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

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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 ($1700\text{ nm} < \lambda < 1900\text{ nm}$) 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 $1700\text{ nm} < \lambda < 1900\text{ nm}$ 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 ($\lambda = 795\text{ nm}$) 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 $1700\text{ nm} < \lambda < 1900\text{ nm}$. 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 $\lambda = 1650\text{ nm}$ [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. Bussieres, 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.