

ELQuRES project

Electronic Quantum Resources

Duration: May 2024 -- October 2027
Budget: 1.2 MEUR

Reserch Team



❖ University of Latvia, Riga, LV
Vyacheslavs Kashcheyevs (coordinator)
Martins Kokainis



❖ Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, DE
Niels Ubbelohde



❖ École Normale Supérieure de Lyon, FR
Pascal Degiovanni



❖ Laboratoire de Physique de l'ENS, Paris, FR
Gerbold Ménard
Gwendal Fève

Contact: Slava Kashcheyevs
slava@latnet.lv



QUANTERA
ERA-NET Cofund in Quantum Technologies



anr

DFG

Deutsche
Forschungsgemeinschaft
German Research Foundation



Physikalisch-Technische Bundesanstalt
National Metrology Institute



UNIVERSITY
OF LATVIA

LPENS

Laboratoire de Physique de l'École Normale Supérieure

CNRS

ENS DE LYON



Meet the team:
video of ELQuRes
collaboration

Goal:

Design, implement and explore **novel types of non-classical states** in semiconductor nanoelectronic circuits

Platforms:

propagating electrons in coherent semiconductors
(proof-of-principle: GaAs, concepts extend to graphene, strained Ge, solid Ne)

Applications:

flying electron qubits, timing electronics (< 10 ps), rf measurement calibration

WP1: Development of a unified framework for **quantum tomography** of electrical currents (B) using different detection techniques (D)

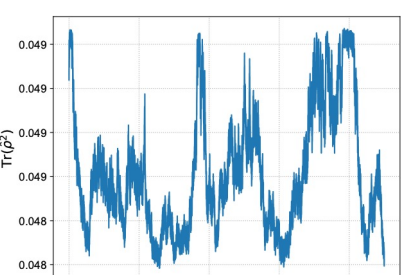
Quantum tomography of electronic states:

Unified tomography protocol utilizing time/energy filters [1] or time-shifted two-particle (Hong-Ou-Mandel) interferences [2,3]



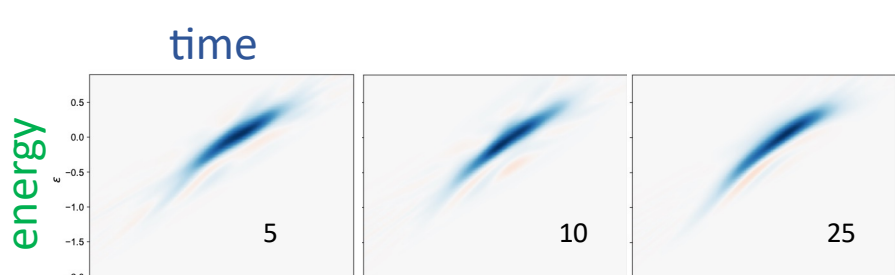
Robust quantum state reconstruction and purity estimation:

Software toolbox based on sampling of Bayesian posterior distribution with Markov Chain Monte Carlo (MCMC) method for uncertainty-aware continuous-variable quantum state tomography



Statistical uncertainty
estimation of quantum purity

ELQuRes results

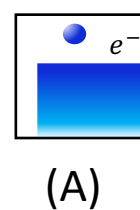


- Iterative reconstruction of Wigner energy-time portrait of a single electron (simulated input data)
- More filters => more accurate portrait

Goal: metrology of electronic coherence

Key elements of **electronic quantum circuits** explored in ELQuRes

Source of on-demand
electron wave-packets



Resonator for bosonic
edge magnetoplasmons



50 Ω transmission line
for microwaves

capacitive
coupler (bosonic
beamsplitter)

