Diamond Membrane Devices for Efficient Coupling to Vacancy Centres

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Recent advances in manufacturing methods for single-crystal diamond have enabled materials with ultra-high purity and low optical losses. This in turn has facilitated the production of high quality integrated optical devices in diamond. [1]

This project aims to maximise the efficiency of the coupling between optical modes and diamond defect centre based qubits. Efficient coupling is crucial to the performance of diamond as a solid state platform for networked quantum technologies. [2]

Two complementary routes for coupling to defect centres are being investigated in this project. In the first case ultra-thin diamond membrane technology is used in conjunction with a compact free-space open cavity. Good spatial overlap of colour centres in the membrane with the cavity mode is necessary, in addition to isolation of the system from mechanical vibrations. Vertical integration of cavity mirrors, diamond films and spacer layers are being developed to maximise coupling efficiencies in a mechanically robust package. The second method involves high resolution emitter characterisation and pick-and-place techniques for integration of nano-diamond based colour centres with free space and fibre based cavity systems.

Here we present the design and build of a confocal microscope system for high-speed micro-photoluminescence mapping of the defect centres. This flexible set-up will have the ability to find, characterise and spatially register the diamond emitters with nanoscale precision. This capability is then combined with an automated pick-and-place system that can use the same registration structures to locate the pre-defined emitters and transfer them with nanoscale accuracy to host cavities.

(1) Sipahigil, A., Evans, R. E., Sukachev, D. D., Burek, M. J., Borregaard, J., Bhaskar, M. K., Nguyen, C. T., Pacheco, J. L., Atikian, H. A., Meuwly, C., Camacho, R. M., Jelezko, F., Bielejec, E., Park, H., Lončar, M. & Lukin, M. D. An integrated diamond nanophotonics platform for quantum-optical networks. *Science* **354,** 847–850 (2016).

(2) Johnson, S., Dolan, P. R. & Smith, J. M. Diamond photonics for distributed quantum networks. *Progress in Quantum Electronics* **55**, 129–165 (2017).