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UCD Dublin – University College Dublin

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STAY IN TOUCH

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linkedin.com/company/quadrature-eu

github.com/quadrature-eu

quadrature-project.eu

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QUADRATURE

SCALABLE MULTI-CHIP QUANTUM ARCHITECTURES

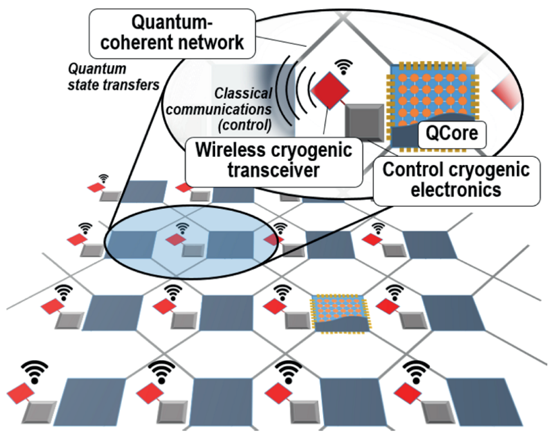
ENABLED BY CRYOGENIC WIRELESS / QUANTUM-COHERENT NETWORK-IN-PACKAGE

quadrature-project.eu

OVERVIEW

Today's tremendous interdisciplinary efforts towards building a quantum computer is aimed at a machine capable of tackling problems beyond the reach of any classical computer. The so-called quantum advantage has been already claimed with state-of-the-art Noisy Intermediate-Scale Quantum (NISQ). Nevertheless, it is widely recognized that addressing any real-world problem will require upscaling to thousands or even millions of qubits. **Scaling quantum computers** to such a large number of qubits is a major challenge due to, among others, the confluence of:

- technology factors confining the qubits to **low fidelity**
- the need for **cryogenic temperatures** for long coherence times
- the **dense integration** of per-qubit digital/RF control circuits
- implications of managing **noisy and short-lived qubits**



The **QUADRATURE** project focuses upon the grand challenge of scalability in quantum computers from an architectural or full-stack standpoint. We are aiming to explore the feasibility of architectures composed of multiple quantum processors (Qcores) that allow to scale up quantum computing systems. This is enabled by networks-in-a-package with a dual character that includes a quantum-coherent link for quantum information transfers coexisting with a cryogenic wireless communication network for exchanging classical data and synchronization.

VISION

The vision of QUADRATURE is the realization of million-qubit quantum computing architectures able to address real-world problems otherwise intractable with conventional computers. Such architectures would be based on a modular and scalable multi-Qcore approach enabled by a quantum-coherent and a classical wireless communication network within the cryogenic package. To realize this vision, QUADRATURE proposes an all-RF solution to the problem of building an integrated, scalable, and agile network spanning both quantum state and classical data transfers.

OBJECTIVES

Scalability of the quantum processor
We envisage to design a quantum system able to scale the to more than ten thousands qubits

Inter-Qcore comm. via quantum cavity channels
To experimentally prove the first micro-integrated all-RF qubit state transfer link between Qcores, aiming to maximize fidelity and coherence times

High-speed and scalable wireless network
To experimentally achieve the transfer of classical data through wireless in-package links enabled by integrated antennas and cryo-RF transreceivers at deep-cryogenic temp.

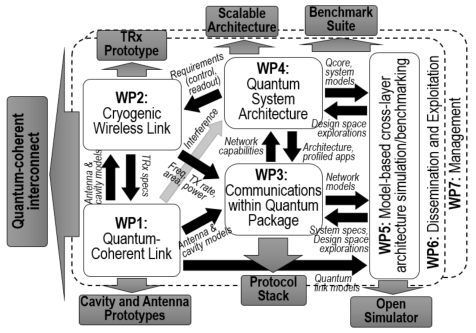
Comprehensive communication protocols
To build protocols for a quantum-coherent integrated network enabling the exchange of qubit states coordinating the quantum-coherent data plane and the wireless control plane.

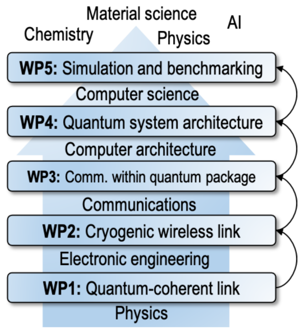
Scalable mapping and coordination approaches
To develop innovative scalable architectural methods such as mapping, scheduling, and coordination approaches across multiple Qcores leveraging a reconfigurable control plane.

Wide dissemination of transversal outcomes
We plan to release simulation platforms and benchmark suites used for design-space optimizations to support future research efforts

WORK PACKAGES

The QUADRATURE research project takes a interdisciplinary full-stack approach and touches upon different aspects of design that go from the implementation of cryogenic quantum cavity channels and wireless communications within package up to the development of scalable architectural strategies and quantum algorithms. Research is divided into seven work packages, five of which are technical work packages.





WP1: Quantum Coherent Link
The quantum cavity channel and its monolithic integration into Qcore solutions will be modeled, fabricated and characterized.

WP2: Cryogenic Wireless Link
Experimental demonstration of deep-cryogenic (1-4 K) short-range (~10cm) communication using the developed high-efficiency transceiver co-integrated with on-chip mm-wave antennas.

WP3: Communications within Quantum Package
Characterizing the wireless channels within the quantum package, developing full stack of protocols including scheduling and network orchestration and obtaining performance and efficiency models to be integrated in the system architecture and algorithm analysis.

WP4: Quantum System Architecture
Design of a parameterizable and reconfigurable multi-Qcore platform, development of mapping and scheduling methodologies, on-line inter-Qcore connectivity optimization, and definition of large-scale quantum algorithms.

WP5: Model-Based Cross-Layer Architecture Simulation and Benchmarking
Deriving optimal configurations of the double full-stack, dimensioning guidelines and scalability trends, performing an architecture-application co-design of the communication and computational stacks, and assessing inter-Qcore communication overheads.