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Quantum Accelerator: Memory-enhanced quantum sensing for GPS-denied Navigation

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Final Technical Report

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13. SUPPLEMENTARY NOTES

14. ABSTRACT
Quantum logic gates between electron and nuclear spin qubits with high fidelity are required for the estimation algorithms. We experimentally investigated a new approach using dynamically corrected geometric quantum logic gates that promises to yield high fidelity even in the presence of dephasing. We developed a custom hardware and software solution to carry out the dynamically corrected quantum logic gates, and implemented them in our system. We implemented and troubleshot randomized benchmarking protocols to characterize the fidelity of the gates, which involved understanding sources of systematic noise and other error sources in our system.

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Final Report for FA9550-21-0049

BAA Name: FA9550-21-S-0001
Proposal Title: [Quantum Accelerator] Memory-enhanced quantum sensing for GPS-denied navigation
Grant Number: FA9550-21-0049
Federal Agency: AFOSR

Lead Principal Investigator (PI): Gurudev Dutt, *Associate Professor of Physics and Astronomy*
Contact Information of Lead PI: gurudev.dutt@pitt.edu (412) 383-6487
Recipient Organization: University of Pittsburgh
Period of performance: 11/15/2020 – 11/14/2022
Total Cost: $75000
Final Report: Yes

Accomplishments

What are the major goals and objectives of this project?

We propose to develop quantum memory-enhanced sensors and novel quantum estimation algorithms that will significantly improve the state of the art in GPS-poor situations.

What was accomplished under these goals?

Quantum logic gates between electron and nuclear spin qubits with high fidelity are required for the estimation algorithms. We experimentally investigated a new approach using dynamically corrected geometric quantum logic gates that promises to yield high fidelity even in the presence of dephasing. We developed a custom hardware and software solution to carry out the dynamically corrected quantum logic gates, and implemented them in our system. We implemented and troubleshot randomized benchmarking protocols to characterize the fidelity of the gates, which involved understanding sources of systematic noise and other error sources in our system.

What opportunities for training and professional development has the project provided?

Three graduate students were trained during this project on advanced experimental techniques for electron and nuclear spin resonance in solid-state systems, quantum information algorithms, quantum control, confocal optical microscopy, python hardware and instrument programming, photolithography and metal deposition, microwave circuits, IQ modulation, and arbitrary waveform generation. Students were given opportunity to present their results at PQI events on campus, as well as the APS March Meeting.

How were the results disseminated to communities of interest?

Presentation was given at APS March Meeting, and at PQI events on campus.

What do you plan to do during the next reporting period to accomplish the goals and objective?

Nothing to report.

Products

Published, submitted, and in-work papers

1. R. Khan, P. Wijesinghe, A. O. Omran, P. Hilaire, E. Barnes, S. E. Economou, M. V. Gurudev Dutt, “Dynamically corrected geometric quantum logic gates in solid-state spin qubits”, APS March Meeting, March 18th 2022, Chicago IL
2. R. Khan, P. Wijesinghe, A. O. Omran, P. Hilaire, E. Barnes, S. E. Economou, M. V. Gurudev Dutt, “Dynamically corrected geometric quantum logic gates in solid-state spin qubits”, in preparation

Participants & Other Collaborating Organizations

What individuals have worked on this project?

1. Name: Gurudev Dutt
   Total months: 0.75
   Role: PI

Contribution: supervised students, designed experiments, wrote software, carried out data analysis
State: PA, USA
Foreign collaboration: None

2. P. Wijesinghe
   Total months: 8
   Role: Graduate student
   Contribution: carried out experiments, and data analysis.
   State: PA, USA
   Foreign collaboration: None

Has there been a change in the active other support of the PD/PI(s) since the last period?
No

What other organizations have been involved as partners?
Organization Name: Virginia Tech University
Contribution: Collaboration

Have other collaborators or contacts been involved?
Graduate students Ahmed Omran and Raees Khan at Pitt also contributed to this project.

Impact

What was the impact on the development of the principal discipline(s) of the project?
Improved fidelity of quantum logic gates in presence of noise sources will potentially impact quantum sensing and quantum computing fields.

What was the impact on the development of other discipline(s) of the project?
Nothing to report

What was the impact on the human resources development?
Three graduate students were trained during the course of this project, learning about frontier research areas and gaining valuable experience in experimental and theoretical areas of quantum science which is a key area identified in the National Quantum Initiative.

What was the impact on the teaching and educational experiences?
Nothing to report

What was the impact on physical, informational, institutional resources?
Nothing to report

What was the impact on technology transfer?
Nothing to report

What was the impact on society beyond science and technology?
Nothing to report

What percentage of budget spent in foreign countries?
None.