Three-dimensional magnetic resonance tomography with sub-10 nanometer resolution

Journal articles

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1. General Information

Dataset title: Three-dimensional magnetic resonance tomography with sub-10 nanometer resolution

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2. Objective/Problem Statement

We demonstrate three-dimensional magnetic resonance tomography with a resolution down to $5.9\ \pm 0.1$ nm.

3. Description

In this work we demonstrate Fourier-accelerated three-dimensional imaging with nanometer-scale resolution. Three microfabricated wires, arranged in a U-shape structure, create linearly independent gradient fields in a plane few microns beneath the structure. This device is used to implement gradient echo pulse sequences. A magnetic field gradient pulse created by a current is applied during one half of the echo sequence. This phase-encodes the position of the NV centers, because an NV center at point $\vec{x}$ acquires a position-dependent phase shift. The various oscillatory signals of all centers can be recovered by an inverse Fourier transform, creating an image of the NV centers in the diamond.

4. Data Format

5. Archive Structure

The data is saved in hdf format. Each hdf file represent a single measurement.

For the one-dimensional measurements (Wire1_1D_Gradient_tomoghraphy_figure1, Wire2_1D_Gradient_tomoghraphy_figure4, Wire3_1D_Gradient_tomoghraphy) the .hdf file contain:

- bin_start: the lower current pulse area of the binned data, unit is [mV*samples] (to convert into [A*s] see python code below)
- bin_end: the upper current pulse area of the binned data, unit is [mV*samples] (to convert into [A*s] see python code below)
- y_real: number of collected photons in the first 0.5µs of the readout pulse, from all current pulses with the area between bin_start and bin_end. Over all readouts where y_real is non zero
- norm_real: number of collected photon in the last 0.5µs of the 4µs readout pulse, over all readouts where y_real is non zero
- nbins_real: number of readout where y_real is non zero

For the two-dimensional measurements (2D_Gradient_tomoghraphy_figure3_b_and_c, 2D_Gradient_tomoghraphy_figure3_d_and_e, 2D_Gradient_tomoghraphy_figure3_f_and_g) the .hdf file contain:

- no_photons__SequenceEndingWith_pi_x: number of collected photons in the first 0.5µs of the readout pulse. Over all readouts which is non zero. For sequences ending with π/2x
- no_photons__SequenceEndingWith_pi_y: number of collected photons in the first 0.5µs of the readout pulse. Over all readouts which is non zero. For sequences ending with π/2y
- Background_SequenceEndingWith_pi_x: number of collected photon in the last 0.5µs of the 4µs readout pulse, over all readouts where no_photons is non zero. For sequences ending with π/2x.

- Background_SequenceEndingWith_pi_y: number of collected photon in the last 0.5μs of the 4μs readout pulse, over all readouts where no_photons is non zero. For sequences ending with π/2y.
- number_bins_SequenceEndingWith_pi_x: number of readout where no_photons is non zero. For sequences ending with π/2x.
- number_bins_SequenceEndingWith_pi_y: number of readout where no_photons is non zero. For sequences ending with π/2y.
- xAxis_Window length: number of samples (number of points on the x axis)
- uAxis_Window length: number of samples (number of points on the y axis)
- xAxis_inverse of the sampling rate_ns: sample spacing in [ns]
- yAxis_inverse of the sampling rate_ns: sample spacing in [ns]

For the three-dimensional measurements (3D_Gradient_tomoghraphy_figure2) the .hdf file contain:

See structure of the two-dimensional measurement above

6. System Requirements

The code is written in python3, all packages needed to recreate the figures are listed at the top of each analysis code.

Code

```
SCARD_SRATE = 500e6 # samples / s

MICROSEC = 1e-6

RES = 50 # Ohm

PROBE_RATIO = 10


def integral_to_as(integral):

    # converts raw integral value (in mV*samples) to current integral value

    # in mA * us

    # 1. divide by number of samples per microsecond to convert to mV * us

    # 2. multiply by probe ratio to compensate for differential probe

    # 3. divide by resistance of current sense resistor to get mA * us

    # 4. multiply by 1e-9 to get A*s

    return integral / (SCARD_SRATE * MICROSEC) * PROBE_RATIO / RES * 1e-9
```