Supplementary Information

Intrinsic Metastabilities in the Charge Configuration of a Double Quantum Dot

D. E. F. Biesinger,[1,*] C. P. Scheller,[1,2,*] B. Braunecker,[3]
J. Zimmerman,[4] A. C. Gossard,[4] and D. M. Zumbühl[1,†]

[1]Department of Physics, University of Basel,
Klingelbergstrasse 82, CH-4056 Basel, Switzerland
[2]Swiss Federal Laboratories for Materials Science and Technology,
EMPA, Überlandstrasse 129, CH-8600 Dübendorf, Switzerland
[3]Scottish Universities Physics Alliance,
School of Physics and Astronomy, University of St Andrews,
North Haugh, St Andrews KY16 9SS, United Kingdom
[4]Materials Department, University of California, Santa Barbara, CA93106, USA

[*]equally contributing authors
[†]Electronic address: `dominik.zumbuhl@unibas.ch`

I. TEMPERATURE DEPENDENCE OF THE DIAMOND OF METASTABILITY

Figure S1 of the supplementary material illustrates how the switching diamond shrinks and finally disappears when increasing temperature, due to faster switching rates at higher temperatures, eventually exceeding the sensor bandwidth.

II. OPTIMIZING SINGLET-TRIPLET QUBITS

The phonon-mediated decay of the singlet-triplet qubit (at the $(1,1)$-$(0,2)$ transition) has been predicted to be strongly suppressed for an unbiased double dot (DD) (i.e. DD at zero detuning), and unbiased singlet-triplet qubits have been predicted to be protected against electrical noise, as described in Kornich et al., Ref. [18] (main manuscript). Interestingly, minimizing qubit phonon decay and charge noise sensitivity at zero detuning is not contradictory to achieving low qubit relaxation rates from the electron reservoir exchange mechanism described in our manuscript. In fact, our model gives a prescription on how to suppress electron exchange at zero detuning, as described below.

The electron exchange process described in the manuscript gives a rate of escape out of the $(1,1)$ singlet-triplet qubit basis states to an intermediate state (either $(0,1)$ for an electron tunneling off, or $(1,2)$ for an additional electron tunneling on). The process either ends up in the $(1,1)$ state, but with the spin state randomized, or in the $(0,2)$ state, defining a leakage rate out of the logical qubit subspace. Both possibilities contribute to the T_1-time of the singlet-triplet qubit. The relevant parameters controlling the escape rate are the energy separations between the reservoir chemical potentials and the relevant DD levels. Thus, one can suppress electron exchange while maintaining zero detuning by maximizing the energy separation between the DD level and the reservoir chemical potentials. This leads to a working point located exactly in the middle of the diamond of metastability, i.e. in the middle between the two adjacent triple points on the zero detuning line.

Should the electron exchange still be a limiting factor at this biasing point, it can be further suppressed by reducing the reservoir tunnel rates (linear suppression) or by reducing temperature (exponential suppression). If necessary, a compromise between charge noise sensitivity and electron exchange rate can be chosen, by pulling $(1,1)$ deeper below the reservoir chemical potential, and simultaneously pushing $(1,2)$ higher up above the reservoir chemical potential. Because raising the $(1, 2)$ energy occurs together with increasing the $(0, 2)$ energy, this means introducing some amount of detuning. We note that the electron exchange rate is very effectively (i.e. exponentially) suppressed with increasing energy separation of the DD levels from the reservoir chemical potentials. Finally, increasing the energy separation Δ between the two triple points can further immunize the device against the electron exchange process. This might be achieved with a smaller device layout with steeper confinement potentials, e.g. obtained by bringing the 2D electron gas plane closer to the gates, or using additional gates, or by going to other dot realizations e.g. in nanowires or nanotubes.

