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Topological Phases, Quantum Error Correction and Detection

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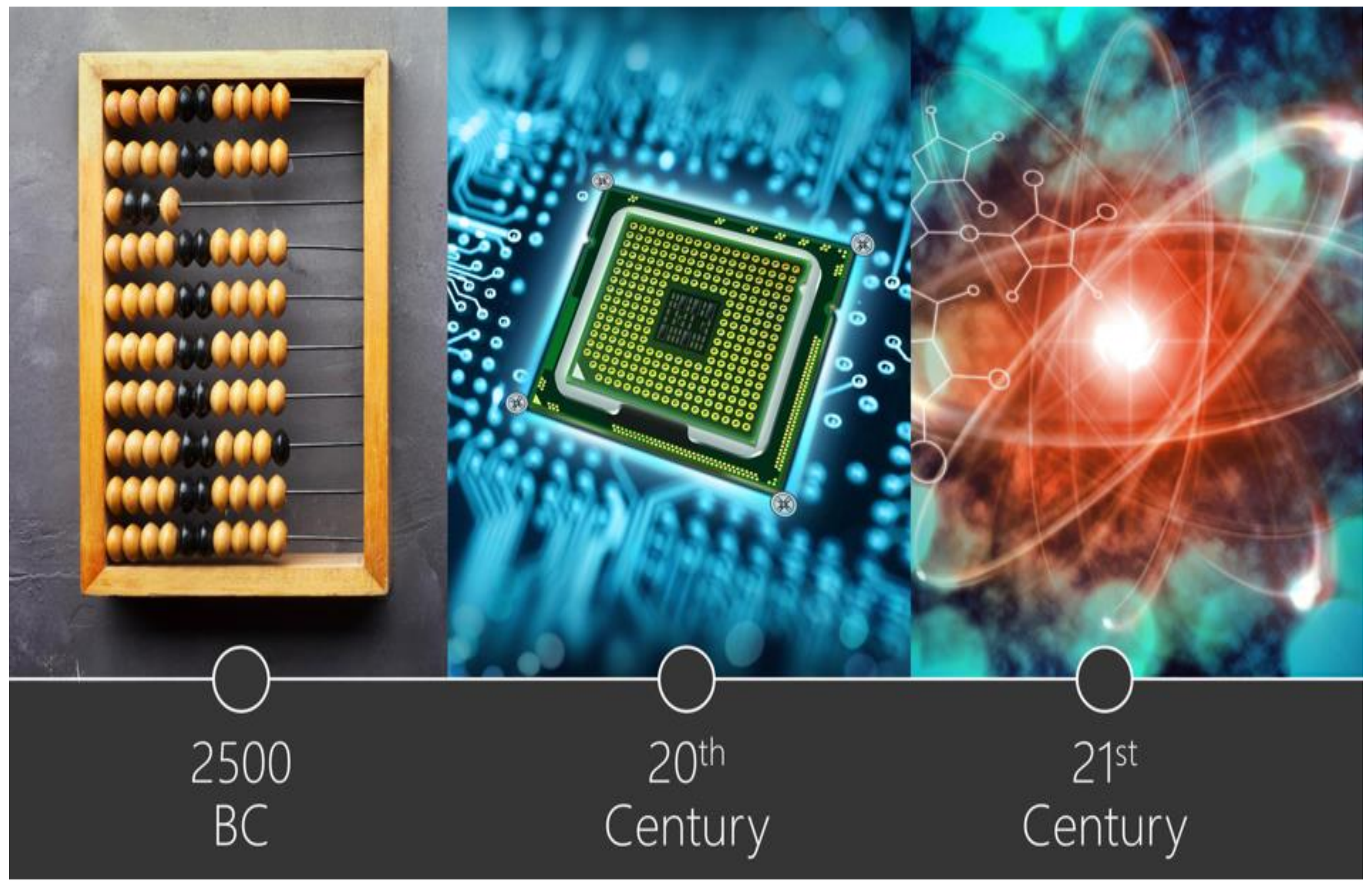
T3: TEXAS A&M TRIADS FOR TRANSFORMATION
A President's Excellence Fund Initiative

