Supplemental Material for
"Escaping detrimental interactions with microwave-dressed transmon qubits"

Z. T. Wang,[1,2] Peng Zhao,[3] Z. H. Yang,[1,2] Ye Tian,[1] H. F. Yu,[3,4] and S. P. Zhao[1,2,4,5,6]

[1] *Beijing National Laboratory for Condensed Matter Physics,*
Institute of Physics, Chinese Academy of Sciences, Beijing 100190, China
[2] *School of Physical Sciences, University of Chinese Academy of Sciences, Beijing 100190, China*
[3] *Beijing Academy of Quantum Information Sciences, Beijing 100193, China*
[4] *Hefei National Laboratory, Hefei 230088, China*
[5] *CAS Center for Excellence in Topological Quantum Computation, UCAS, Beijing 100190, China*
[6] *Songshan Lake Materials Laboratory, Dongguan 523808, China*

This Supplemental Material provides a brief description of the device and measurement system.

I. DEVICE DESCRIPTION

Fig. S1 schematically shows the superconducting 21-qubit device with tunable couplers used in this work, which is fabricated using the flip-chip technology [1]. We use Q_3 to mimic a fixed frequency qubit in the present experiment with Q_1 acting as an artificial coherent defect and C_1 as the coupler to tune the coupling strength between them. The device has very small crosstalk among the Z control lines (~ 0.1 %) and relatively small XY crosstalk on the order of 1%. Q_3 (Q_1) has an anharmonicity of $\alpha/2\pi$ = 284 (280) MHz and the maximum frequency at the sweet point of $\omega_q/2\pi$ = 5.330 (5.263) GHz. The readout frequency of Q_3 (Q_1) is 4.159 (4.228) GHz, below the qubit frequency. C_1 is also a qubit [2] but without readout resonator and its maximum frequency exceeds 12 GHz. The frequency of C_1 can be tuned through a Z control line so that the effective coupling strength can varied between -12 and 0.5 MHz. The coherence times, including the energy relaxation time T_1 and Ramsey dephasing time T_2^*, are among the main quantities studied in this work and are described in detail in the main text.

II. MEASUREMENT SETUP

Our device is mounted in a double-layer magnetic shield in a BlueFors dilution refrigerator with base temperature of 10 mK [3]. Details of the measurement setup are shown in Fig. S2, in which the qubit readout, qubit control, and coupler control circuits can be seen. The qubit readout part contains the readout input and output lines (light blue). The multitone readout signals pass through a total of 69 dB attenuation into the transmission line, ensuring that the signal amplitude reaching the sample is large enough while suppressing thermal noise as much as possible. Then the readout signals with the qubit state information pass through four circulators with 60 dB isolation and are amplified by a high electron mobility transistor (HEMT) and two room temperature amplifiers, and finally are demodulated by the analog digital converter. The qubit XY and Z control lines are combined by a duplexer at room temperature and transmitted through one qubit control line (dark green) with attenuators and a CR124 filter to the device. The coupler has only one Z control line (purple) for the control of its frequency.

---

[1] Xuegang Li, Yingshan Zhang, Chuhong Yang, Zhiyuan Li *et al.*, Vacuum-gap transmon qubits realized using flip-chip technology, Appl. Phys. Lett. **119**, 184003 (2021).

[2] F. Yan, P. Krantz, Y. Sung, M. Kjaergaard, D. L. Campbell, T. P. Orlando, S. Gustavsson, and W. D. Oliver, Tunable Coupling Scheme for Implementing High-Fidelity Two-Qubit Gates, Phys. Rev. Appl. **10**, 054062 (2018).

[3] Xue-Gang Li, Hui-Kai Xu, Jun-Hua Wang, Ling-Zhi Tang *et al.*, Mapping a topology-disorder phase diagram with a quantum simulator, arXiv:2301.12138.

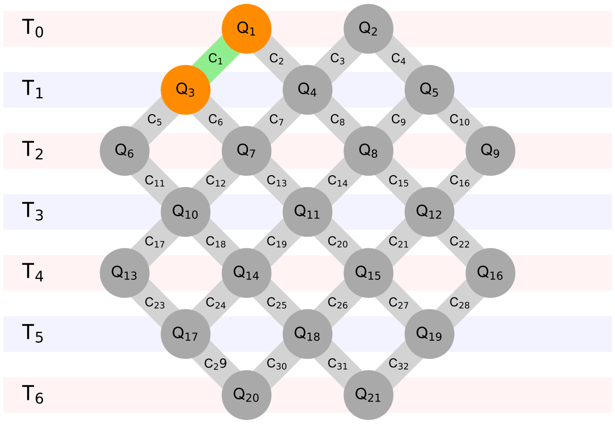

FIG. S1. Schematic of the superconducting 21-qubit device with tunable couplers used in this work, which is fabricated using the flip-chip technology [1]. Here Q, C, and T denote frequency-tunable qubit, frequency-tunable coupler, and transmission line for measurement, respectively. Q_3 is used in the present experiment with Q_1 acting as an artificial coherent defect and C_1 as the coupler to tune the coupling strength between them.

