

Call 2021
Final Evaluation



ExTRaQT

Experiment and Theory of Resources
in Quantum Technologies
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extraqt.eu
2022–2026

COLLABORATION (overview)



PARTNER INSTITUTES

Institute of Fundamental Technological Research, PAS (Poland), coordinator

University of Gdańsk (Poland)

Ulm University (Germany)

University of Kassel (Germany)

The Institute of Photonic Sciences (Spain)

Universitat Autònoma de Barcelona (Spain)



COMPLEMENTARY EXPERTISE

Theoretical: resource theories, open-system dynamics and tensor-network simulations, coherence, entanglement and quantum thermodynamics.

Experimental: trapped-ion control and molecular spectroscopy.



QUALITY OF COOPERATION

Five joint meetings, including three with all six partners.

Ulm–Kassel: regular meetings and joint design of engineered baths.

Ulm shared t-TEDOPA expertise with Gdańsk to simulate open quantum systems.

Gdańsk extended the tensor-network implementation.

Institute of Photonic Sciences–Ulm: joint plans for molecular switches.



SUCCESS STORY (highlights)



CHALLENGE

Turn coherence and memory into useful resources for nanoscale devices.



SOLUTION

Link resource theories and numerical methods to molecular spectroscopy and trapped ions.



PLANNED AND UNEXPECTED OUTCOMES

Planned results: coherence and catalysis theorems, molecular efficiency bounds and efficient simulations of structured environments.

Experiments: vibrational coherence in photosystem I, zeptonewton force amplification and radial ion-mode characterization.

Unexpected: signal cancellation limited electronic contrast in action detection.



SCIENTIFIC OUTPUTS



PUBLICATIONS

56 publications

7 additional preprints

55 journal articles (published or accepted) and 1 proceedings paper.

18 articles in leading journals

9 PRL, 3 PRX Quantum, 3 Quantum
1 PRX, 1 npj Quantum Information
1 Reports on Progress in Physics

PRESENTATIONS

50 talks and posters

37 international, 13 national

Including QTD, QuEBS and
Quantum Resources
workshops.



THESES

2 PhD theses completed

Bo Deng
Giovanni Spaventa



PUBLICATION HIGHLIGHTS

STRUCTURED ENVIRONMENTS AND PHOTOSWITCHES

Lautenbacher et al., arXiv:2608.28488 (2026 preprint)

Bridges model-independent thermodynamic resource theory bounds with an explicit microscopic model of a molecular photoswitch in a structured vibrational environment.

Environmental memory overcomes restrictions imposed by Markovian thermal dynamics.

Identifies microscopic coupling topology and memory as key ingredients for expanding the dynamically reachable region.

