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European Research Council
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Solid State Quantum Technology and Metrology Using Spins

Informe

Información del proyecto

SQUTEC

Identificador del acuerdo de subvención: 267991

Proyecto cerrado

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1 Marzo 2011

Fecha de finalización
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€ 2 308 000,00

Aportación de la UE
€ 2 308 000,00

Coordinado por
UNIVERSITY OF STUTTGART
Germany

Este proyecto figura en...

8 Junio 2016

Final Report Summary - SQUTEC (Solid State Quantum Technology and Metrology Using Spins)

The project SQUTEC aimed at developing diamond and rare earth spin quantum physics and thier application. Specific targets were the detection and investigation of the spin and photonic properties of single rare earth ions as well as the fabrication of photonic elements in the host materials for those ions. Further on, the generation of robust multiparticle entanglement in diamond and the use of diamond defects for quantum sensing was explored. Indeed the project yielded the first detection of single rare earth ions as well as the investigation of their spin properties. More specifically, single Pr ions in a Yttrium Aluminum garnet were detected by a two-photon upconversion process. By using a dynamical decoupling method, the spin coherence times of the rare earth ions were extended to above one ms. A further and initially unplanned achievement was the detection of single silicon vacancies centers in SiC. Here, the first detection of single defects in the material was reported. The optical properties as well as the spin relaxation and dephasing times were investigated and found to be quite comparable to diamond. While prior to the project single spin detection in the aforementioned materials was not accomplished, the diamond spin systems were already explored at the beginning of the project. Here, the fabrication and use of more complex structures as well as use of spin defects for quantum sensing was at the focus of the project. A first major result was the fabrication and investigation of diamond light emitting diodes containing defects at the recombination zone. We succeeded in demonstrating electroluminescence of single defect centers in those structures and investigated the photodynamics of charge carriers recombining of single impurities. Further on, we fabricated the first structures in which we entangled two defects by their magnetic dipole interaction. To that end we implanted two defects in close vicinity (25nm) such that they are strongly coupled. We demonstrated deterministic entanglement with fidelities of around 0.85. In a subsequent work, we showed how to swap that entanglement to the nitrogen nuclear spin achieving a storage time on ms at room temperature. The fidelity of the overall process was amounting to about 0.87.
In the course of the project a variety of sensing modalities were investigated. Most notably we demonstrated detection of the electric field of a single electron spin under ambient conditions. We also succeeded in precision temperature measurements using single defects. To this end, a novel spin decoupling method was used to eliminate noise effects from e.g. magnetic fields on the single spin dynamics, and achieve a mK measurement accuracy over a 1s averaging time and with nanoscale spatial resolution. In a further set of experiments we were exploring methods to enhance the magnetic field

sensitivity in our experiments. For a single defect the magnetic field sensitivity is limited by the dephasing time of the defect (ms at room temperature) and the signal-to-noise ratio for the spin readout. To make efficient use of the measurement time we developed a phase estimation technique to enhance scaling of measurement precision with time beyond the standard quantum limit. We were using improved sample fabrication and implantation technology to enable sensing of nuclear spin magnetism. By employing nitrogen vacancy (NV) defect centers implanted a few nanometers below the diamond surface we succeeded in the defection of a the nuclear magnetic resonance signal of a few hundred proton spins. We have elaborated on this achievement in various directions. On the one hand, we were able to detect the electron spin resonance signature of a single protein under ambient conditions. On the other hand, we imaged nuclear spins in a polymer sample using a scanning probe magnetometer. In this set of experiments we demonstrated magnetic resonance imaging (MRI) experiments with chemical contrast and a spatial resolution of around 20nm. In a separate set of experiments we applied the technique to demonstrate MRI on biological cells.

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