Metrology for single-photon technologies

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Industrial technologies based on the production, manipulation, and detection of single and entangled photons are emerging. NPL is developing the measurement infrastructure for traceably characterising such technologies, with a current focus on the quantum optical components of quantum key distribution (QKD) systems and quantum random number generators (QRNGs); two of the most commercially advanced quantum optical technologies. This infrastructure will enable NPL to support the development and implementation of agreed standards which are: (i) necessary for establishing a supply chain for components used in such technologies; (ii) required to validate and certify the constructed technology devices [1].

These developments have so far enabled NPL to traceably characterise the single photon transmitter (‘Alice’) and receiver (‘Bob’) modules of weak-laser-pulse QKD systems operating at clock rates up to 1 GHz over optical fibre in the 1550 nm telecommunications band [2]. Characterising Alice and Bob can establish: (i) the performance of the system in terms of expected secure bit-rate and range; (ii) whether they satisfy the assumptions and requirements of the security proofs; (iii) immunity from known side-channel attacks; (iv) whether component performance has changed, either from natural ageing, or from hacking.

The NPL measurement instrumentation can be synchronized with low jitter (< 10 ps r.m.s.) to the pulse emission or detector gate. The properties measured range from ‘traditional’ ones such as mean photon number(s), temporal bandwidth and jitter (transmitted pulses), dark count probability, after-pulse probability and detection efficiency (single-photon detectors within the receiver) to others such as any distinguishing information that may have been imparted onto the transmitted photons (e.g. spectral information) which can be utilised by an eavesdropper. The spectral and temporal distinguishability of the photon receivers can also be measured.

We will describe the facilities that have been developed for traceably characterising the quantum optical components of QKD systems, and measurements obtained with them. At the single-photon level, the general approach is to calibrate the single-photon detectors in the receiver module, and use a similarly-calibrated commercial single-photon detector to calibrate the transmitter. The latest developments in single-photon metrology capability at NPL will also be reported.

References

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