Erratum: Trapping potentials and quantum gates for microwave-dressed Rydberg atoms on an atom chip [Phys. Rev. Research 8, 013088 (2026)]

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We have discovered an important omission in the treatment of the cavity-mediated quantum gates between the trapped Rydberg qubits.

Starting with the states $|0, n\rangle$ and $|1, n\rangle$ for each atom $j = 1, 2$ and the cavity mode containing n photons, upon adiabatic elimination of the nonresonant cavity mode, we obtain not only the second-order transition amplitude $G \approx -g^2/\delta_c$ between the two-atom states $|10, n\rangle$ and $|01, n\rangle$ in Eq. (13), but also the single-atom level shifts $-Gn$ for state $|0, n\rangle$ and $G(n+1)$ for state $|1, n\rangle$, which were not mentioned in the article. These single-atom level shifts mean that the two-qubit states $|10, n\rangle$, $|01, n\rangle$, $|00, n\rangle$, and $|11, n\rangle$ have the corresponding energies $E_{10} = E_{01} = G$, $E_{00} = \delta_c - 2Gn$, and $E_{11} = -\delta_c + 2G(n+1)$. Hence, the energies E_{10} and E_{01} of states $|10, n\rangle$ and $|01, n\rangle$ and their exchange interaction rate G are n independent, and the state transfer via SWAP and entanglement generation via $\sqrt{\text{SWAP}}$ operations between them as described in the article hold. But the n dependence of energies E_{00} and E_{11} of states $|00, n\rangle$ and $|11, n\rangle$ would scramble the fidelity of the iSWAP and $\sqrt{\text{SWAP}}$ gates acting on an arbitrary input state $|\Psi_{\text{in}}\rangle = c_{00}|00, n\rangle + c_{01}|01, n\rangle + c_{10}|10, n\rangle + c_{11}|11, n\rangle$ of two qubits, since the cavity photon number n is a random variable with the probability distribution $P_{\bar{n}_{\text{th}}}(n)$.

During the evolution, the states $|00, n\rangle$ and $|11, n\rangle$ acquire the n-dependent phase shifts $\varphi_{00,11} = -E_{00,11}t = \pm 2Gnt$, where we dropped the n-independent phases $-\delta_c t$ and $(\delta_c - 2G)t$ that can be easily amended or absorbed in the state definition. Since for any n these phase shifts have the same magnitude but opposite sign, and provided n does not change during the evolution time t, they can be completely canceled by using an echo sequence that involves the application of strong ($\Omega_q \gg |G|$), resonant ($\omega_q = \omega_{10} + G$) microwave π pulses to all the atoms. Thus, for the gate duration t_{gate} [$t_{\text{gate}} = t_{\text{tr}} = \pi/(2|G|)$ for iSWAP and $t_{\text{gate}} = t_{\text{tr}}/2$ for $\sqrt{\text{SWAP}}$], the first global pulse is applied at time $t = t_{\text{gate}}/2$, resulting in the transformation $|0\rangle \to -i|1\rangle$ and $|1\rangle \to -i|0\rangle$ for both atoms. The evolution involving the exchange interaction then proceeds until $t = t_{\text{gate}}$, at which time the second global π pulse is applied to restore the target state of the gate.

During the evolution involving the echo sequence, the relaxation of the cavity field resulting in change of n and the decay of the Rydberg qubit states reduce the gate fidelity exactly as simulated in the article for the state transfer or entanglement generation. Thus, with these corrections, the results and conclusions of the paper, and its claims to realize quantum gates for Rydberg atoms, hold.