



Integrated PhotonPair Sources, Quantum Memories, and Lasers in Lithium Niobate

Wolfgang Sohler, Harrald Herrmann, Raimund Ricken, Viktor Quiring,
Mathew George, Shantanu Pal, Xu Yang, Kai Luo, Christine Silberhorn,
Florian Kaiser, et al.

► To cite this version:

Wolfgang Sohler, Harrald Herrmann, Raimund Ricken, Viktor Quiring, Mathew George, et al..
Integrated PhotonPair Sources, Quantum Memories, and Lasers in Lithium Niobate. 5th In-
ternational Photonics and OptoElectronics Meetings (POEM 2012), Nov 2012, Wuham, China.
<hal-00847650>

HAL Id: hal-00847650

<https://hal.archives-ouvertes.fr/hal-00847650>

Submitted on 24 Jul 2013

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Integrated Photon Pair Sources, Quantum Memories, and Lasers in Lithium Niobate

W. Sohler¹, H. Herrmann¹, R. Ricken¹, V. Quiring¹, M. George¹, S. Pal¹, X. Yang¹, K. H. Luo¹, C. Silberhorn¹,
F. Kaiser², S. Tanzilli², E. Saglamyurek³, N. Sinclair³, D. Oblak³, W. Tittel³,

¹University of Paderborn, 33098 Paderborn, Germany; ²University of Nice–Sophia Antipolis, 06108 Nice France; ³University of Calgary, Calgary, Canada.
sohler@physik.upb.de

Abstract: Recent advances of type II quasi phase matched (entangled) photon pair sources with Ti:PPLN waveguide, of quantum memories with Ti:Tm:LiNbO₃ waveguide, and of Ti:Tm:LiNbO₃ in-band pumped optical amplifiers (1700 nm < λ < 1900 nm) and lasers are reported.

OCIS codes: (130.0130) Integrated optics; (270.0270) Quantum optics;

1. Introduction

There are exciting new developments in the field of integrated quantum optics [1] exploiting lithium niobate (LN) waveguide technology: single photon pair sources with Ti:PPLN (periodically poled lithium niobate) waveguide, quantum memories with Ti:Tm:LiNbO₃ waveguide, and optical amplifiers and lasers with Ti:Tm:LiNbO₃ waveguide for emission in the 1700 nm < λ < 1900 nm wavelength band. However, the combination of such devices in integrated circuits on a common substrate remains as a major challenge.

2. Single Photon Pair Sources

Exploiting spontaneous parametric down conversion (SPDC) in low loss Ti:PPLN waveguides, several types of single photon pair sources have been developed. Type II quasi phase matching (QPM) is preferred yielding a narrower photon bandwidth than type I QPM processes. Some examples are presented [2]. Among them are special, resonant sources of extremely small linewidth currently developed for photon storage in quantum memories: the wavelength of one photon matches an absorption line of a Nd- or Tm-doped crystal or waveguide quantum memory (e.g. 795 nm for Tm), while the wavelength of the other one is in a telecom band.

3. Quantum Memories

Thulium-doped Ti:LN single mode channel waveguides have recently been developed for applications as photon echo-based quantum memories. Quantum memories are key components of future quantum repeaters, which are the elementary building blocks required for long-distance quantum communication. Using Ti:Tm:LN waveguides, the storage and retrieval of photons ($\lambda = 795$ nm) from entangled photon pairs has been demonstrated, thereby temporarily creating entanglement between a photon and a collective atomic excitation [3]. Storage of simultaneously arriving, frequency multiplexed photons and recall on demand in the frequency domain has been shown as well.

4. Tm-Doped Waveguide Amplifiers and Lasers

Tm-doped LN waveguides have also been designed for the development of optical amplifiers and lasers with potential applications in optical communications, spectroscopy and sensing. By exploiting the $^3F_4 \rightarrow ^3H_6$ transition, amplification and laser emission is within the wavelength band 1700 nm < λ < 1900 nm. As example, a simple 30 mm long Fabry-Perot type Ti:Tm:LN waveguide laser of very low threshold and 1890 nm emission wavelength will be presented. The laser has a cavity defined by dielectric end face mirrors; it is in-band pumped by a laser diode at $\lambda = 1650$ nm [4]. Longer Ti:Tm:LN waveguides can be used as optical amplifiers. Simulation results promise (wavelength dependent) gain exceeding 30 dB in 90 mm long structures.

5. References

- [1] S. Tanzilli, A. Martin, F. Kaiser, M.P. De Micheli, O. Alibart and D.B. Ostrowsky, "On the genesis and evolution of Integrated Quantum Optics", *Laser Photonics Rev.* **6**, No. 1, 115–143 (2012).
- [2] e.g.: F. Kaiser, A. Issautier, L. A. Ngah, O. Danila, H. Herrmann, W. Sohler, A. Martin, and S. Tanzilli, „High-quality polarization entanglement state preparation and manipulation in standard telecommunication channels”, submitted to *New J. Phys.*
- [3] E. Saglamyurek, N. Sinclair, J. Jin, J. A. Slater, D. Oblak, F. Bussi eres, M. George, R. Ricken, W. Sohler, and W. Tittel, "Broadband waveguide quantum memory for entangled photons", *Nature*, Vol. **469** (7331), 512-515 (2011).
- [4] M. George, R. Ricken, V. Quiring, and W. Sohler, "In-band pumped low threshold Ti:Tm:LiNbO₃ waveguide laser", *European Conference on Integrated Optics ECIO'2012, Sitges (Barcelona)*, 2012.