The GIQS project

Graphene Impedance Quantum Standard

... three years in 15 minutes (≈ 10 ppm)

Luca Callegaro INRiM ISTITUTO NAZIONALE DI RICERCA METROLOGICA

+ a *lot* of people from the consortium!

EMPIR EURAMET

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

The GIQS project

GIQS — Graphene Impedance Quantum Standard

Joint Research Project of the
European Metrology Programme
for Innovation and Research

The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

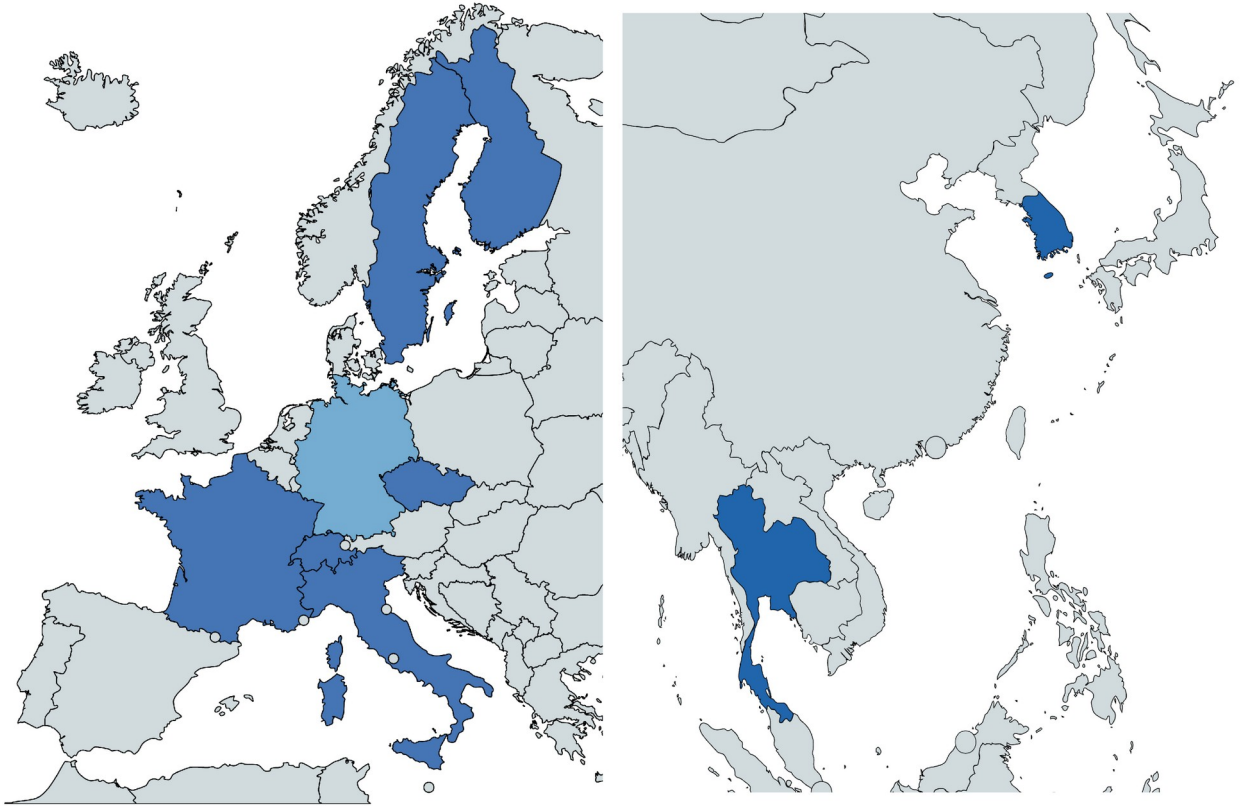
coordinated by the
European Association of National
Metrology Institutes

3 year duration (Jul 2019–Jun 2022)
EU contribution: 1560 k€

The project goals

1. Realisation of impedance units (ohm, farad, henry) in the revised SI traceable to fundamental constants
2. Shortening primary traceability chain of calibrations at stakeholder sites
3. Strengthening calibration facilities at smaller NMIs, calibration centres, industry
4. Electrical quantum standards for all metrology institutes
5. Fabrication of robust graphene-based quantum standards
6. Development of cryo-cooler system for all-in-one operation
7. Effective knowledge transfer

