Relaxation and Readout Visibility of a Singlet-Triplet Qubit in an Overhauser Field Gradient

Martin Brühlmann

University of Basel

December 2, 2011
Observation: DNP reduces Overhauser field gradients and induces net polarization.

This paper shows

- DNP enhances Overhauser field gradients ($\Delta B_z$) and induces net polarization

- $\Delta B_z$ leads to a mixing of $S(1,1)$ and $T_0(1,1)$

- influence of increased $\Delta B_z$ and measurement detuning on
  - qubit readout Visibility
  - $T_1$
GaAs/Al$_{0.3}$Ga$_{0.7}$As, 2DEG 100nm below

- electron density: $2 \times 10^{15} m^{-2}$
- mobility $20 \frac{m^2}{Vs}$
- $B_{ext} = 200mT$
- reflectometry measurement with SQD
Energy level diagram

(a) (0,2)S

(b) (0,2)T

\[ \begin{align*}
(0,2)T_+ & \to (0,2)T_0 \to (0,2)T_+ \\
S & \to T_0 \\
T_+ & \to \text{fast} \\
\text{slow} & \to \text{diabatic} \\
\tau_R \to 0 & \to \text{adiabatic}
\end{align*} \]
Pumping Cycle
Probe Cycle

\[ (0,2)S \rightarrow T_0 \rightarrow S \]

\[ S \rightarrow T_0 \rightarrow S \]

\[ (0,2)T_+ \rightarrow (0,2)T_0 \rightarrow (0,2)T_+ \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]

\[ \Gamma_T \ll \Gamma_S \]
Measurements

- $P_s$: Probability of a singlet after probe cycle
- $\Delta t$: time between pump- and probe cycle
- $\tau_s$: mixing/precession time
- $f_s$: frequency
- $\Delta B_z$: nuclear field differences
- $V$: Visibility
Measurements

- $\langle v_{rf} \rangle$: averaged output voltage of SQD
- $t$: measurement time
- $T_1$: Triplet relaxation times
- $\Delta B_z$: nuclear field differences
- $\epsilon$: detuning (of measurement)
- $V$: Visibility
Measurements

- $V$: Visibility
- $\Delta B_z$: nuclear field differences
- $T_1$: Triplet relaxation times
- **$V$: Visibility**
- **$\Delta B_z$: nuclear field differences**
- **$T_1$: Triplet relaxation times**
- **$V_R$: ramp-time-dependent factor of $V$, here $V/V_T$**
- **$\tau_R$: ramp time**
- **$\tau_R^{-1}$: ramp rate**
- **$B_{90\%}: \Delta B_z$, where $V_R = 0.9$**
• Overhauser field gradients ($\Delta B_z$) can be increased by electron-nuclear spin pumping

• $\Delta B_z$ leads to a mixing of $S(1,1)$ and $T_0(1,1)$

• The different Visibilities and $T_1$:
  - decrease with increasing $\Delta B_z$
  - decrease slower on $\Delta B_z$ with larger measurement detuning $\varepsilon_M$
  - are independent on the external magnetic field

• $T_1$ is independent on the ramp-time

• $V$ decreases faster with longer ramp-time