

ML4Q

MATTER AND LIGHT FOR
QUANTUM COMPUTING

ML4Q
AT A GLANCE



RWTHAACHEN
UNIVERSITY



ML4Q AT A GLANCE

ML4Q stands for Matter and Light for Quantum Computing. The Cluster of Excellence set off in 2019 for a long collaborative journey in order to develop new computing and networking architectures using new findings in fundamental research in solid-state physics, quantum optics and quantum information.

THE CLUSTER'S MISSION

Using the principles of quantum mechanics, it is the long-term goal of ML4Q to develop new computing and networking architectures with a power beyond anything classically imaginable. Quantum computers could be powerful tools in key areas such as materials design, pharmaceuticals, or artificial intelligence.

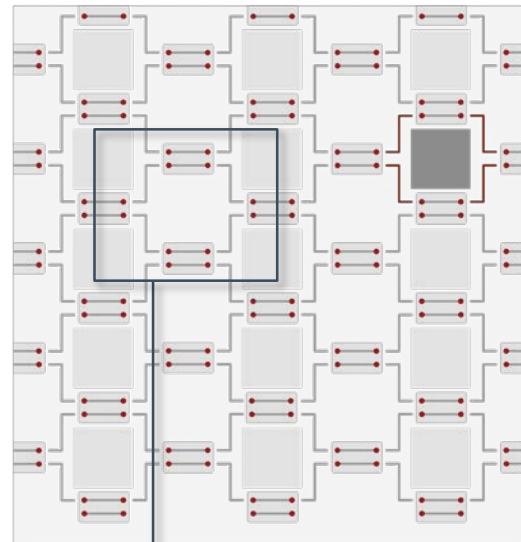
Quantum communication could be made effectively secure. ML4Q builds on the complementary expertise in the three key research fields of solid-state physics, quantum optics, and quantum information science to develop the best hardware platform for quantum information technology, and provide comprehensive blueprints for a functional quantum information network.

The long-term goal of the cluster is to realize network and processing architectures protected by error-correction protocols and eventually connected to a quantum version of the internet.

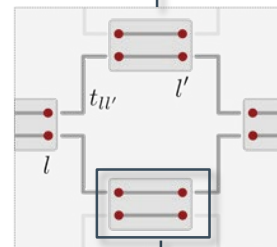
This goal defines a hierarchy of challenges, both in fundamental science and in technology, which must be overcome at early and intermediate stages.



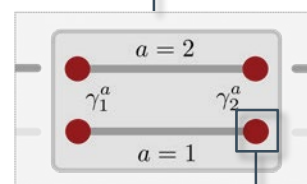
THE VISION



The processor units of a network comprise arrays of qubits whose implementation requires scalable designs. We envision to realize these units by the end of the second funding period.



The ML4Q core projects are dedicated to the development of both spin qubit platforms as well as topologically protected Majorana qubits as an alternative platform with the prospect of superior performance in the long term.



As Majorana-based quantum information hardware is still in its infancy, major intermediate challenges need to be overcome. These include the actual engineering of Majorana qubits.



On an even more fundamental level, the realization and optimization of quantum materials harboring Majorana states are goals for the first two years of the running period.



We want to contribute to accelerating the promising developments this field has seen in the recent years.

THE SCIENTIFIC APPROACH

The scientific structure of ML4Q spans four Focus Areas, each addressing a specific set of problems relevant to the cluster's mission. All Focus Areas include theoretical as well as experimental components and transcend the boundaries of disciplines and institutions.

- **Focus Area 1** aims to identify and explore novel topological hardware platforms for quantum information processing, including hybrid structures of topological insulators and superconductors as well as the ways to realize parafermions.
- **Focus Area 2** aims to realize Majorana qubits as a promising alternative to superconducting qubits or spin qubits. In parallel, protocols for readout, manipulation, and error correction are designed.
- **Focus Area 3** designs novel schemes of quantum control, error correction and mitigation. It investigates the operation of quantum devices under realistic noisy environmental conditions and explores topological and computational quantum matter subject to external driving.
- **Focus Area 4** focuses on the linkage of quantum processing units. Specifically, it will take steps towards realizing integrated atomic/optical and solid-state platforms and implementing quantum links between heterogeneous qubit setups.



Photo by Simon Wegener

YOUNG SCIENTISTS

Attracting and retaining the best young talent in the field by offering competitive career opportunities is a top priority for ML4Q. Current offers include:

- Undergraduate grants
- Independence grants for postdoctoral researchers
- New tenure-track professorships
- ML4Q Research School with cluster-specific courses, e.g. "Platforms for Quantum Technologies" for Master students
- Master program for Quantum Technology in Aachen as well as specialized lectures on quantum technologies in Bonn and Cologne

PARTICIPATING INSTITUTIONS

ML4Q is a cooperation by the University of Cologne, University of Bonn, RWTH Aachen University as well as the Forschungszentrum Jülich. Partner institutions are the Heinrich Heine University Düsseldorf, the Fraunhofer Institute for Laser Technology ILT and the Fraunhofer Institute for High Frequency Physics and Radar Techniques FHR.