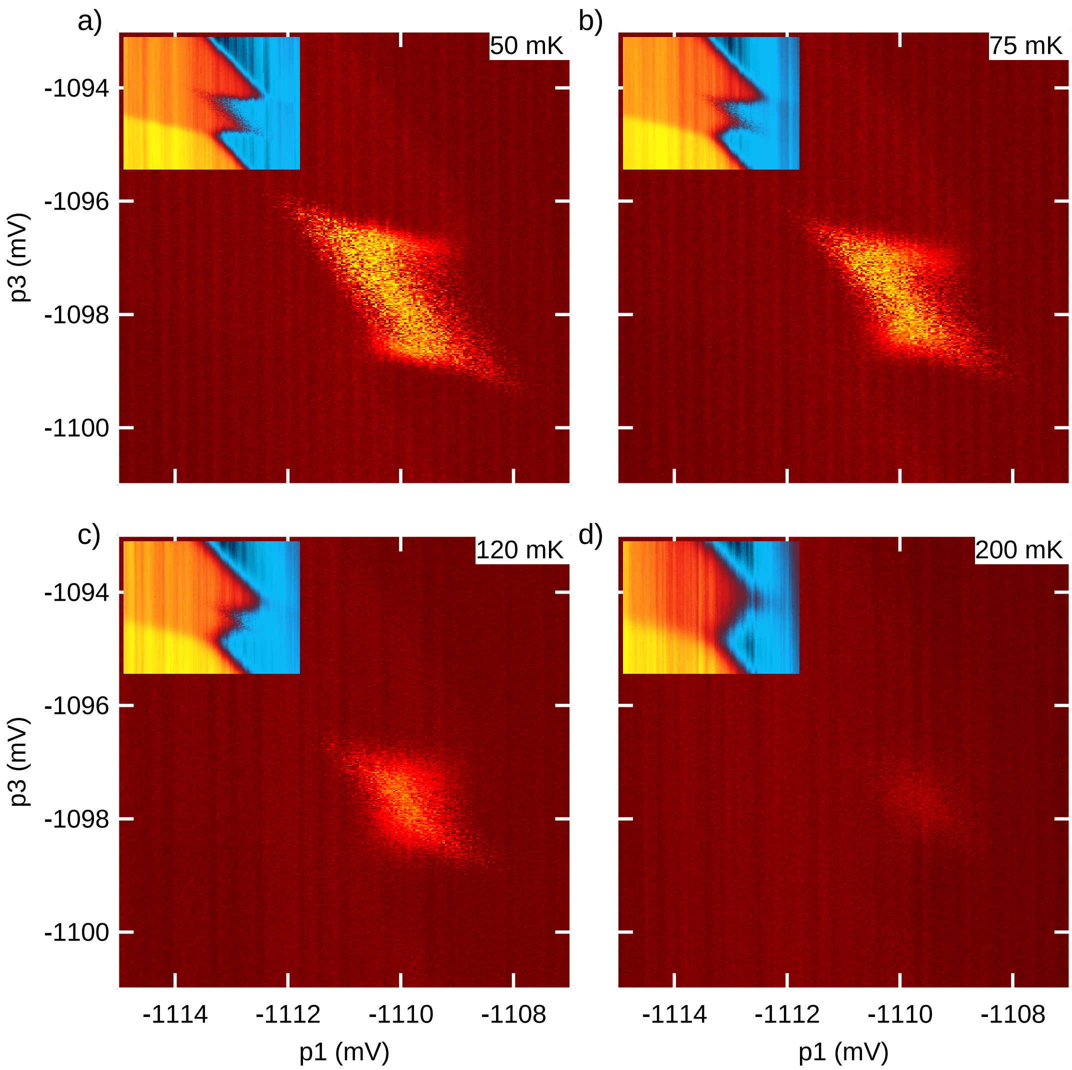

FIG. S1: (a) Standard deviation sdev(g_{CC}) of the left sensor conductance, measured in the region of the (0,0) to (1,1) transition at a refrigerator temperature T_{MC} of 50 mK. The simultaneously measured conductance g_{CC} is shown in the inset (raw data, no numerical derivative done). Equivalent measurements at elevated temperatures are shown in panel (b),(c),(d) for $T_{MC} = 75$ mK, 120 mK, and 200 mK, respectively. We note that all panels are plotted against the same gate voltages and identical color scales. The switching rate at high temperatures increases beyond the bandwidth of our system, resulting in an apparent shrinking of the diamond with T_{MC}, as discussed in the main article. We note that sensor backaction due to the larger sensor bias of 75 μeV results in a more pronounced S-shape, here appearing as a Z-shape. The corresponding Fig. 3 in the main article was measured with only 30 μeV sensor bias.