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High quality entanglement on a silicon-chip

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Abstract

We report the fully telecom compliant generation of photon pairs using a microring resonator on a silicon chip. The ring cavity is designed such as to demultiplex the emitted frequency-comb like spectrum using standard off-the-shelves telecom 100GHz dense wavelength division multiplexers (DWDM). We measure energy-time entanglement in different channel pairs with raw visibilities exceeding 98%, which paves the way for silicon photonics based quantum key distribution (QKD) with either increased bit rates, or more users.

1. Introduction

Integrated quantum photonics has already proven its suitability for high-performance photon-pairs source realizations [1]. Silicon technological platforms have recently found huge interest in photonics, and more particularly for entangled photon-pairs sources (EPPS) [2] thanks to their outstanding properties, such as high integration density, CMOS compatibility, and efficient nonlinear optical properties, associated with well-established and mature technology. The silicon photonics platform stands as one of the most promising for dense functionality integration, such as integrated ring resonators which already enable producing entangled photons thanks to enhanced third-order nonlinear processes [3]. On the other hand, a very appealing challenge for resonant non-linear cavities, which has only just recently been addressed [4], consists in taking advantage of the full capacity offered by commercial optical communication networks in a multimodal operation. To achieve this purpose, the entangled photon-pairs source has to show its ability to manage the generation of many independent signals at different wavelengths into a single communication channel compliant with commercial optical communications networks. Furthermore, this development could also benefit to high-dimensional quantum communication protocol in order to increase the number of encoded bits per photon. Here, we report an on-chip Si generator of multiplexed telecom entangled photons pairs showing high quality of entanglement along telecom channels. The choice of the SOI platform, which enjoys a high refractive index mismatch between the core of Si and the silica cladding, instead of another doped glass platform, was clearly dictated by its strong capacity to densely integrate EPPS towards the real implementations of wavelength (de)multiplexed network.

2. Experiment & discussion

In our experiment, energy-time entangled photon pairs are generated through degenerate spontaneous four wave mixing (DSFWM) process in a Si micro-ring resonator pumped by a 1537 nm continuous wave laser. The laser wavelength is adjusted, within the standard 100 GHz telecom channel 50 to match one of the micro-ring resonances. Via DSFWM, energy time entangled photon pairs are generated. Due to the conservation of energy, the pairs are always generated pairwise symmetrically around the pump wavelength. The emission is further restricted to the micro-ring resonator modes which form a frequency comb like structure in the telecom C-band (1530-1565nm). The spacing between the different modes is chosen such that the emission can be conveniently demultiplexed using off-the-shelves 100 GHz DWDM. Furthermore, thanks to the high quality of the ring resonator ($Q \sim 40000$), we achieve a high photon pair production rate of 2. 10^6 pairs per second for 500 μW pump power only. Taking into account the narrow bandwidth of the cavity modes ($\sim$ 5 GHz), we obtain a spectral brightness of ~400 pairs/s/MHz/mW. Note that these performances are measured at a pump power low enough to not be affected by any non-linear losses (two-photon absorption, free carrier absorption). We emphasize further that stabilizing the temperature of the chip is sufficient to achieve excellent long term stability, i.e. the cavity modes do not drift away.

In order to demonstrate the potential of our device for increasing bit rate in QKD applications, we measure entanglement over the full emission of the source using the following arrangement. The photon pairs are sent to an unbalanced Michelson interferometer which allows to reveal energy-time entanglement. Photons are then demultiplexed using a 16 channel DWDM centered at the pump laser wavelength, and finally detected thanks to InGaAs avalanche photodetectors. Two-photon coincidences between wavelength correlated channels are measured using time-tagging electronics. We observe a sinusoidal modulation of the coincidence rate as a function of the phase of the Michelson interferometer. The fringe visibility is a genuine marker of the quality of both the experimental setup and the produced entanglement.

We infer visibilities of 99.2 ± 2.3%, 98.9 ± 2.7%, 98.1 ± 0.9%, 98.8 ± 1.5% respectively for the ITU paired channels 48/52, 45/55, 43/57 and 41/59 which represent a clear violation of the Bell inequalities (classical limit ~71 %).

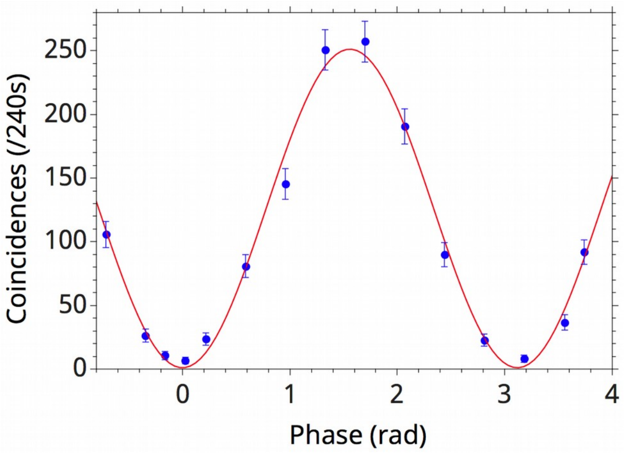

Figure 1. Two-photon interference fringes for the ITU paired channels 48/52

3. Conclusion

We demonstrated on-chip generation of multiplexed entangled photons pairs at telecom wavelengths with near perfect visibilities in different telecom channel pairs. The efficiency of our source and its spectral multiplexing capability make a promising candidate for future fully integrated quantum information and networking applications.

4. References

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