Stabilizing method of a double quantum dot towards long-term and stable spin-qubit operation

Tokyo Institute of Technology.[1], National Institute of Advanced Industrial Science and Technology.[2],

°Sayyid Irsyadul Ibad[1], Hiroki Takahashi[1], Shimpei Nishiyama[1,2], Kimihiko Kato[2], Yongxun Liu[2], Shigenori Murakami[2], Takahiro Mori[2], Raisei Mizokuchi[1], Jun Yoneda[1], Tetsuo Kodera[1]

E-mail: ibad.s.aa@m.titech.ac.jp

Semiconductor has been a compelling material in the field of quantum information including quantum computing [1]. Qubits can be realized by harnessing the spin properties of a semiconductor charge confined in an island called quantum dot. Operating this type of qubit requires the device to be adjusted to suitable gate voltage conditions. However, various mechanisms such as charge noise often cause shift and drift, interfering in long-time qubit operation. The situation becomes more complex when integrating multiple qubits as the number of gate electrodes increases. While single gate-voltage feedback control has previously been developed, there is scant research on multi-dimensional gate voltage stabilization.

Here we implement a method to keep the potential conditions of multiple gate voltages of a quantum device in a desirable regime towards long-time spin-qubit operation. We use a physically-defined silicon double quantum dot (DQD) [2] of a typical multi-gate layout as a testbed. We first use a PID controller as the one-dimensional stabilization method (Fig. 1). We then extend it to multi-dimensional control by rapidly switching the control axes and incorporating a method inspired by gradient decent. We observe that our method can stabilize the potential conditions for hours, effectively suppressing the low frequency noise (below ~ 1 Hz). We furthermore confirm the effectiveness of our method by measuring the current fluctuations under artificial disturbance. We anticipate this work will contribute towards reducing charge noise effects on large-scale spin qubit devices as well as reducing the readjustment time in near-term devices.

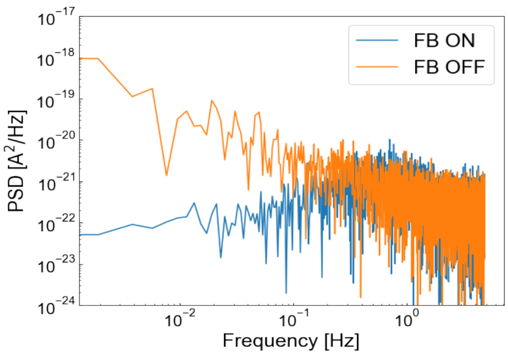

Fig. 1 Power spectral densities (PSDs) of current noise measured in a DQD, with PID feedback (FB) control turned on (blue) and off (orange). Noise below ~0.5 Hz is suppressed. The values of the PID parameters are P = 0, I = -1×10^{8} and D = 0.

This work was financially supported by MEXT Quantum Leap Flagship Program (MEXT QLEAP) Grant No. JPMXS0118069228, JST Moonshot R&D Grant Number JPMJMS2065, JST CREST (JPMJCR1675), JSPS KAKENHI Grant Numbers, JP20H00237, JP20K15114, JP21K14485, The Precise Measurement Technology Promotion Foundation, and Suematsu Fund.

[1] X. Zhang *et al.*, *National Science Review* **6**, 32-54 (2019).

[2] K. Yamada, T. Kodera, T. Kambara and S. Oda, *Applied Physics Letters* **105**, 113110 (2014).