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Realistic Photon-Number Resolution and Its Impact on Gaussian Boson Sampling

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Gaussian boson sampling (GBS) (see Ref. [1]) is a promising quantum computing model that exploits photonic systems to perform computations beyond the reach of classical methods. A crucial aspect of GBS is the detection of photon patterns at the output of an interferometer. However, most experiments rely on on-off detectors that can only identify whether photons are present, without resolving the exact number of photons. While photon-number resolving (PNR) detectors offer the ability to accurately count photons, building perfect PNR detectors remains a challenge due to technical limitations.

In this talk, we present a theoretical framework that models GBS experiments using realistic photon number resolving detectors, see Ref.[2]. We derive a probability distribution for photoncounting that accounts for detector imperfections and can be adapted for both on-off and imperfect PNR detectors. This distribution is expressed in terms of matrix functionals, such as the Hafnian and Torontonian, which are central to the description of different types of photodetectors.

By implementing realistic photon number resolution in our model, we explore how detection imperfections affect the overall performance of GBS experiments. We also propose validation techniques that are robust to these imperfections. This work contributes to the improvement of experimental setups and paves the way for more accurate GBS-based quantum technologies, with potential applications to computational problems that are hard to solve on classical computers.

[1] C. S. Hamilton, R. Kruse, L. Sansoni, S. Barkhofen, C. Silberhorn, and I. Jex, Gaussian Boson Sampling, Phys. Rev. Lett. 119, 170501 (2017).
[2] I. S. Yeremenko, M. A. Dmytruk, and A. A. Semenov, Realistic photon-number resolution in gaussian boson sampling, Phys. Rev. A 110, 043715 (2024).

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Presence at Taras Shevchenko National University

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