The project partners



PTB

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METROLOGY
INSTITUTE

LABORATOIRE
NATIONAL
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ET D'ESSAIS

LNE

METAS

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MIKES METROLOGY

NIMT

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Korea Research Institute of Standards and Science

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cnrs

The project implementation

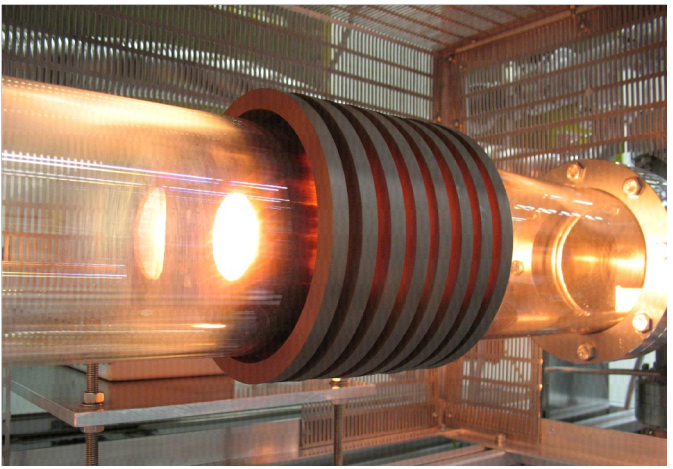
WP1: Graphene devices for AC-QHE applications

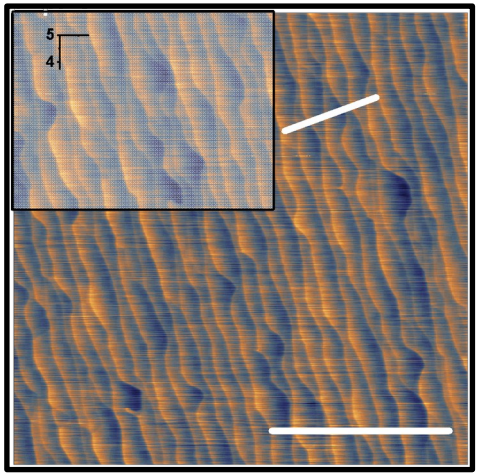
WP2: Digital- and Josephson impedance bridges for the realisation of capacitance

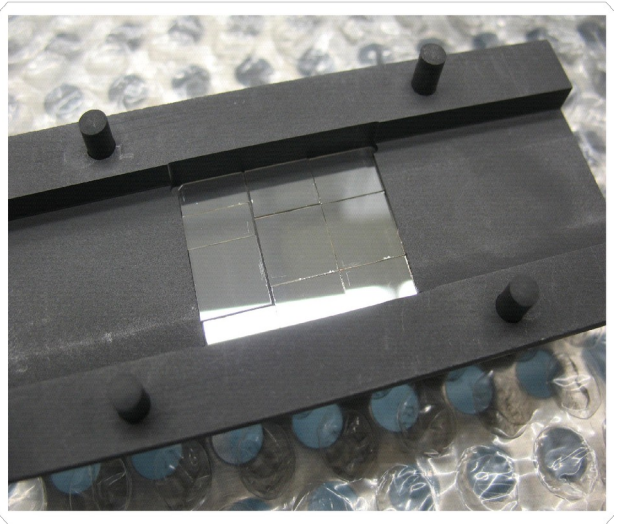
WP3: Graphene AC-QHR with digital and Josephson impedance bridges