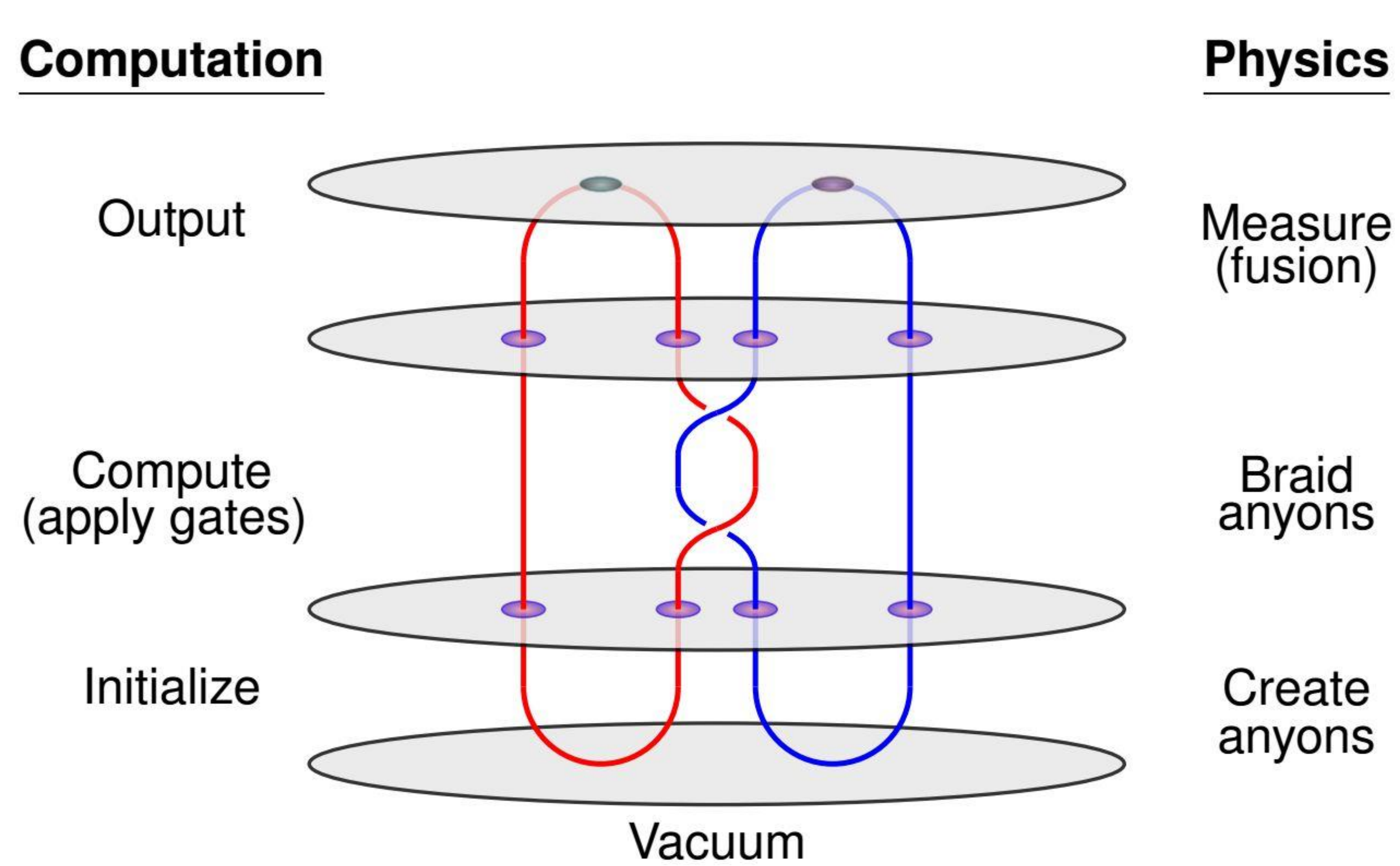


BACKGROUND:

- One of the fundamental technological challenges of the 21st century is the quest to develop practical and effective quantum computational devices.
- The digital computers that currently dominate our everyday lives store information in the form of bit-strings (strings of 0's or 1's), and computational tasks are performed via arithmetical operations on these bit-strings. On the other hand, a *quantum computer* is a computational device that harnesses *quantum mechanical effects*. Quantum computers store information in the states of quantum mechanical systems (qubits), and computations are performed by allowing the quantum systems to evolve via unitary evolutions (quantum gates).
- Quantum computers promise to solve critical problems in science and technology that are currently constrained by existing standards of computational power.

