Open Source Experiments in Quantum Photonics: an Affordable Approach

Sebastian Ritter[1,2,3], Johannes Kretzschmar[2,3], Thomas Kaiser[2], Reinhard Geiss[2,3], Tobias Vogl[1,2], Falk Eilenberger[1,2,3,4]

1. *Institute of Applied Physics, Abbe Center of Photonics, Friedrich Schiller University, Albert-Einstein-Str. 15, 07745 Jena, Germany*
2. *Abbe Center of Photonics, Friedrich Schiller University, Albert-Einstein-Str. 15, 07745 Jena, Germany*
3. *Max Planck School of Photonics, Hans-Knöll-Str. 1, 07745 Jena, Germany*
4. *Fraunhofer-Institute of Applied Optics and Precision Engineering IOF*

Abstract: Advances in quantum technologies have made canonical experiments, such as the Hanbury-Brown-Twiss interferometer, common in state-of-the-art optics labs. Here we demonstrate a path towards an open-source low-cost single-photon HBT-interferometer, targeted at the photonic maker-community.

Recent experimental and technological advances have seen a surge in experiments and applications, which make use of the properties of single photons, entanglement, and other non-classical states of light. These activities have caused a proliferation of quantum photonic devices into optical labs, the most prominent of which are single photon sources, single photon detectors, and time to digital converters (TDC). These devices make many fundamental quantum effects experimentally accessible; changing the character of this scientific community from a highly theoretical and conceptual to one, which is driven by experiments.

Canonical experiments, such as the Hanbury-Brown-Twiss (HBT) interferometer have also augmented the way, quantum physics is taught at university level. The more experimental approach has opened the subject to a larger audience, which is now much better able to connect abstract quantum phenomena, such as correlation and entanglement with specific real-world experiments.

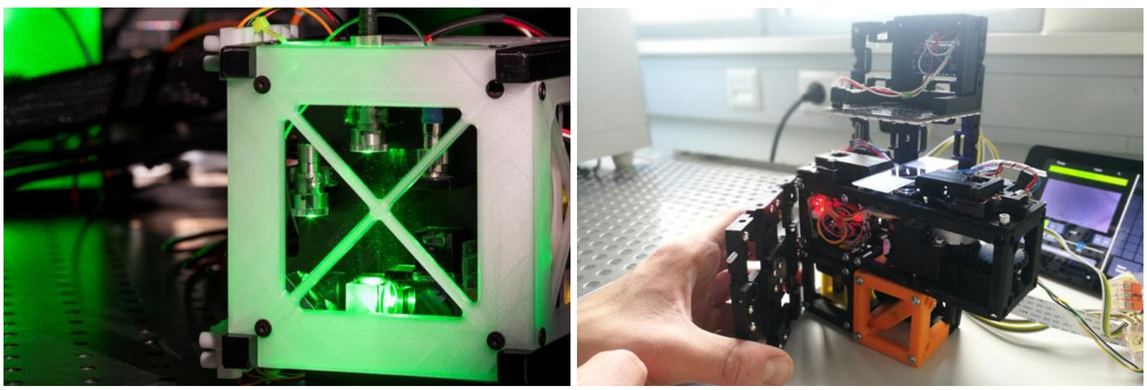

Fig. 1 (left) A prototype of a self-contained Hanbury-Brown-Twiss interferometer developed by the authors of this work based on a single photon source using a defect state emitter in hexagonal Boron Nitride. (right) An example of a complex experimental setup implemented in the UC2-platform.

A proliferation of these experiments as pure teaching tools outside of the scientific context is, however, hampered by the comparatively high price of the required quantum components. The comparatively simple HBT-interferometer, e.g., requires a (1) single-photon source, (2) high grade optics, (3) two single-photon detectors, (4) a TDC, and a (5) substantial amount of optical know-how to be put together. As laboratory-grade equipment each of these constitutes can easily cost tens of thousands of dollars and thus pose an insurmountable barrier to a wider proliferation of quantum photonics from the scientific to the science-interested community.

In this work we will demonstrate low-cost approaches to each of the constituents and a platform that aims to bring them all together in a palpable format, which addresses the learning taxonomy of maker spaces. The real-world setup allows to access the topic Quantum Photonics from a phenomenological approach and motivate learning from self-experienced experimental findings. Especially for quantum physics, which usually requires years of academic study to understand, this is a viable route of transporting the topic to a broader public audience.

Single photon sources are implemented from optically active defect centres in hexagonal boron-nitride [1]. These can be drop-cast from a non-toxic solution onto a glass substrate and excited by a simple laser diode; they have excellent quantum properties, are very robust, can be operated at room temperature and under other harsh conditions [2]. The optical setup is implemented in the UC2-format [3]; a free-to-use set of cuboid frames, which can be 3D-printed with integrated optical components and stacked into compact and robust optical setups. Single-photon detectors and TDCs are constructed from off-the-shelf components, available at various online shops, albeit with much reduced performance parameters, if compared with cutting-edge laboratory equipment.

Sixteenth Conference on Education and Training in Optics and Photonics: ETOP 2021,
edited by A. Danner, A. Poulin-Girard, N. Wong, Proc. of SPIE Vol. 12297, 1229728
 · 0277-786X · doi: 10.1117/12.2635582

The entire construction of the HBT-interferometer will be documented and made available online, such that interested member of the general public would be able to build their own quantum physical experiment.

The presentation will focus on the development of the individual components and their combination into a functional HBT-interferometer based on the UC2-platform. An outlook onto the dissemination efforts and the collaboration with the maker-community will also be given.

References

[1] T. Vogl, G. Campbell, B.C. Buchler, et al., Fabrication and deterministic transfer of high quality quantum emitter in hexagonal boron nitride, ACS Photonics 5, 2305 (2018)-

[2] T. Vogl, K. Sripathy, A. Sharma, et al., Radiation tolerance of two-dimensional material-based devices for space applications, Nat. Commun. 10, 1202 (2019)-

[3] B. Diederich, R. Lachmann, S. Carlstedt et al., A versatile and customizable low-cost 3D-printed open standard for microscopic imaging, Nat. Commun. 11, 5979 (2020).