High Fidelity NV – Diamond Spin Qubits Quantum State Tomography

M Nesladek[1]

[1] *Physics, University Hasselt @ IMEC, division IMOMEC, Wetenschapspark 1, 3591 Diepenbeek, Hasselt, Belgium. Contact Phone: +32-491569600*
Contact Email: milos.nesladek@uhasselt.be

NV diamond spin qubits attract important interests of quantum information science and quantum sensing. We report on a major improvement of the control and characterization capabilities of electron spin and 14N nuclear spin of a single NV centre spin register, as well as on a new method that we have devised to characterize the single-qubit quantum state, i.e. quantum state tomography using Rabi experiments (RQST). The advantage of RQST is that it lifts the requirement of complex unitary operations, used to transfer unobservable elements into observable elements, which is beneficial for reducing classical computational resources and the time in finding the unitaries. By optimising the electron and nuclear spin driving and readout protocols, we reached the record 99.998 and 99.96 fidelities performed on electron an nuclear spins at room temperature respectively. Further on, we compare optical (ODMR) and photoelectric (PDMR) spin state readout [1,2]. Although the PDMR RQST performed lower as ODMR, 99.99 fidelities for PDMR read electron spin gates were reached [3].

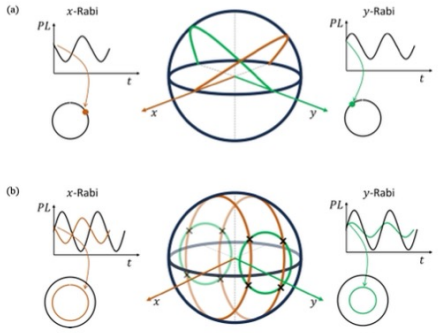

Figure 1: Schematic presentation of the quantum state tomography (QST) based on the Rabi cycle. In the center is the Bloch sphere, a single point on which represents a superposition state of two-level system unequivocally. First Rabi measurement (left) narrows down the possibilities to a single (brown) line. The intersection point with the similar (green) line from a 90° shifted Rabi measurement (right) is the result of the tomogra-phy. (a) Phase Rabi QST. (b) Amplitude Rabi QST

Finally, in the second part of the talk, we discuss novel methodology enabling at the same time temperature and magnetic field sensing, reaching the limit of 1.2 mK/Sqrt(Hz) and pushing magnetic field sensitivity about 8 times up, by making the magnetic field sensing protocols insensitive to temperature.

References

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[3] A Shukla, B Carmans, M Petrov, D Vrancken and M Nesladek, arXiv:2312.14310v2 (2024)