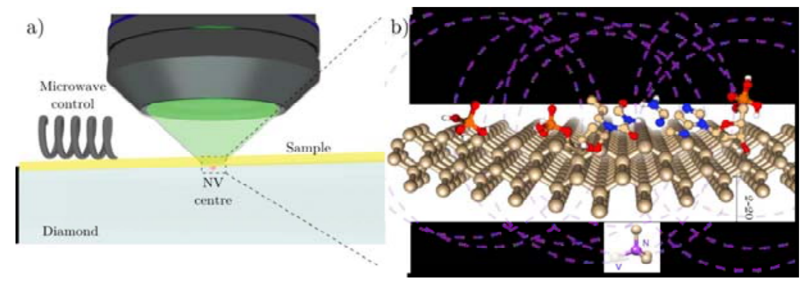
Micro-scale CMOS oscillators for single spin MRI (microCOSSM) | 13GS	Start Date: August 1st 2016

PhD:
Denis Djekic (Ulm)

PIs:
J. Anders (Ulm), F. Jelezko (Ulm), M. Plenio (Ulm)



Abstract: Since its inception in the late 1970's, magnetic resonance imaging (MRI) has made an enormous impact on human health. Yet for all its diagnostic power, conventional MRI technologies are limited to resolutions greater than micrometers and samples consisting of roughly one trillion atoms. The development of single-spin sensitive MRI techniques is expected to revolutionize the MRI field by allowing for non-invasive chemical analysis at the nanoscale. In contrast to electron and scanning force microscopy, the technique is performed under ambient conditions, where molecular dynamics may also be investigated. For example, single spin MRI would enable the direct imaging and structural determination of individual molecules such as membrane proteins, which are notoriously difficult to crystallize for X-ray crystallography. Additional applications include rapid sequencing of individual DNA strands without amplification, and development of a critical tool for rational drug design.
The experimental framework is based on controllable magnetic dipole interaction between shallow NV centers and nuclear spins near the diamond surface. The developed hardware will allow experiments to be performed at magnetic fields of up to 3 T, where chemical shifts can be observed, thereby realizing a key step towards ambient structural determination of molecules at the nanoscale.
To achieve the application-related goals, we will build upon our previously manufactured free-running ESR detectors for cw- and rapid-scan experiments to develop miniaturized PLL-stabilized, voltage controlled oscillators (VCOs) for frequencies between 9 – 84 GHz in a standard CMOS silicon on insulator (SOI) technology, which is adapted specifically for NV sensing.

Recent results:

- First experimental setup incorporating a PLL-stabilized 12 – 14 GHz VCO for precise frequency settingd using an external reference
- First working prototype of a large-scale B_1 source consisting of an array of coupled 12 –14 GHz VCOs
- New techniques enabling nanoscale NMR with NV centers
- Presentation of NV NMR results at GRC conference (Hong Kong 2017)
- Development and demonstration of phase locked NMR detection
- Development and demonstration of pulsed polarization schemes and design of nanoscale NMR setup.

Publications:

S. Schmitt, T. Gefen, F.M. Stürmer, T. Unden, G. Wolff, Ch. Müller, J. Scheuer, B. Naydenov, M. Markham, S. Pezzagna, J. Meijer, I. Schwarz, M. B. Plenio, A. Retzker, L.P. McGuinness, and F. Jelezko. *Sub-millihertz magnetic spectroscopy performed with a nanoscale quantum sensor.* Science **356**, 832 (2017)
I. Schwartz, J. Rosskopf, S. Schmitt, B. Tratzmiller, Q. Chen, L. McGuinness, F. Jelezko, and M.B. Plenio. *A Blueprint for Nanoscale Nuclear Magnetic Resonance.* In preparation and E-Print arXiv:1706.02877
I. Schwartz, J. Scheuer, B. Tratzmiller, S. Müller, Q. Chen, I. Dhand, Z. Wang, Ch. Müller, B. Naydenov, F. jelezko, and M.B. Plenio. *Pulsed Polarisation for robust DNP*. Under Review

Further Collaborators: NVision GmbH (start-up)