# **QNet:** Transport, metastability, and neuromorphic applications in quantum networks

Proyectos de colaboración internacional AEI-PCI-ERA

QUANTERA
ERA-NET Cofund in Quantum Technologies

MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

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PCI2024-153410

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**The QuantERA Programme is a leading European network of 41 Research Funding Organisations from 31 countries.**

**QuantERA is dedicated to advancing high-quality Research and Innovation within the field of Quantum Technologies (QT).**

Three years, starting date 31/07/2024

Budget: 150.000€ plus 37.500€ of indirect costs

# Consortium

QNet

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|---|---|---|---|---|---|
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| INSTITUT ZA FIZIKU | UNIVERSITÄT DES SAARLANDES | ETH zürich | | IFISC Universitat de les Illes Balears CSIC | Aalto University |

# Work Packages

| | month | 1-6 | 7-12 | 13-18 | 19-24 | 25-30 | 31-36 |
|---|---|---|---|---|---|---|---|
| **WP1** Quantum Transport | **T1.1** Theory of quantum transport in noisy network | | | | D1.1, D1.2 & M1.1 | | |
| | **T1.2** Quantum transport in disordered, fully-connected potentials | | | | D1.2 & M1.2 | | |
| | **T1.3** Transport of heat via a quantum network | | | | D1.2 | | |
| **WP2** Metastability | **T2.1** Characterization of metastability in fully connected systems | | | M2.1 | D2.1, D2.3 | | |
| | **T2.2** Characterization of thermal state in superconducting qubit networks | | | M2.2 | | | D2.2, D2.3 |
| | **T2.3** Realization of fast quantum information scrambling | | | | | | D2.3 |
| **WP3** Applications to neuromorphic | **T3.1** Dynamical regimes in quantum networks for neuromorphic applications | | | M3.1 | D3.1 | | |
| | **T3.2** Design and testing of protocols for QAM in atomic and superconducting sys. | | | | M3.2 | | D3.2 |
| **WP4** Management and dissemination | **T4.1** Management | | | | | | |
| | **T4.2** Dissemination and Communication | D4.1 & D4.2 | | | | | |
| | **T4.3** Data management | D4.3 | | | | | |
| | **T4.4** Organization of final workshop | | | | | | D4.4 |

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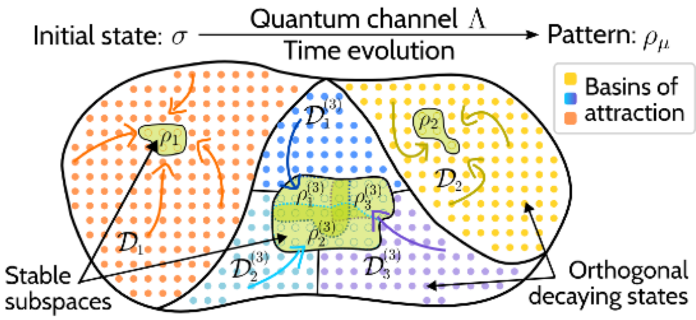
Aim of WP3 is to develop a theoretical framework and experimental schemes for application of concepts of WP1 and WP2 in the context of neuromorphic computing, more specifically in the areas of quantum reservoir computing and quantum associative memory. We will develop a general theory of the transport and disorder properties of quantum networks in concrete computational tasks and pursue the goal of a proof-of-principle experimental implementation analyzing all the platforms available in the consortium.

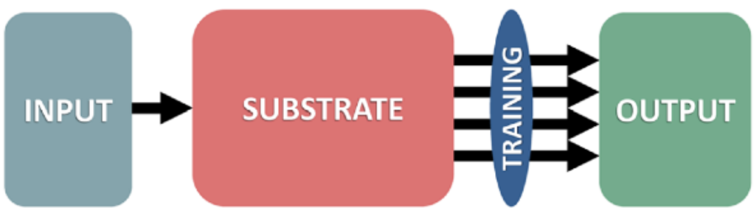
# Quantum Associative Memory

Associative memory (QAM) refers to the ability to relate a memory with an input and targets the restoration of corrupted patterns. We built a framework for QAM which allows us to encode non-orthogonal states and potentially store an exponentially large number of patterns efficiently. In our formulation, both classical and quantum patterns can be stored, and such patterns can be either stable or metastable dynamical attractors. In QNet, our aim is to arrive at a proof-of-principle implementation of QAM in atomic and superconducting systems




