Practical noise models for CV-QKD implementations

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We present a set of analytic models for various experimental imperfections occurring in any realistic implementation of continuous-variable quantum key distribution (CV-QKD). Our models encompass transmitter-, channel- and receiver-related noise sources and allow for a realistic estimate on how a given set of hardware will perform in a CV-QKD system.

Continuous-variable quantum key distribution using coherent states [1–4] is a promising candidate for practical applications of quantum cryptography. This is mainly due to (1) high compatibility with existing telecom components and (2) high detection efficiency of PIN diodes that are used for homodyne detection of the coherent states (compared to single-photon detectors as used in discrete-variable QKD). However, since in CV-QKD any noise beyond the obligatory quantum shot noise is crucially related to the security of the resulting key, it is important to reliably quantify any experimental imperfection that is necessarily introduced by realistic hardware components. Knowledge of their impact on the experimental performance allows us to identify the bottlenecks of a successful CV-QKD implementation *ahead of the experiment.* It gives us an estimate of how the specifications of the used devices (laser, modulator, detectors, ADC, etc.) will affect the total excess noise and therefore the final key rate.

In total, we developed analytic models for eight independent noise sources and their contribution to the total excess noise [5] (in the order of occurrence from transmitter to receiver):

- Relative intensity noise of the signal laser
- Modulation noise, caused by voltage fluctuations of the digital-to-analog converter
- Phase noise, caused by phase fluctuations of the transmitter laser
- Raman noise, caused by Raman scattering, generated by a classical DWDM channel in the fibre
- Relative intensity noise of the local oscillator
- Noise caused by the common-mode rejection ratio of the homodyne detectors
- Electronic noise, caused by the homodyne receivers
- Quantisation noise, caused by an analog-to-digital converter.

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In our presentation we will not only exhibit the analytic expressions for these noise components but also many graphical illustrations indicating the relative magnitude of the individual noise sources as well as the impact of various hardware-related parameters (modulation voltage, Raman scattering, local-oscillator power, ADC bit resolution, noise-equivalent power of the receivers, etc.) on the key figures of a CV-QKD system (excess noise, key rate and achievable transmission distance). Moreover, we will compare our theoretical models with our own experimental results.

We believe that our presentation can make a valuable contribution when it comes to identifying the limitations and removing the major impairments of a realistic CV-QKD system.

References

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