Generation of Multiphoton States by Multiplexing of Heralded Photon Sources

B M Szilasi[1,2], M Mechler[1,2], and P Adam[1,2]

[1] *Research Institute for Solid State Physics and Optics, Wigner Research Centre for Physics, Konkoly-Thege Miklós út 29-33., Budapest, Hungary. Contact Phone: +3613922768*
[2] *Institute of Physics, University of Pécs, Ifjúság útja 6., Pécs, Hungary. Contact Phone: +3672503600/24399*
Contact Email: szilasi.balint@wigner.hun-ren.hu

Recent experiments aiming at studying phenomena in the fields of quantum information processing and photonic quantum technology require the development and improvement of reliable on-demand multiphoton sources. An experimentally realizable technique of the generation of multiphoton states is based on heralded photon sources, where photon pairs are generated in two modes in some nonlinear optical processes. The detection of a given number of photons by a photon-number-resolving detector in the idler mode heralds the presence of the corresponding multiphoton state in the signal. This technique has been efficiently applied for single-photon generation. The multiphoton noise of heralded single-photon sources originating from the probabilistic nature of the pair generation can be minimized by multiplexing [1, 2]. In the case of spatially multiplexed single-photon sources, several heralded sources are applied in parallel. Decreasing the mean photon numbers of the generated photon pairs in each sources in combination with the application of several sources ensures the high single-photon probability with low multiphoton contribution. Using the statistical theory of these sources developed recently, both the input mean photon number and the number of the multiplexed sources can be optimized [3–6].

In this work, we propose spatially multiplexed heralded multiphoton sources to generate multiphoton states. We consider multiphoton sources based on minimum-based, maximum-logic output-extended incomplete binary-tree multiplexers built of asymmetric photon routers [6]. We optimize the performance of this system using the extension of the method applied earlier for the optimization of spatially multiplexed single-photon sources. We show that, using the proposed scheme, it is possible to generate multiphoton states up to $n = 5$ photons with considerably higher multiphoton probabilities than the one that can be achieved with a single heralded multiphoton source. We analyze the performance of the proposed spatially multiplexed multi-photon sources assuming two-photon output states for a wide range of the loss parameters characterizing the system. We show that the proposed system can be used to generate few-photon states with high probabilities, even for suboptimal system sizes.

References

[1] E Meyer-Scott, C Silberhorn and A Migdall, Rev. Sci. Instrum. **91**, 041101 (2020)

[2] P. Adam and M. Mechler, Appl. Sci. **14**, 11249 (2024)

[3] F Bodog, M Mechler, M Koniorczyk and P. Adam, Phys. Rev. A **102**, 013513 (2020)

[4] P Adam, F Bodog and M Mechler, Opt. Express **30**, 6999 (2022)

[5] P Adam, F Bodog, M Koniorczyk and M Mechler, Phys. Rev. A **105**, 063721 (2022)

[6] P Adam and M Mechler, Opt. Express **31**, 30194 (2023)