On-Demand Single-Photon Emission via Hot Electron Recombination in GaAs/AlGaAs

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On-demand single-photon emitters are a key enabling technology for quantum communication and computing. GaAs/AlGaAs heterostructures, in which injected hot electrons travel through quantum Hall edge channels from a n-type region into a surface-gated p-type region, have been shown to emit photons upon electron–hole recombination [1]. Building on this mechanism, the National Physical Laboratory has proposed that injecting a single-electron into the device triggers a single-photon emission [2].

In this work, we analyse the possibility of electron–photon transduction in which electronic degrees of freedom (spin, temporal, spatial, and energy) map onto the emitted photonic state. These engineered photonic states hold promise for quantum technologies, including quantum key distribution (QKD), quantum illumination, and optical quantum computing (OQC).

To quantify and optimise the performance of our emitter, we investigate an adaptive, retrodictive Bayesian discrimination scheme and outline its uses for Fock, coherent and thermal states of light. Using only simple click detectors, we demonstrate that this approach not only yields photon-number resolution but also provides a method of estimating the mean photon number of a continuous distribution and a sources temperature.

Together, tailored single-electron injection produces customisable photonic states, and Bayesian retrodiction extracts maximal information for further device optimisation. This unified framework paves the way for robust, scalable single-photon sources with added performance verification for next-generation quantum devices.

[1] Nazarov, Y.V. and Blanter, Y.M., 2009. *Quantum transport: introduction to nanoscience*. Cambridge university press.

[2] Norimoto, S., Saxena, R., See, P., Nasir, A., Griffiths, J.P., Chen, C., Ritchie, D.A. and Kataoka, M., 2024. Photon emission by hot electron injection across a lateral pn junction. *arXiv preprint arXiv:2406.04556.*