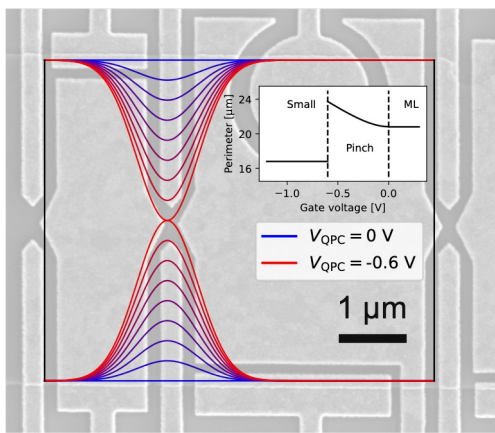
Quantum-limited

detector – dispersive fermionic beamsplitter or a charge qubit

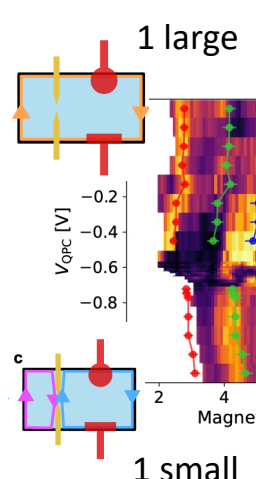
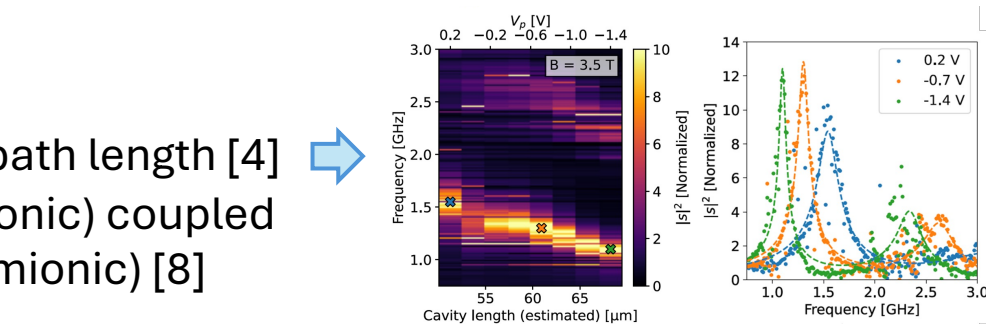
WP2: Demonstration of **edge magnetoplasmon resonator technology** (C) and of a **coherent source** of on-demand picosecond-scale wave packets (A)

EMP resonator:

- Frequency controlled by path length [4]
- Two EMP resonators (bosonic) coupled by electron tunneling (fermionic) [8]



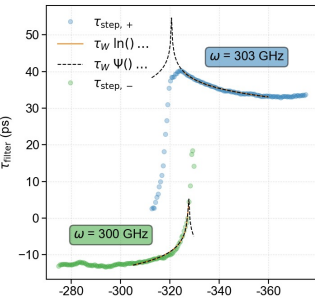
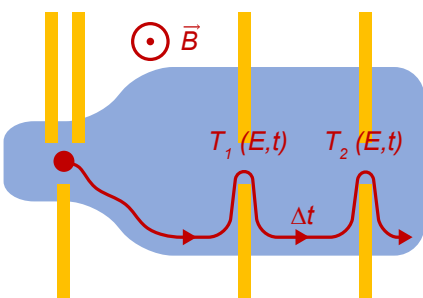
Goal:
realization of coupled
EMP quantum resonators



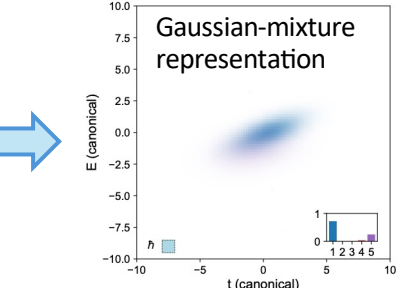
Frequency splitting:
first evidence of coherent
coupling of 2 resonators [8]

On-demand sources:

Coherent control of electron emission and filter selectivity



Preliminary time-of-flight
energy-time filter characterization (PTB)



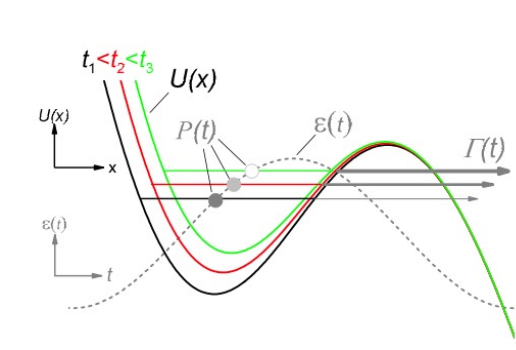
Reconstruction of 1e wave-packet Wigner distribution
from energy-time filter measurements using WP1 tools

Goal: minimal-uncertainty single-electron wavepacket as quantum-limited probe

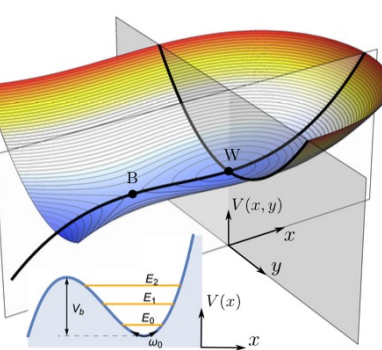
WP3: Establishing the **physics limits** for generation and detection of on-chip semiconductor electronic signals (A, B, D) and the electronic preparation-interaction-detection scheme for **non-classical EM states** (A-D)