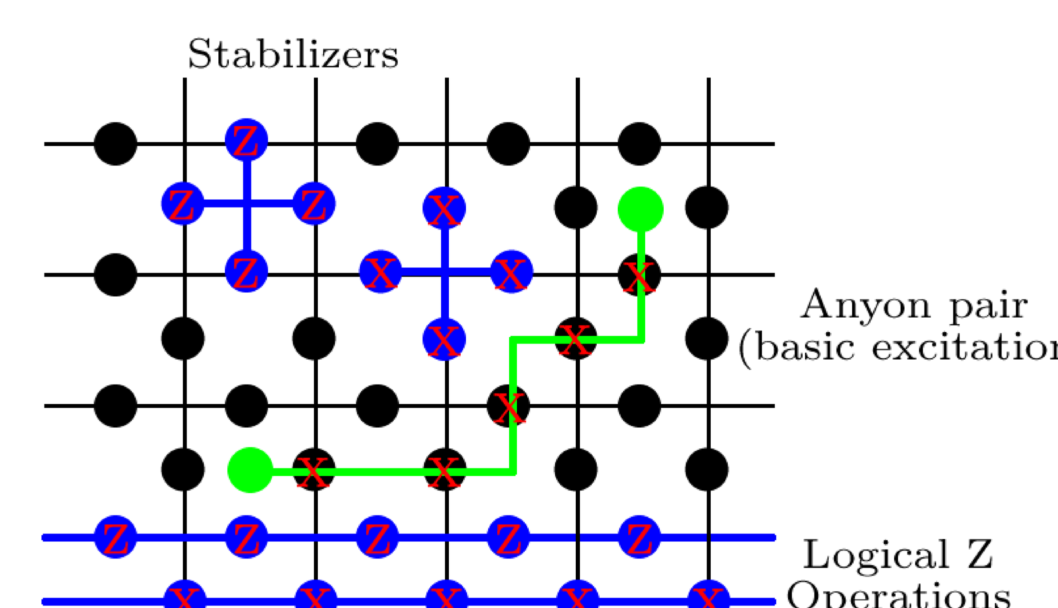
PROJECT GOALS:

- Two existing paradigms for quantum computation are the *quantum circuit array model* and the *topological model*. The ultimate goal is the same: build a computational device that out-performs digital computers using quantum mechanical systems. However, the strategies differ in fundamental ways: the quantum circuit model stores information locally whereas the topological model stores information globally. As a consequence, topological quantum computers are more resilient to errors while quantum circuit arrays allow for more direct processing of information.
- The goal of this project is to develop a hybrid approach, utilizing topological materials to implement quantum error-correction. Answering this open question requires expertise in quantum error-correction, topological quantum materials and an analytical catalyst of operator theory.



T3 RELATED ACTIVITES AND OUTCOMES:

- 2nd IAMCS Workshop on Quantum Compuation and Information. The T3 grant supported the first jointly organized conference with Los Alamos National Lab on this topic. This meeting brought leading researchers from across the nation to TAMU.
- Undergraduate and Graduate Research: We organized a year-long working seminar which provided research opportunities for 5 TAMU graduate students and 3 TAMU undergraduates (from physics, mathematics, and computer science). The focus of the seminar was to introduce students to the background for this project, with a particular emphasis on topological error correcting codes, such as the Toric code (depicted below) and its generalizations:



- Publications:

1. A. Nemec, A. Klappenecker**:** *Infinite families of Quantum-Classical Hybrid Codes*, submitted to IEEE Trans. Inform. Theory, 2020.
2. S.H. Ng, E. Rowell, Y. Wang, Q. Zhang: *Higher Central Charges and Witt Groups*, preprint, arXiv:2002.03570.
3. P. Ganesan, L. Gao, S. Pandey, S. Plosker*: Quantum majorization on semifinite von Neumann algebras*, Journal of Functional Analysis, 2020.