Thermal susceptibility of hole spins

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In recent years, spectacular advances have been made with semiconductor spin qubits. In particular, processors containing a few spin qubits have been demonstrated, based on electrons [1] in silicon and holes in germanium [2]. Unfortunately, the simultaneous operation of qubits on these platforms has shown an unanticipated limitation: the energy locally dissipated by qubit control pulses heats up the environment [3]. For reasons still poorly understood, this leads to changes in their Larmor frequency and ultimately limits their gate fidelity. Recently, the thermal susceptibility of electron spin qubits in silicon has been studied, i.e. the changes of Larmor frequency in response to a temperature change [4]. The authors reported variations of around 1 MHz over 200 mK, with a sweet spot around 250 mK where the thermal susceptibility cancels out. This work triggered interest and to date a phenomological model of randomly placed dipoles unfreezing with increasing temperature seems to capture the experimental behavior.
In this study, we extend these investigations to hole spins in silicon. Thanks to their gyromagnetic matrix, holes exhibit a highly anisotropic response to the external magnetic field. In particular, their electrical susceptibility (LSES) depends on the orientation of the magnetic field, and can even become zero for certain preferential orientations, called electrical sweet spots [6]. By studying how the temperature dependence of the Larmor frequency changes with the orientation of the magnetic field, we have been able to show that their thermal susceptibility is very strongly correlated with their LSES. This demonstrates that the underlying mechanism for thermal susceptibility is the spin-orbit interaction. We also show that some specific magnetic field orientations provide a thermal sweet spot, at which the temperature sensitivity cancels out, providing a route to circumvent this bottleneck. Ultimately, we provide a full model of the device accounting for the LSES. Including random electric dipoles surrounding the spin qubit, we can faithfully reproduce the observed behaviour and shine light on the thermal susceptibility of spin qubits.

References

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Figures

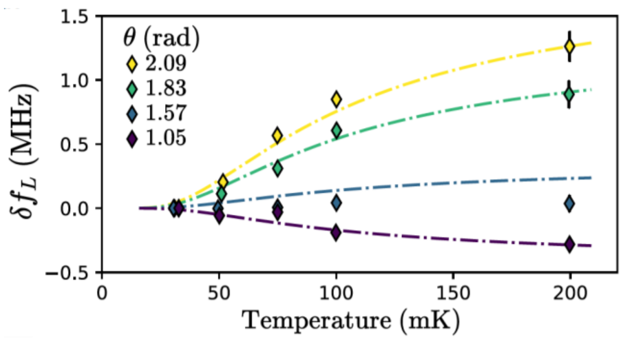

Figure 1: Temperature sensitivity of a single hole spin qubit Larmor frequency, for 4 different magnetic field orientations. The susceptibility can change sign and cancels out for a specific orientation (light blue points)