# The usability of optical parametric amplification (OPA) of the light for astronomical imaging

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High angular resolution imaging is crucial for many applications in modern astronomy and astrophysics. The fundamental diffraction limit constrains the resolving power of both ground-based and spaceborne telescopes. The recent idea of a Quantum Telescope (QT, [1]) based on the Optical Parametric Amplification (OPA) of the light is aimed at bypassing this limit for imaging of extended sources. We present a scheme of an OPA-based device and a semiclassical model of signal amplification by such device. Our semiclassical, more accurate than previously considered model shows that the intrinsic parametric amplification noise tends to form random clumps when passing the telescope optics. This effect was not included in the previous models of the QT [1, 2].

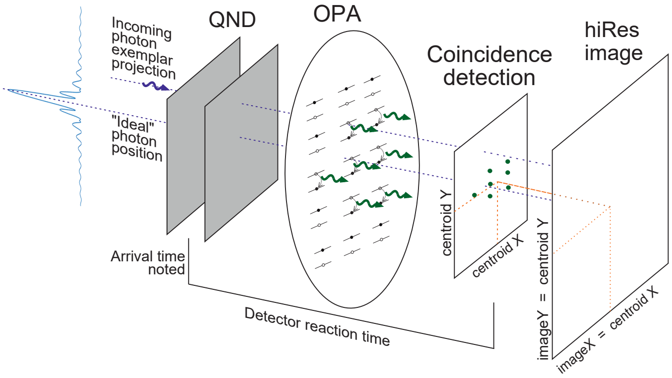

Figure 1: A general Quantum Telescope scheme. Elements are not to scale.

In the proposed device each photon inbounding from a celestial extended source is first detected by the cavity-free Quantum Non-Demolition (QND, [3]) device wherein the time of its arrival is registered. Importantly, the photon is not absorbed by QND detection. As the arrival time is known, it is possible to turn on the detector only for a specified time interval, in which photon's arrival is expected. After the detection, the photon passes through a pumped amplifying medium and is cloned by parametric amplification [4]. The photon from the astronomical target and its clones (stimulated emission) are from this moment indistinguishable and treated as one photon cloud which is registered by a fast two dimensional coincidence detector, e.g. ICCD or EMCCD camera. Unfortunately, the amplifier produces unavoidable spontaneous emission. Although very fast electronic gating of the detector prevents the system from registering too much spontaneous emission photons, the final image is still contaminated by significant noise. Centroid position of the photons' cloud is computed offline and passed as a count into a final high resolution image. The entire process is illustrated in Fig. 1, which shows a toy-model of the QT. The process is repeated for every photon detected by QND and in this way the high resolution image is constructed, photon by photon, during sufficiently long exposition. Toy model of such device is presented in Fig. 2.

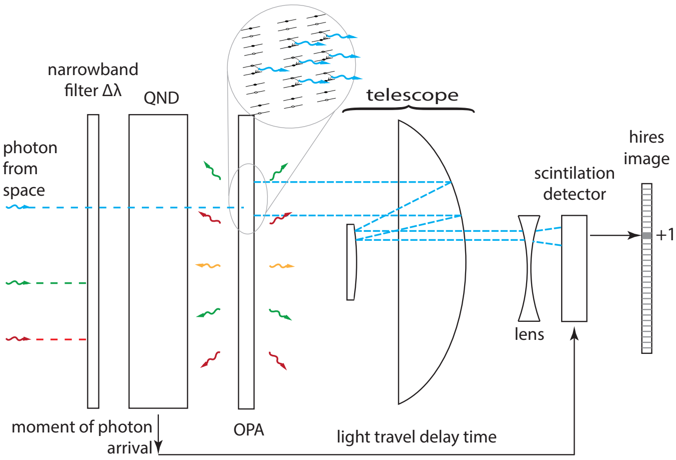

Figure 2: Scheme of QT. Quantum addition to the telescope is placed in front of the mirror.

We analyzed the efficiency of the OPA in increasing the angular resolution of imaging of extended targets and precise localization of a distant point source (astrometry). Our analysis is based on a different, more efficient signal analysis method than the one used before [1, 2]. According to our results, OPA is offering a ∼2.5-fold gain in resolved imaging in comparison to "classical optics" (Fig 3). Moreover, OPA can be more efficient in localizing a single distant point source in comparison to classical telescopes.

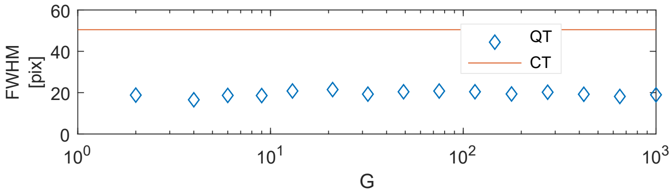

Figure 3: Comparison of the FWHM for QT and "classical" telescope (CT) for the same aperture size as a function of OPA amplification gain $G$.

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