QUASI-DETERMINISTIC SINGLE PHOTON SOURCE

KEYWORDS

- Single Photon Source
- Frequency multiplexing

Collaboration type
License agreement
R&D collaboration

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THE TECHNOLOGY IN A NUTSHELL

We have developed a quasi-deterministic heralded single photon source in which an active frequency-multiplexing technique provides photons that are monomode [a.k.a. undistinguishable] both in term of timing, frequency, polarization and spatial profile. The photons properties (central wavelength, bandwidth) are widely adjustable. The source can be implemented using several different technologies (fiber optics, integrated optics). Photon emission probabilities greater than 80% are foreseen.

STATE OF THE ART

The present invention relates to the field of single photon sources and methods of generating single photons. It addresses a long-standing demand in the field of quantum optics, namely the realization of a single photon source that produces on demand, quasi-deterministically, single photons in a well-defined temporal mode, in a guiding medium (typically a single mode optical fiber, or an integrated waveguide), while being resource efficient and widely tunable in frequency.

On-demand single photon sources are a fundamental resource in quantum communication, quantum cryptography and quantum computing, and are at the heart of much research on the quantum behavior of light and light-matter interactions. Unlike probabilistic sources of single photons, on-demand sources emit a single photon with quasi-certainty each time they are triggered. This makes the process of single photon generation and distribution more reliable and efficient in practical quantum technology applications.

THE INVENTION

The quasi-deterministic heralded photon sources relies on an active frequency-multiplexing technique. Photons are generated independently in different frequency bins and many (100+) frequency bins are in principle available.

A parametric down conversion source produces frequency entangled photon pairs. The signal photon is dispersed using dispersion medium (three circles denoted D+) and detected by a single photon detector at time t. The time of detection t is correlated to the frequency of the signal photon, and therefore to the frequency of the idler photon. Simultaneously a high-power laser pulse passes through a medium with the same dispersion D+. A short piece of the dispersed laser pulse is carved out at time t by an Electro-Optic Modulator (EOM). The carved laser pulse is therefore frequency correlated with the signal photon. In order to synchronize it with the idler photon, the carved laser pulse passes through a medium with inverse dispersion D-. The carved laser pulse and the idler photon then pass through a nonlinear medium that realizes frequency conversion of the idler photon to a predefined frequency. Unwanted idler photons at other frequencies are removed by a spectral filter.

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LE FONDS SOCIAL EUROPÉEN ET LA WALLONIE INVESTISSENT DANS VOTRE AVENIR

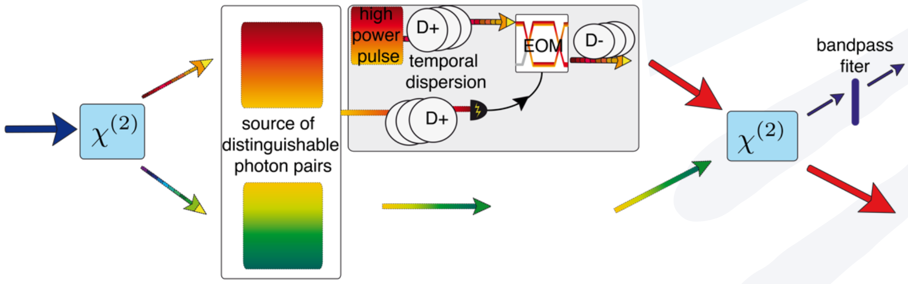

Fig 1: High level description of the proposed single photon source

KEY ADVANTAGES OF THE TECHNOLOGY

- Applicable to any wavelength and with a wide variety of bandwidths
- Various technological implementation are possible
- Active resources can be reduced to one laser and one single photon detector

TECHNOLOGY READINESS LEVEL

1 **2** 3 4 5 6 7 8 9

A preliminary experimental demonstration was reported in [1]. In this work, the authors use active frequency-multiplexing technique as an equivalent of having a plurality of individual sources. Photons are generated independently in different frequency bins and many frequency bins are in principle available. The switching loss scaling is avoided in this approach. However, the up-conversion of the heralded single photons to the targeted output frequency of the source required the replication of expensive high-power pulsed laser sources, proportional in number to the number of frequency bins used.

In [2] we showed how to overcome the problem of scaling the number of laser sources for frequency up-conversion of the heralded single photons. In fact, the active resources can be reduced to one laser and one single photon detector. The main new idea is to use dispersive elements to convert back and forth between the frequency degree of freedom and the time degree of freedom. The analysis of [2] shows that using present day components, a fidelity greater than 99,8% is possible, with a probability of generating a single photon per clock cycle greater than 80%. The advances of [2] are the basis of the patent application [3].

We are currently working on realizing an experimental demonstration of the method proposed in [2] using fiber optics technology. Nanophotonic implementations are also possible, promising sources of single photons fitting on a photonic chip.

POTENTIAL APPLICATIONS

- Quantum Cryptography
- Quantum Computing
- Fundamental investigations of light and light-matter interactions

THE INVENTORS

Stéphane CLEMMEN and **Serge MASSAR** have a strong track record in quantum optics and quantum information processing.

RELEVANT PUBLICATIONS

[1] Frequency multiplexing for quasi-deterministic heralded single-photon sources, C. Joshi, A. Farsi, S. Clemmen, S. Ramelow, and A. L. Gaeta, Nat. Commun. 9, 847 (2018).
[2] Resource efficient single photon source based on active frequency multiplexing, Serge Massar and Stephane Clemmen, Optics Letters 46, 2832 (2021).
[3] Quasi Deterministic Single Photon Source, Serge Massar and Stephane Clemmen, Patent application PCT/EP2021/077866.