1 Tutorial Content and Agenda

The two tutorial sessions will cover the following content:
Session I will focus on background, theory, circuit construction, and basic applications of LCNU decomposition. Specific topics along with the time allocation include:

- Basics of standard Pauli basis based LCU and motivation for using Sigma basis based LCNU for more effectively exploiting problem structure and sparsity (10 min).
- Mathematical properties of Sigma basis and numerical and semi-analytical methods for computing LCNU decomposition (10 min).
- Concept of unitary completion and its application for developing efficient quantum circuit construction implementing Sigma basis tensor product terms (15 min).
- Utilization of LCNU framework within hybrid quantum-classical (e.g, variational quantum linear solver [**?**]) and fully fault-tolerant algorithms (e.g., quantum linear system algorithm [**?**]) for linear algebra (20 min).
- Applications to simulating physical systems (e.g., mechanical, electrical, biological and chemical) described by linear ODEs (e.g, electrical circuits, thermal networks, signal processing) and linear PDEs (e.g, heat conduction/diffusion, wave propagation, potential theory/electrostatics). This will include an end-to-end resource estimation using the standard LCU approach with the Pauli basis and the LCNU approach with the Sigma basis (20 min).
- Pros/cons of LCNU compared with other alternative methods including standard LCU, unitary dilatation, and block encoding methods especially designed for sparse/structured matrices (10 min).
- Guidelines on how to identify problems where the LCNU technique could be beneficial (5 min).

Session II will focus on generalization of the Sigma basis based LCNU concept, applications to nonlinear PDEs and fluid problems, and hands-on coding exercise. Specific topics include:

- Quick recap of session I (5 min).
- Framework to generalize Sigma basis based LCNU by incorporating other unitary and non-unitary operators to expand/modify the Sigma basis and tailor the decomposition for specific problems (10 min).
- Application to nonlinear PDEs including introduction to Carleman linearization technique (15 min).

- End-to-end case study and hands-on coding exercise for simulating fluid flows (e.g. Burgers equation, Lattice Boltzman Method) with explicit circuit construction, resource estimates, and executing prototypical examples on quantum simulators (50 min).
- Conclusions and avenues for future work (10 min).

The above content will be presented to facilitate easy access and appeal to a broad audience with varying levels of expertise.