Free-space quantum key distribution at a wavelength of 10.6 µm using continuous variables

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When a beam of light is transmitted through the atmosphere, it is scattered by atmospheric particles, e. g. water droplets. However, if the wavelength of light is much larger than the particle size, losses through scattering are significantly reduced. A first experiment has investigated the use of longer wavelengths (ca. 5 µm) in the discrete-variable regime [1]. Single photon detection in this regime requires frequency up-conversion, which is very challenging and the detection efficiency is low. In addition, when going to longer wavelengths, quantum key distribution is influenced by background noise sources (e. g. thermal radiation).

Here, we propose a novel free-space quantum key distribution system operating at a wavelength of 10.6 µm in the continuous-variable domain in which quantum limited homodyne detection still works. We plan to use the polarization degree of freedom to encode quantum states and Stokes detection as a measurement scheme, which acts as a narrowband filter against background noise sources [2]. We study the feasibility of employing this wavelength for atmospheric quantum communication, considering both beam propagation effects as well as the performance of the available technology. The wavelength regime around 10 µm seems to be a good compromise as it is both technologically available and uses a significantly longer wavelength than previously demonstrated free-space quantum key distribution systems [3]. Furthermore, there exists an atmospheric window of high transmission for wavelengths around 10 µm.

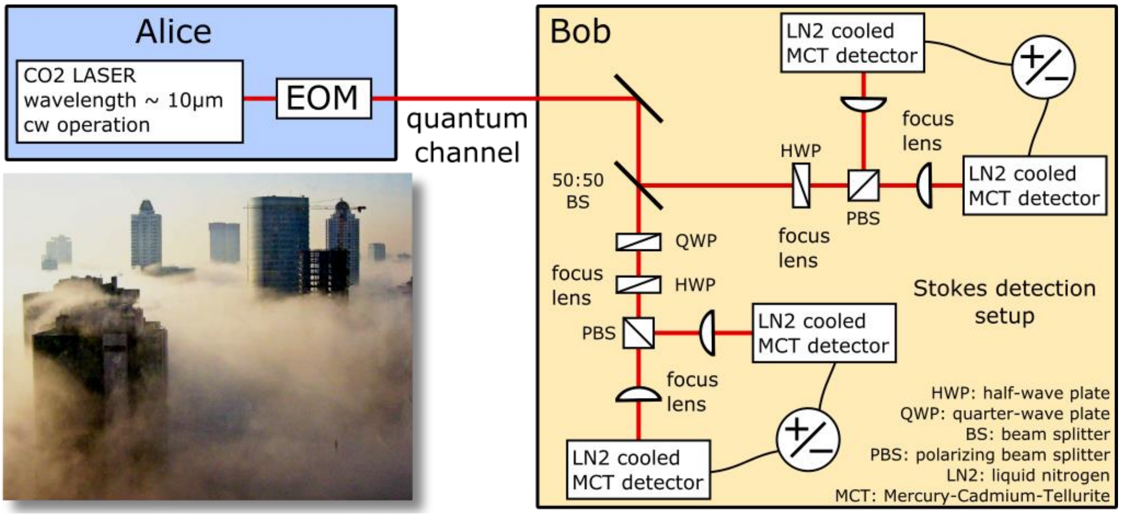

Figure 1: Experimental setup of our free-space continuous-variable quantum key distribution setup operating at a wavelength of 10.6 µm; Alice prepares an alphabet of weak coherent states encoded in the polarization of a bright carrier beam using an electro-optic modulator (EOM) and sends them to Bob through a quantum channel. In our laboratory experiment this will be a fog chamber. Future plans involve transmissions through realistic inner-city environments. Bob receives these quantum states and analyzes them via a Stokes measurement of the polarization using liquid-nitrogen cooled Mercury-Cadmium-Tellurite detectors. The picture shows the fog over the city of Istanbul, pointing to the application of metropolitan QKD networks [4, 5].

[1] G. Temporao, H. Zbinden, S. Tanzilli, N. Gisin, T. Aellen, M. Giovannini, J. Faist and J. v. d. Weid, Journal of Quantum Information & Computation **8**, 1-11 (2008)
[2] B. Heim, C. Peuntinger, N. Killoran, I. Khan, C. Wittmann, Ch Marquardt and G. Leuchs, New Journal of Physics **16,** 113018 (2014)
[3] H. W. Mocker, Applied Optics **8**, 677 (1969)
[4] Photograph: https://www.flickr.com/photos/whatcouldgowrong/2245309248
[5] K. W. Fischer, M. R. Witiw, J. A. Baars and T. R. Oke, Bulletin of the American Metereological Society **85**, 725 (2004)