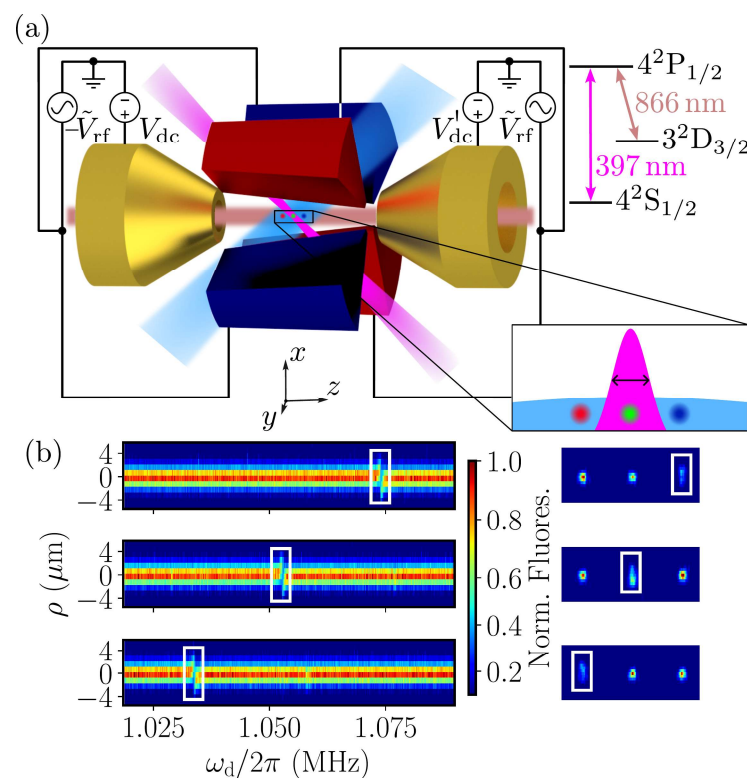
COHERENCE AND CATALYSIS

Kondra et al., PRL 132, 200201 (2024), arXiv:2308.12814

An incoherent free-energy source and a catalyst amplify existing coherence. The catalyst's reduced state returns exactly, with arbitrarily small correlations. Arbitrarily accurate amplification requires an unbounded catalyst energy spectrum. Provides rules for coherence conversion in quantum thermodynamics.



PUBLICATION HIGHLIGHTS



RADIAL MODES OF THREE IONS

Bhardwaj et al. (2026 preprint)
arXiv:2605.25125

(a) Broad and focused laser beams for applying force to all three calcium ions or an individual ion in the tapered trap.

(b) At weak axial confinement, separate resonances (white boxes) reveal motion localized mainly on individual ions.

Varying confinement tunes local and collective motion, supporting future studies of heat transport.



RESPONSE TO THE FINAL REVIEW

REVIEW CONCERN

Limited joint outputs and delayed deliverable D1.1.

EVIDENCE OF SCIENTIFIC COLLABORATION

5 formal meetings: 3 with all partners and 2 focused workshops.

Ulm–Kassel: regular meetings and joint design of engineered baths.

Ulm shared t-TEDOPA expertise with Gdańsk to simulate open quantum systems.

Gdańsk extended the tensor-network implementation.

Institute of Photonic Sciences–Ulm: joint plans for molecular switches.

D1.1: ORIGINAL PLAN AND RESEARCH REDIRECTION

Planned: report on a general resource theory of operations.

Instead: applied resource theory to molecular switches and photoisomerization, linking efficiency limits to vibrations, correlations and environmental memory.

Results: two PRA papers (2025) and a structured-environments preprint (2026).



IMPACT (potential users)



RELEVANT SECTORS

Quantum technologies: simulation, sensing and thermodynamic devices.
Photonics and molecular science: spectroscopy and light harvesting.
Scientific instrumentation: trapped-ion platforms and experimental control.



POTENTIAL APPLICATIONS

Sensing very weak forces and measuring temperature with ion oscillators.
Designing quantum heat-engine cycles and battery-charging protocols.
Modeling energy transfer and photoswitching in structured environments.



POTENTIAL USERS

Trapped-ion laboratories developing simulators, baths and motional control.
Molecular scientists studying vibrations, spectra and light-driven dynamics.
Quantum-information researchers testing resource bounds and protocols.



IMPACT (RRI aspects)



GENDER

Women recruited at PhD and postdoctoral levels.



OPEN SCIENCE

All project publications are available on arXiv.



SCIENCE EDUCATION

Doctoral training and Girls' Day experiments at Kassel.



PUBLIC ENGAGEMENT

Project film and shared outreach activities.



ETHICS

No ethical issues reported.



WHAT'S NEXT

- **THEORY-EXPERIMENT COLLABORATION**

Turn established tools into tested quantum thermodynamic protocols.

- **TRAPPED-ION PLATFORM**

Complete ion cooling and tests of engineered baths.

- **HEAT ENGINES AND TRANSPORT**

Validate coherent heat-engine and transport models.

- **MOLECULAR SWITCHES**

Refine molecular-switch experiments and improve signal contrast.





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