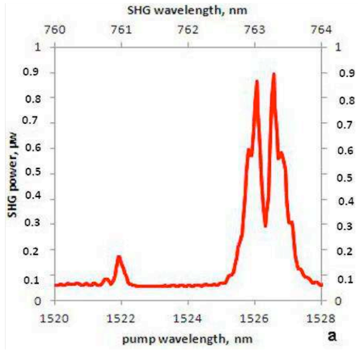

Fig. 5c: SHG in the same than Fig. 4c waveguide.

5. Conclusion

We have shown that both SHG and SPDC can be used to characterize the nonlinear optical properties of non-homogenous QPM waveguides. Both characterizations are in good agreement. SHG needs simpler set-up equipments compared to SPDC but requires to know quite accurately the QPM wavelength. SPDC has a much larger acceptance in terms of QPM conditions but requires detecting low (in the pW range) powers.

References

[1] S. Tanzilli *et al*., *Laser Photonics Rev*. **6**, pp. 115–143 (2012).
[2] M.M. Fejer *et al*., *IEEE J. Quantum Electron*. **28**, pp. 2631–2654 (1992).
[3] S. Helmfrid *et al*., *JOSA B* **8**, pp. 797-804 (1991).
[4] L. Chanvillard *et al*., *Appl. Phys. Lett*. **76**, pp. 1089-1090 (2000).
[5] P. Baldi *et al*., *IEEE J. Quantum Electron*. **31**, pp. 997–1008 (1995).