[0082] Figs. 5A-5D show the initialization process for initializing double quantum dots with singlet-triplet qubits, including the probability of initialising particular states depending on system parameters. Energy dependent tunneling to a reservoir would be compromised by the fact that the electron spin is driven continuously, i.e., the driving microwave field is not turned off for the readout step. This allows for the readout of some processing elements while the other elements remain operational.

[0083] It is important to note that the Pauli blockade will isolate singlet states (e.g., $|S(0,2)\rangle, |S(1,1)\rangle$). Singlet states have zero total spin and are invariant under rotations. Therefore, singlet states are independent of the choice of basis (frame) for describing spins. Singlet states are also immune to the external global field 302. This allows for pairwise readout and initialization in an isolated double dot system without the need for a nearby reservoir of electrons.

[0084] The behavior of each eigenenergy in the dressed five-level system is investigated as a function of the detuning ϵ between the two quantum dots. This is shown in Figs. 5A-C. In particular, Fig. 5A shows an energy diagram as a function of potential detuning when there is no difference in Zeeman energies between the two quantum dots (i.e., when $\Delta\nu_1 = \Delta\nu_2 = 0$), and Fig. 5B shows an energy diagram as a function of potential detuning when the driving frequency hits the center of the Zeeman energy differences (i.e., when $\Delta\nu_1 = -\Delta\nu_2$. The lines show the contributions of each state $|S(0,2)\rangle$, $|S(1,1)\rangle$, $|T_{0,\rho}\rangle$, $|T_{+,\rho}\rangle$ and $|T_{-,\rho}\rangle$. The black arrows show the path of initialization, either crossing the anti-crossing (in both Figs. 5A and 5B) or avoiding it (only in Fig. 5B). Fig. 5C shows the singlet state in the (0,2) configuration $|S(0,2)\rangle$ with an energy axis focused near the spin conserving transition. The initialization sequence is shown in Fig. 5D with time on the vertical axis, and detuning on the horizontal. For each initialization, detuning ϵ is ramped for a particular ramp time at a constant rate from a positive to a negative energy – see Fig. 5D.

[0085] To start with, the case where energy detuning between the two dots ϵ is ramped to transfer $|S(0,2)\rangle$to $|S(1,1)\rangle$ is considered. In one example the qubit frequency detuning may be such that there is no difference in the Zeeman energies between the states of the two quantum dots (i.e., $\Delta\nu_1 = \Delta\nu_2 = 0$). In this case there is no coupling term, which is demonstrated in Fig. 5A with an absence of an anti-crossing between $|S(1,1)\rangle$ and $|T_{-,\rho}\rangle$, allowing for a smooth transition from $|S(0,2)\rangle$ to $|S(1,1)\rangle$.

quadrant (in Fig. 9D) has positive sign, and the one in the second quadrant has negative sign. The projected areas therefore sum to zero for the sinusoidal driving field, but not for the continuous drive which has a net circular area projected onto the *x-y* plane. Hence, where the SMART technique cancels out both first and second order noise, the dressed qubit only provides first order noise cancellation.

[0135] Information about the single-qubit operator can be found in the slope of $\vec{s}(\tau)$ at τ = 0 relative to $\tau = T$. Parallel slopes correspond to the identity operator, which is the case for the ideal noise cancellation in Fig. 9D represented by $U_0(T)$ (solid and hollow arrow parallel). Perpendicular slopes correspond to $\sqrt{\mathrm{X}}$ and $\sqrt{\mathrm{Y}}$ gates etc. The optimal modulation conditions for the global field can be identified by forcing the first and second order Magnus expansion series terms to zero. The optimal modulation frequency $f_{\mathrm{mod}}^{\mathrm{opt}}$ is found to have the following relation with Ω_{R}

$$f_{\mathrm{mod}}^{\mathrm{opt}} = \Omega_{\mathrm{R}}\sqrt{2}\,/\pi j_i \quad (4)$$

[0136] where j_i is solution i to the Bessel function of zeroth order.