- Quantum associative memory with a single driven-dissipative nonlinear oscillator A Labay-Mora, et al., Physical Review Letters 130, 190602 (2023)
- Quantum memories for squeezed and coherent superpositions in a driven-dissipative nonlinear oscillator, A Labay-Mora, et al., Physical Review A 109, 032407 (2024)
- Theoretical framework for quantum associative memories, A Labay-Mora et al., arXiv preprint arXiv:2408.14272

# Quantum Reservoir Computing



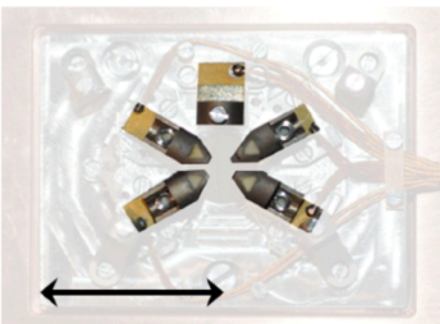

Quantum Reservoir Computing (QRC) is a machine learning paradigm that exploits the unique properties of quantum systems to process and represent information. It exploits the complex dynamics of a quautum system with an exponentially large state space. It can be implemented using various quantum systems, such as superconducting qubits, trapped ions, or optical systems. We will theoretically analyze the conditions to be met for the physical implementation of QRC within the QNet consortium.

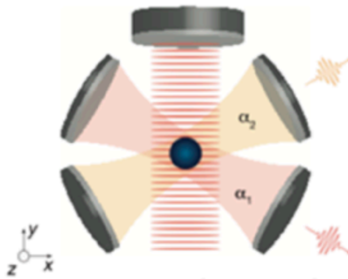
- Opportunities in quantum reservoir computing and extreme learning machines, P Mujal, et al., Advanced Quantum Technologies 4, 2100027 (2021)
- Dynamical phase transitions in quantum reservoir computing,R Martínez-Peña et al., Physical Review Letters 127, 100502 (2021)
- Time-series quantum reservoir computing with weak and projective measurements, P Mujal et al., npj Quantum Information 9, 16 (2023)
- Scalable photonic platform for real-time quantum reservoir computing, J García-Beni et al., Physical Review Applied 20 (1), 014051
- Dissipation as a resource for Quantum Reservoir Computing, A Sannia. Et al., Quantum 8, 1291 (2024)

# Main goal

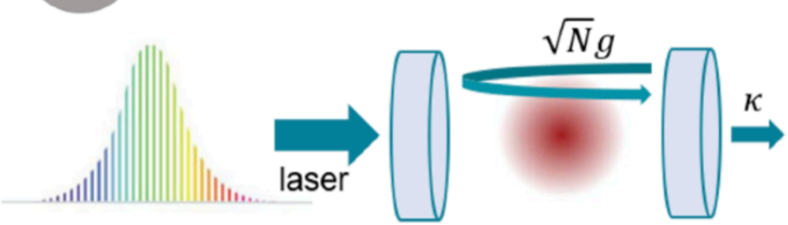
## Cavity QED setups

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



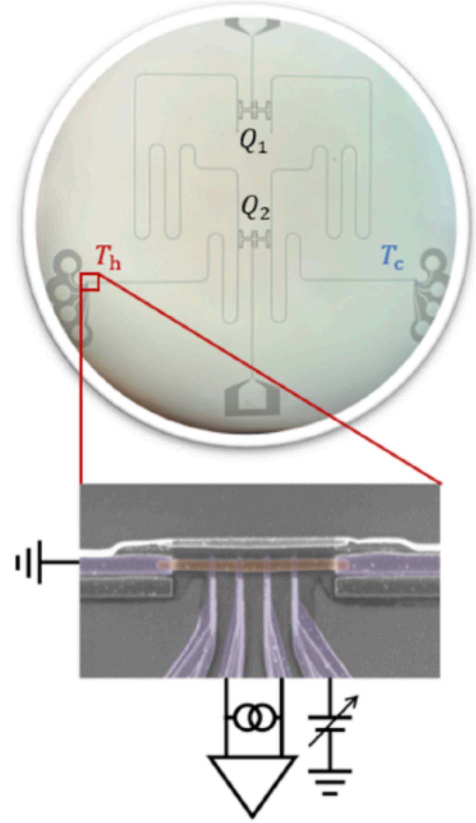



INSTITUT ZA FIZIKU




## Superconducting quantum circuits

A!
Aalto University



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# THANK YOU

for your attention

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