Tomography of Quantum Dots in a Non-Hermitian Photonic Chip

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Quantum optical information systems offer the potential for secure communication and fast quantum computation. To fully characterise a quantum optical system one has to use quantum tomography [1]. Integration of quantum optics onto photonic chips provides advantages such as miniaturisation and stability, and also significantly improves quantum tomography using both re-configurable [2], and more recently, simpler static designs [3,4]. These on-chip designs have, so far, only used probabilistic single photon sources. Here we are working towards quantum tomography using a true deterministic source - a quantum dot. The scheme of the proposed experiment is shown in Fig. 1A. So far we have fabricated and characterised the performance of an InGaAs quantum dot monolithically integrated into a microlens [5], and completed the design, fabrication and classical characterisation of a photonic chip for quantum tomography.

The chip operates by splitting a state of a photon, generated by a quantum dot, from two inputs (0 and 1) into four outputs. This is achieved through a combination of lossless and non-Hermitian couplers (couplers with loss). Non-Hermitian couplers typically lead to poor performance of quantum optical systems, but here we show that by carefully controlling the loss we can optimise the chip for tomography. We represent a photon quantum state as a point on a sphere, known as a Bloch sphere. Since we use 4 output ports, any photon state can be represented by a combination of the four output intensities. To optimise the chip, we ensure that all outputs are spread over the entire sphere, see Fig. 1B. This decreases the susceptibility to error, known as the condition number. After classical characterisation [6] at 890nm, the condition number [7] for this chip was found to be around 4, which is over 2 times lower than conventional tomography techniques. Currently we are working on a complete quantum dot tomography experiment.
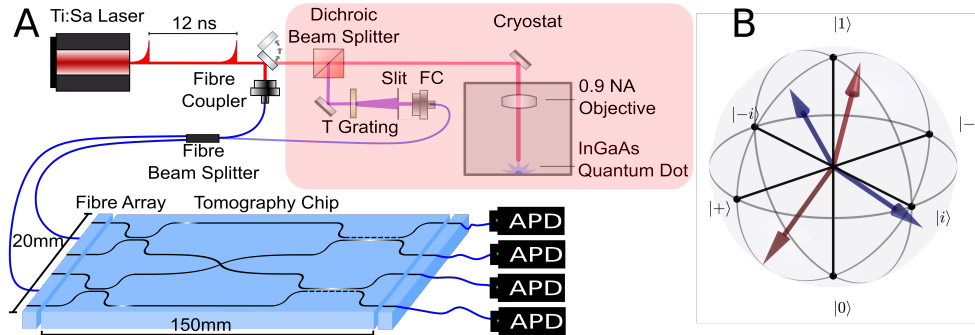
Fig. 1 A. The schematic of the quantum dot tomography experiment. A Ti:Sapphire laser can be coupled into a tomography chip for classical characterisation (completed), or into a quantum dot (red shaded area, currently in progress). B. Experimentally determined projections of the four outputs of the tomography chip onto the Bloch sphere.

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