A bright integrated photon pair source

Gui-Lu Long^{*}

Department of Physics, Tsinghua University, Beijing 100084, China

Received September 2, 2019; accepted October 12, 2019; published online December 11, 2019

Citation: G.-L. Long, A bright integrated photon pair source, *Sci. China-Phys. Mech. Astron.* **63**, 220361 (2020), <https://doi.org/10.1007/s11433-019-1460-2>

The generation and detection of single photons and photon pairs are crucial to quantum information processing [1-7]. Of the various techniques, integrated photonics plays an important role. It has the advantages of mature complementary metal-oxide-semiconductor (CMOS) mass-fabrication, miniaturization, scalability, stability and reconfigurability, thus becoming a natural choice for integrated quantum information processing. However, due to the lack of second-order nonlinearity, the silicon chip usually adopts the relatively weak third-order nonlinear interaction, namely the spontaneous four-wave mixing, to generate photon pairs. To improve the photon pair generation rate, silicon micro-ring resonators are considered candidates capable of enhancing the intense intracavity field for the pump, signal and idler photons. In practice, a high pair generation rate requires the signal and idler photons in the under-coupling regime, while a high extraction rate requires such photons in the over-coupling regime, which seriously hinders the optimization of this technique. The optimal condition is deduced to be some point in the over-coupling regime for the signal and idler photons, simultaneously with critical coupling for the continuous wave (CW) pump. This can hardly be satisfied in either single-bus waveguide resonators or double-bus ring resonators.

Recently a research team led by Prof. Ping Xu from National University of Defense Technology, in collaboration with the Science and Technology on Monolithic Integrated Circuits and Modules Laboratory of Nanjing Electronic Devices Institute, realized the aforementioned optimal con-

dition using a dual asymmetric Mach-Zehnder Interferometers (AMZI) coupled ring resonator and optimized the photon pair flux [8]. They fabricated a series of dual AMZI coupled micro-ring resonators consisting of twelve individual samples with different coupling gaps. They showed that the maximum rate of photon-pair generation under CW pumping requires the critical coupling of the pump as well as an over-coupling of the signal and idler photons. This is the first time the dependence of photon flux on the coupling condition is explicitly characterized.

Specifically, at a pump power as low as 156 μW , the measured coincidence rate under optimal coupling peaked at 3596 Hz, which is equivalent to 15604 Hz when the on-chip propagation loss is subtracted. Taking account of other factors of loss, this is equivalent to an on-chip pair generation rate of 0.45 MHz. Meanwhile, the on-chip spectral brightness reached $2 \times 10^8 \text{ pairs s}^{-1} \text{ nm}^{-1} \text{ mW}^{-2}$, higher than that from a typical second-order nonlinear chip like ion-exchange lithium niobate waveguide [9]. This result exceeds most of the reported investigations on silicon photon sources. In addition, the dual AMZI coupled ring resonator showed some unique advantages. It greatly enhanced the collection efficiency with a through-to-drop suppression ratio up to 30 dB, and efficiently filtered the noisy photons and residual pump beams. This work provides a valuable and feasible quantum light source for on-chip quantum information processing.

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^{*}Corresponding author (email: gllong@mail.tsinghua.edu.cn)

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