[0137] The duration of one period of the global field is denoted T_{mod}. For a SMART qubit initialized in the plane perpendicular to the global field axis, driven at $f_{\mathrm{mod}}^{\mathrm{opt}}$ with normalized amplitude and $\Delta\nu(\tau) = 0$, a positive rotation of $\sim 3\pi/2$ followed by a negative rotation of the same angle occurs for every T_{mod} of the global drive, as shown in Fig. 9B. The dressed qubit on the other hand continuously rotates without change in angular acceleration. The back and forth rocking of the SMART qubit and the continuous rotation of the dressed qubit about the global field axis contributes to continuous echoing.

[0138] Note that the resulting control axes that emerge from this modulation scheme are not parallel to the coordinate system used to describe the Hamiltonian. Instead, the rotation axes w and v can be calculated from the time evolution operators.

[0139] FIG. 10A shows rotation axis parameter ϕ_r for axis ν_v. Fig. 10B rotation axis parameter ϕ_r for axis ν_w. Fig. 10C shows rotation axis parameter θ_r for axis ν_v and Fig. 10D shows rotation axis parameter θ_r for axis ν_w of the SMART method for different values of control amplitude $\nu_{v,w}$ and phase offset between the global microwave field 302 and the gate modulation ϕ_{mod} . The rotation axes are diagonal to the axes of the coordinate system. Phase $\pi/2$ has been indicated with a dashed horizontal line. The rotation efficiency η is shown in Figs. 10E and 10F with the maximum values of 53.9% and 37.3% for axis v and w, respectively.

and SMART control techniques. Fig. 17A also shows an amplitude modulated sinusoidal global field 1704 applied to the apparatus 1700 and a plot 1706 showing the *x* gate and *y* gate modulated signals applied to the qubit via the electrodes G1, G2.

[0152] Fig. 17B shows a cross-section of the device from the dashed line shown in Fig. 17A. As seen in Fig. 17B, the quantum dot is formed at the interface between a silicon 28 substrate and a silicon dioxide layer. Figs. 17C and 17D show the basis transformation and the qubit stability diagram used for readout, respectively.

Experiment 1: Coherence time of qubits in the dressed and SMART protocols

[0153] In a first experiment, a given qubit (e.g., qubit 304A of the qubit array of Fig. 3A) is prepared in the $|i\rangle$ state, and is subject to a continuous driving microwave field 302 (i.e., constant for the dressed control method and sinusoidally modulated for the SMART control method) for a certain wait time. Subsequently, the qubit is projected back onto the measurement basis and the state probability is recorded (similar to traditional Ramsey experiment). The decay rate of the qubit indicates the noise performance of the continuous driving.

[0154] FIG. 18 shows the Ramsey experiment using the SMART qubit method. In particular, Fig. 18A shows the Ramsey experiment results where the period of the global modulated field is varied. Fig. 18B shows extracted decay rates (black line) fitted to the absolute value of the Bessel function of zeroth order. Figs. 18 C and 18D show comparison between bare qubit (100 shots, six repeats), dressed (300 shots, two repeats) and SMART qubit method (at $T_{\mathrm{mod}} = 24.12\ \mu s$) decay times (left column), together with the respective microwave pulse sequences (right column). In this experiment, $\sqrt{\mathrm{X}}_{\mathrm{rot}}$ is in the rotating basis.

[0155] Driven spin qubits are dominated by noise at the frequency of the driving field 302. For the SMART qubit method with a modulated driving field, the coherence time is also sensitive to the initial state in the plane perpendicular to the quantization axis. T_{decay} is defined as the measured coherence time of the spin rotation resulting from the driving field, when initialized to $|i\rangle$.

[0156] After initializing the qubit to $|i\rangle$ via a $\pi/2$ rotation about i (x in the rotating frame) the modulated driving about the same axis is turned on for a certain wait time, t_{wait}, followed by a final $\pi/2$ rotation about $i[\sqrt{\mathrm{X}}_{\mathrm{rot}} - t_{\mathrm{wait}} - \sqrt{\mathrm{X}}_{\mathrm{rot}}$, see Fig. 18E. The spin is then measured every n-th period of the sinusoidal modulation, where the modulated driving itself ideally equates to an identity operation after every period. By keeping Ω_{R} fixed and varying the period