FUNDING

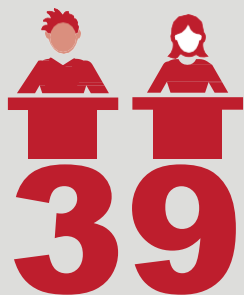
ML4Q is funded within the Excellence Strategy by the German Research Foundation (DFG) since January 2019. The first funding period ends in 2025.

ML4Q
IN
NUMBERS



151

MEMBERS AND ASSOCIATES



PROFESSORS



52

INTERNATIONAL
SCIENTISTS



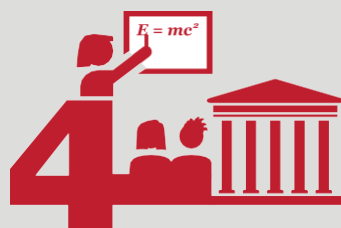
PHD STUDENTS



FEMALE SCIENTISTS



ADMINISTRATIVE &
TECHNICAL STAFF



UNIVERSITIES



22

PUBLICATIONS IN 2019



35

POSTDOCS



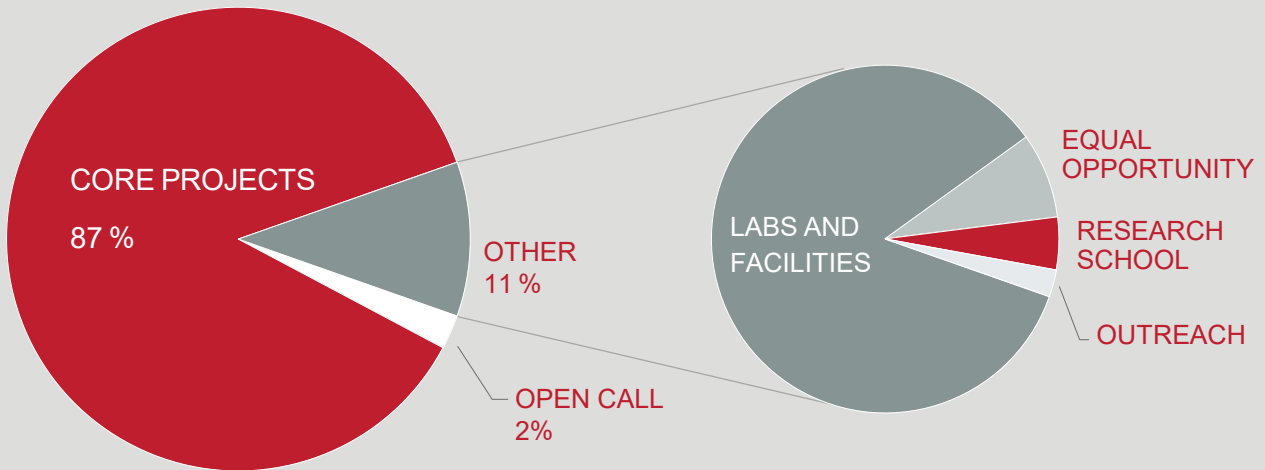
NON-UNIVERSITY
RESEARCH
INSTITUTIONS



PUBLICATIONS IN 2019
WITH TWO OR MORE GROUPS
INVOLVED (3 CROSS-SITE
PUBLICATIONS)

ML4Q IN NUMBERS

CORE PROJECTS & CENTRAL MEASURES



In 2019, 87% of the expenses were dedicated to personnel, instrumentation and consumables in the core projects. 2% were allocated to Open Call projects. Expenses for supporting measures (equal opportunity, ML4Q Research School, outreach), labs and facilities (Fiber Lab, ML4Q Devices and central office) made up about one-tenth of the annual budget.



All Focus Areas include theoretical as well as experimental components bringing different needs for personnel, consumables and instrumentation. Here is an overview of the allocation of core project funds in 2019 broken down by Focus Area and type of fund.

ML4Q IN NUMBERS

INTERNATIONALISATION



Postdoctoral scientists have shown in 2019 the highest level of internationalization. Almost 35% of ML4Q members and associated members are international scientists coming from over 20 countries (see map below).

For 2020/21, ML4Q aims at attracting top international researchers to faculty positions offered in Cologne, Bonn and Aachen in both theoretical as well as experimental physics.



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www.ml4q.de

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