INTERNSHIP PROPOSAL

(One page maximum)

Laboratory name: EDF lab, Palaiseau
CNRS identification code:
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Thesis possibility after internship: YES
Funding: YES If YES, which type of funding: PhD CIFRE

Title: FTQC quantum block encoding for the partial differential equations

A key challenge in quantum computing is efficiently encoding classical data into quantum systems via quantum gates and extracting meaningful outputs through measurements. This is particularly relevant for Variational Quantum Algorithms (VQAs), which introduce data additively and process it iteratively.

At EDF R&D's ERMES department, research began in late 2021 to apply VQAs to solve Partial Differential Equations (PDEs), starting with linear problems like fracture mechanics and heat diffusion. Initial studies successfully reformulated finite elements (FEM) discretization of the problem within the VQA framework and executed them on various quantum processing units (QPUs), demonstrating the feasibility of quantum-enhanced engineering simulations [1,2].While VQAs are suitable for NISQ devices, they face limitations such as the barren plateau phenomenon, which impedes convergence and lacks formal scalability guarantees. In contrast, Fault-Tolerant Quantum Computing (FTQC) algorithms, like HHL, offer more robust solutions by avoiding these issues. To address the bottleneck in data encoding, this internship will explore block encoding techniques [3], which represent classical information as unitary matrix multiplications within a quantum system. This builds on previous results [1,2] and aims to enhance both expressivity and computational efficiency in quantum simulations.The proposed scheme will be tested on EDF's high-performance computing (HPC) emulator of a QPU and partners QPUs, enabling benchmarking and scalability analysis under realistic conditions. Additionally, the student will contribute to a long-term research goal: the quantum reformulation of non-linear PDEs, forming the basis for a future PhD proposal.

[1] U Remond, PE Emeriau, L Lysaght, J Ruel, J Mikael, K Kazymyrenko. Quantum remeshing and efficient encoding for fracture mechanics; arXiv:2510.14746, 2025
[2] S Donachie, U Remond, A Mathorel, K Kazymyrenko. Solving the 3D Heat Equation with VQA via Remeshing-Based Warm Starts; arXiv:2510.15645, 2025
[3] Lin Lin. Lecture notes on quantum algorithms for scientific computation. arXiv:2201.08309, 2022

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics: YES/NO Soft Matter and Biological Physics: NO
Quantum Physics: YES Theoretical Physics: YES