Entanglement Provides a New Avenue for Correcting Aberrations

A. Nicholas Black[1], Enno Giese[2, 3], Boris Braverman[2], Nicholas Zollo[4], Stephen M. Barnett[5], and Robert W. Boyd[1, 2]

[1]Department of Physics and Astronomy, University of Rochester, Rochester, NY, USA 14627
[2]Department of Physics, University of Ottawa, Ottawa, ON, Canada K1N 6N5
[3]Current address: Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ$^{\mathrm{ST}}$), Universität Ulm, Albert-Einstein-Allee 11, Ulm, Germany D-89069
[4]The College of Optics and Photonics, University of Central Florida, Orlando, FL, USA 32816
[5]School of Physics and Astronomy, University of Glasgow, Glasgow, UK G12 8QQ

Using entangled photon pairs, we experimentally demonstrate for the first time a scheme that enables one to correct for aberrations present in one photon's path by introducing the appropriate conjugate aberrations in the other photon's path [1]. Because the two photons are entangled, we can perform this aberration correction even when the two photons are separated in space. While this scheme allows for the correction of all orders of aberration, we demonstrate the correction of defocus and coma. Previous studies have shown that entanglement can be used to construct the image of an object placed in one photon's path using only a single-pixel detector in the object path and a camera in the other photon's path [2, 3]. This scheme, known as ghost imaging, allows one to effectively image an object at wavelengths where cameras are unavailable. Aberrations in either photon's path will negatively impact the quality of this imaging system. Our work demonstrates that aberrations present in either path can be corrected in the partner photon's path, meaning that aberration correction can be performed even for wavelengths where corrective equipment is unavailable. Specifically, we correct defocus introduced in one photon's path by introducing the opposite defocus in the other photon's path, recovering the "ghost" image an object. Furthermore, our scheme could be extended to realize secret sharing and secret verification [4].

References

[1] A. Nicholas Black, Enno Giese, Boris Braverman, Nicholas Zollo, Stephen M. Barnett, and Robert W. Boyd. Quantum nonlocal aberration cancellation. *Phys. Rev. Lett.*, 123:143603, Sep 2019.

[2] D. V. Strekalov, A. V. Sergienko, D. N. Klyshko, and Y. H. Shih. Observation of two-photon "ghost" interference and diffraction. *Phys. Rev. Lett.*, 74:3600–3603, May 1995.

[3] T. B. Pittman, Y. H. Shih, D. V. Strekalov, and A. V. Sergienko. Optical imaging by means of two-photon quantum entanglement. *Phys. Rev. A*, 52:R3429–R3432, Nov 1995.

[4] Joseph M. Lukens, Amir Dezfooliyan, Carsten Langrock, Martin M. Fejer, Daniel E. Leaird, and Andrew M. Weiner. Orthogonal spectral coding of entangled photons. *Phys. Rev. Lett.*, 112:133602, Apr 2014.

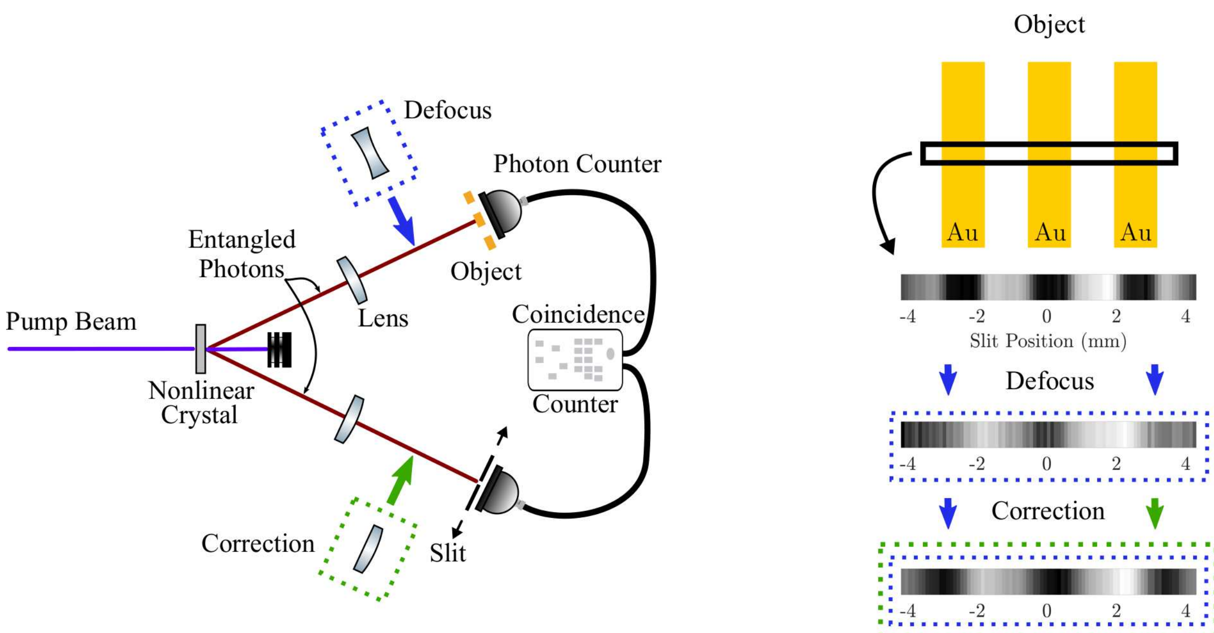

Figure 1: Nonlocal aberration cancellation scheme. (left) Experimental setup for ghost imaging with nonlocal aberration cancellation. (right) Coincidence images of three gold bars without aberration (top), with defocus (middle), and after correction of defocus (bottom).