Single-electron wavepackets:

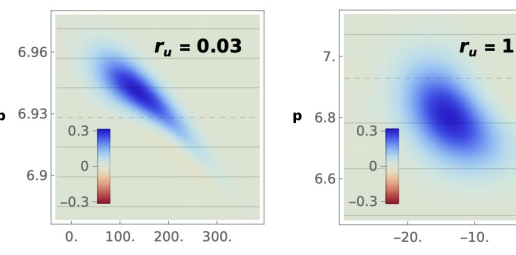
Validation of microscopic models of ultra-fast emission



On-demand emission of
single-electron wavepacket [1]



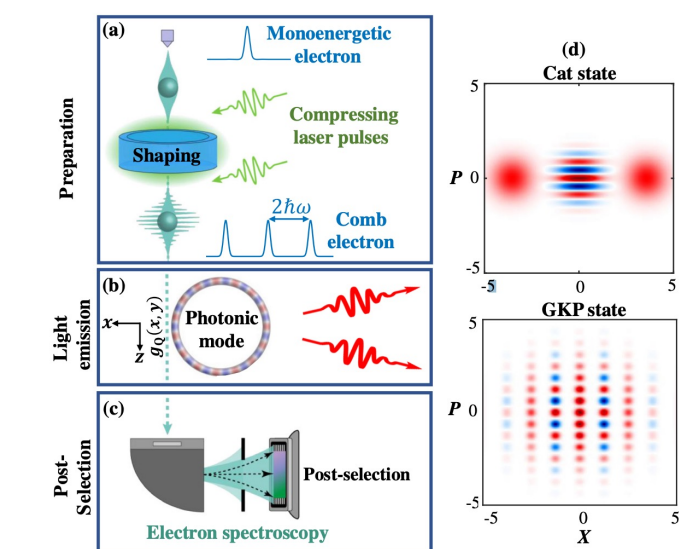
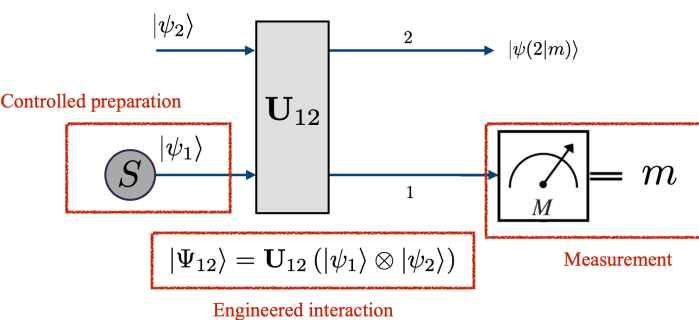
Cubic-potential models for
shallow confinement [6]



Three emission regimes identified in a theoretical model

Goal: all-electrical metrology of electrical
signals with quantum resolution

Heralded source of non-classical electromagnetic states:



Proposal for free-space electrons [7]
to be adapted for on-chip technology

References (*with contributions from consortium partners)

- [1*] J. Fletcher et al., Continuous-variable tomography of solitary electrons, Nature Comm. **10**, 5298 (2019)
- [2*] R. Bisognin et al., Quantum tomography of electrical currents, Nature Comm. **10**, 3379 (2019)
- [3*] B. Roussel et al., Processing quantum signals carried by electrical currents, PRX Quantum **2**, 020314 (2021)
- [4*] E. Frigerio et al., Gate tunable edge magnetoplasmon resonators, Communications Physics, **7** 314 (2024)
- [5*] V. Kashcheyevs & P. Samuelsson, Classical-to-quantum crossover in electron on-demand emission, Phys. Rev. B **95**, 245424 (2017)
- [6*] A. Akmentinsh et al., Modelling shallow confinement in tuneable quantum dots, Phys. Rev. B **111**, 075303 (2025)
- [7] R. Dahan et al., Creation of optical cat and GKP states using shaped free electrons, Phys. Rev. X **13**, 031001(2023)
- [8*] S. Kouamé et al., Electrostatic splitting of an Edge Magnetoplasmon Resonator, arXiv2609.05188 (2026)

Related European projects:

- EIC Pathfinder Open
- Metrology Partnership
- Horizon 2020 FET Open
- EURMET EMPIR
- "ELEQUANT" (2025 – 2029)
- "AQuanteC" (2024 – 2027)
- "UltraFastNano" (2020 – 2024)
- "SEQUIOA" (2018 – 2021)

This project is funded within the QuantERA II Programme that has received funding from the EU's H2020 research and innovation programme under the GA No 101017733, and with funding organisations LFP, ANR and DFG.