Correlations with on-chip detection and modulation for continuous-variable QKD

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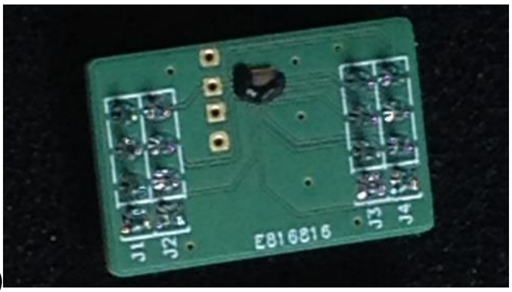
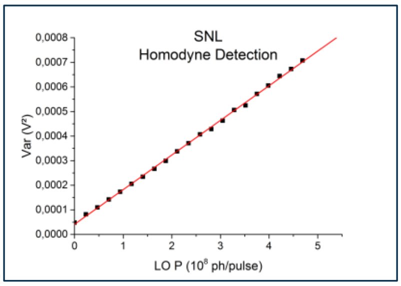
Despite the great progress in quantum key distribution (QKD) implementations in the recent years, QKD remains a technically demanding and costly technology, which hinders its widespread use for high-security applications. To this end, the photonic integration of QKD devices can play a crucial role by reducing size and cost by several orders of magnitude. Recent efforts in this direction include the development of chip-based devices using various integrated technologies for QKD protocols relying on single-photon detection [1].

Here we report on the on-chip demonstration of the main functionalities of continuous variable (CV) QKD, which requires standard telecommunication technology and in particular no photon counting [2]. Our demonstration is based on silicon chips (Fig. a), which comprise all the components of a CV-QKD system, including attenuators, amplitude and phase modulators, and homodyne detectors. Silicon photonics [3] allows for CMOS compatible technology and wide scale production of the developed devices, and has been used extensively in classical optical communications. Device requirements, however, differ significantly for CV-QKD operation, where for instance high extinction ratio and low loss modulators are necessary. In addition, homodyne detectors based on Si-integrated Ge photodiodes must be optimized to reach shot noise limited performance, which is more challenging than for the InGaAs photodiodes typically used in bulk systems [2].

In initial experiments, the CV-QKD emitter (Alice) and receiver (Bob) were integrated into a surface area of roughly 2.4 x 1.0 mm². More recently, they have been tested independently, with different chips used for the modulation and for the homodyne detection (0.7 x 0.5 mm² each). Modulation and attenuation are performed using carrier injection/depletion and thermal effects in PIN diodes. We first tested the modulation devices: the phase modulator is a PIN junction, hence the dephasing is generated by changing the refractive index with carrier injection. The same device inserted in a Mach-Zehnder interferometer provides the variable attenuation and amplitude modulation functionalities required in the signal path. We found a maximal extinction ratio of ~20 dB. For a higher and stable attenuation thermal devices are used, achieving more than 35 dB attenuation. We also measured the variance at the output of the independent homodyne detector as a function of the phase reference (or local oscillator) power, and obtained the linear relationship expected from a shot noise limited (SNL) detector (Fig. b). To fully characterize the device we extracted the value for the excess noise ξ by measuring correlations between the modulated signal sent by Alice and the sifted data received by Bob.

Our results were obtained under typical CV-QKD system operation conditions (100 ns pulses at 1550 nm and 0.5 MHz repetition rate [2]) and are compatible with the generation of secret keys; hence, they illustrate the potential of Si-integrated CV-QKD for the widespread use of this technology in communication networks.

a) 

b) 

Mis en forme : Retrait : Première ligne : 0 cm

[1] P. Sibson et al, Nature Commun. 8, 13984 (2017) ; P. Sibson et al, Optica 2, 172 (2017).
[2] P. Jouguet, S. Kunz-Jacques, A. Leverrier, P. Grangier, E. Diamanti, Nature Photon. 7, 378 (2013).
[3] L. Vivien and L. Pavesi, Handbook of Silicon Photonics, CRC Press (2013).