EEEN40690 Quantum Computing

Homework 4
Homework Problem Set for Topic 6: Decoherence

Instructions

- This is homework set 4 of 8. This homework set accounts for 5% of the marks for this module.
- In your report, please provide answers to the questions of this homework set. Explain clearly how the answers are obtained and what are their meaning or interpretation. Include relevant intermediate steps of the solution and explain your approach.
- Make sure that the report is readable, and the graphs (if any) are presented according to scientific/engineering standards.
- Some of the questions of the homework sets and the projects in this module may be open-ended and include a research component. Please formulate clearly your hypothesis and explain what will prove (or disprove) your hypothesis. Make sure that you provide sufficient evidence (analytical results, numerical results, modelling and simulations, evidence from the literature) to support your answer to open-ended or research problems.
- The report must be submitted online through UCD Brightspace:

  My Brightspace → EEEN40690 → Assessment → Assignments → Homework 4 (Homework for Topic 6: Decoherence)
- Late submissions will be accepted but a penalty will apply. In the case of late submissions, this module applies the standard UCD policy.
- Plagiarism and copying are offences under the terms of the Student Code, and you should be aware of the possible consequences.

Aim

The aim of this homework assignment is to reinforce the knowledge on the characterisation and control of a qubit.

- Characterisation experiments: Energy Relaxation and Ramsey experiment
- Qubit metrics - T_1 and T_2 times.

Problem Set

This homework uses a measured data set that characterises a spin qubit from Reference [1]. The **supplementary material** for this paper contains the data from two characterisation experiments for three qubits fabricated in the same technology. The first experiment is energy relaxation; the second experiment is the Ramsey experiment. For curve fitting you should look at using `https://docs.scipy.org/doc/scipy/reference/generated/scipy.optimize.curve_fit.html`.

1. From the given data sets, identify the energy relaxation experiment data, sketch its equivalent quantum circuit and extract the relaxation times T_1 of the thee qubits. Using the graphs, comment on the meaning of the T_1 time. You should fit to $Ae^{-Bt} + C$ to identify the T_1 time.
2. In the data set, identify the Ramsey experiment data, sketch its equivalent quantum circuit, and extract the dephasing time T_2^* of the thee qubits. Using the graphs, comment on the meaning of the T_2^* time.
   - You should first write a function to extract the envelope of the Ramsey oscillation. This could be as simple as extracting the peaks of the decaying sinusoid.
   - Using the extracted envelope points, you should then fit using $Ae^{-Bt} + C$ to identify the T_2^* time for all 3 qubits.
3. In your own words, what is the meaning of the Hahn echo experiment? Do you expect T_2^H be less or greater than T_2^*? Why? You should do some further research for this question and go beyond the discussion in the lecture notes.

References

[1] K. Takeda, A. Noiri, T. Nakajima, J. Yoneda, T. Kobayashi, and S. Tarucha, "Quantum tomography of an entangled three-qubit state in silicon," Nat. Nanotechnol., vol. 16, no. 9, pp. 965–969, Sep. 2021, doi: 10.1038/s41565-021-00925-0.