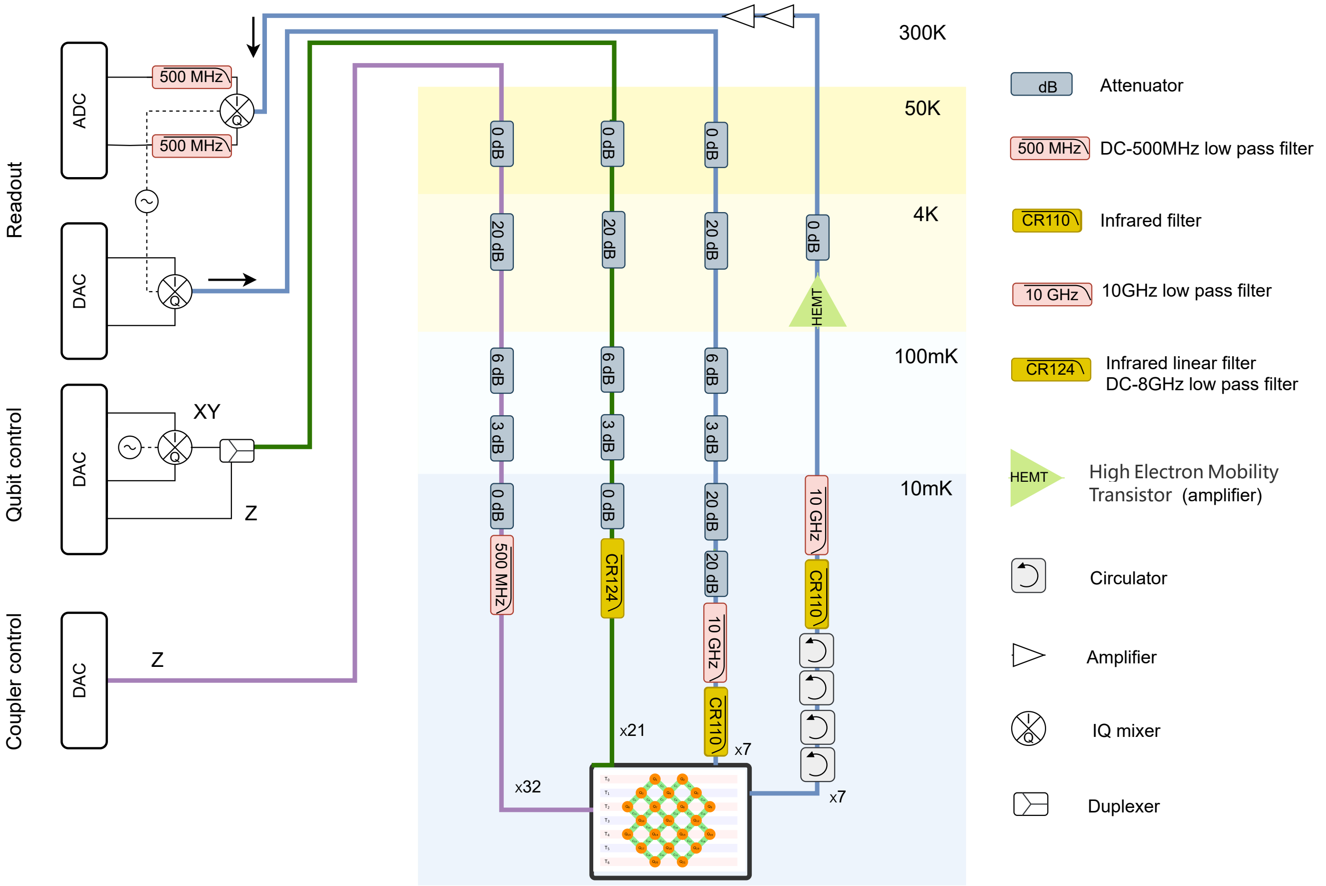

FIG. S2. Measurement setup including the qubit control (XY and Z), qubit readout (input and output), and coupler control (Z), respectively.