Micro-magnet technology for electrical control of single electron spin

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The rapidly developing fields of spintronics and quantum information science have led to a strong interest in the ability to probe and coherently manipulate electron spins at the single spin level. Electron spin resonance (ESR) is a powerful technique to manipulate spins but it must be time controlled and selective for each spins. Application of an external high-frequency magnetic field in a static uniform Zeeman field is a straightforward approach for ESR but usually not useful to address individual spins. In contrast, by mixing the spin and orbital degrees of freedom in a controlled way, electron spin can be manipulated electrically without the need of an external high-frequency magnetic field. The method is to modulate a quantum dot electric field in a non-uniform static magnetic field [1]. We demonstrate the concept by displacing at microwave frequencies a single electron spin in the stray field produced by a micro-magnet integrated to a quantum dot device [2]. We find that the slanting component of the stray magnetic field enables fast spin rotations for relatively small ac electric fields whilst the Zeeman component shifts the quantum dot resonance frequency from neighbouring spins. By bursting the microwave, we also investigated the coherence of the rotations. The large magnetic field gradient produced by the micro-magnet has various other important applications. It serves as an effective spin read-out scheme and allows the addressing of individual spins if a common ESR gate is used. Our results demonstrate the feasibility of manipulating and addressing single electron spin electrically in a scalable way, without relying on g-factor modulation or spin-orbit interaction.

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