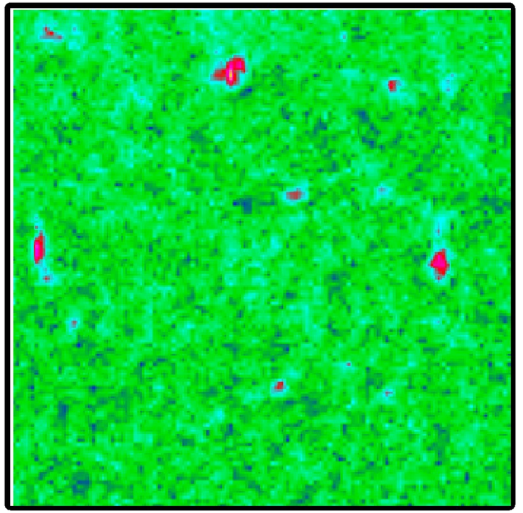
WP4: Creating impact

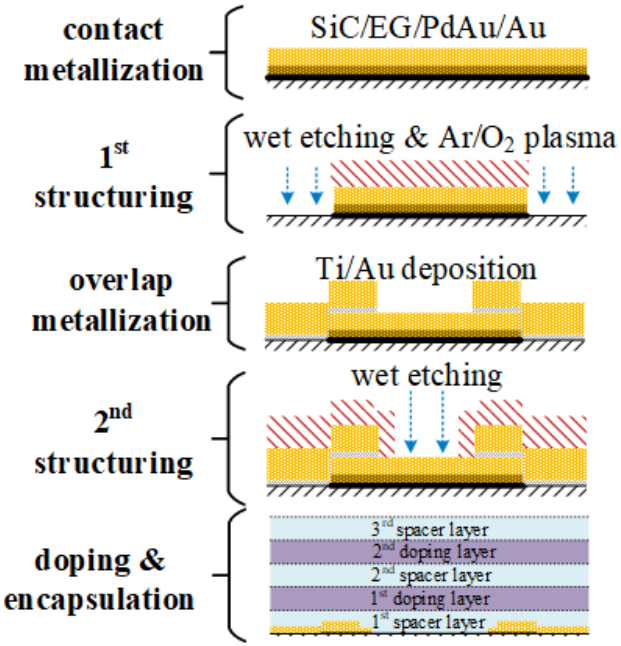
The devices: epigraphene on SiC

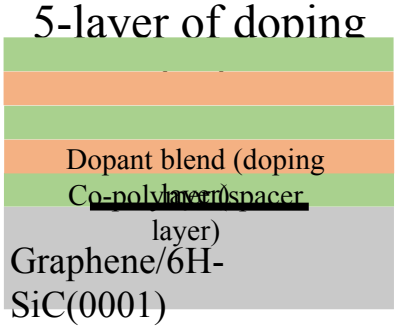




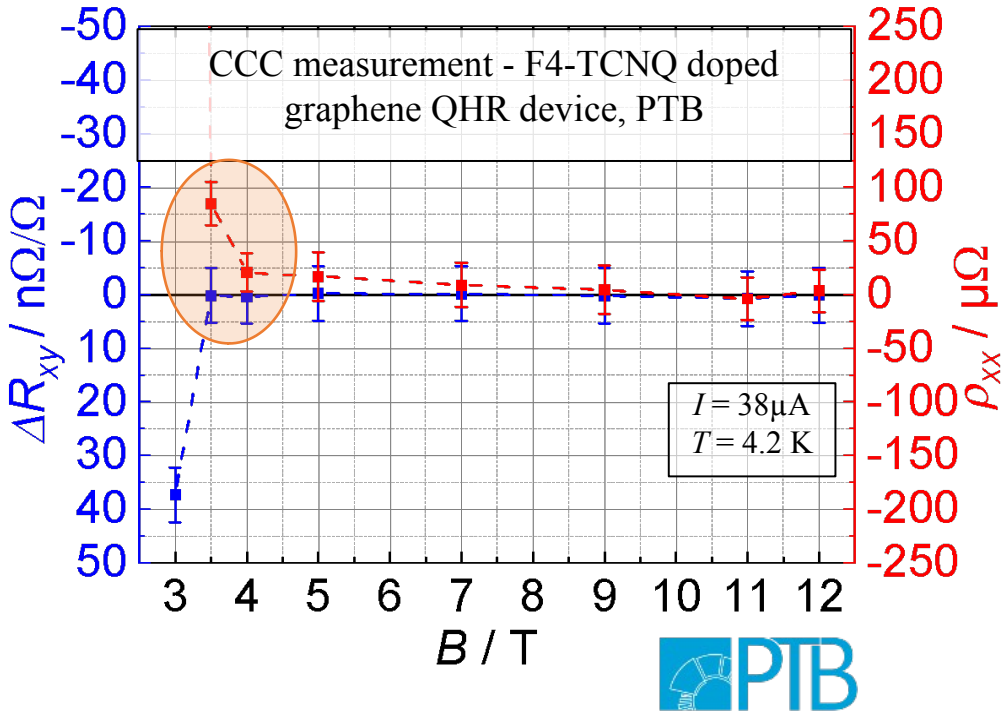


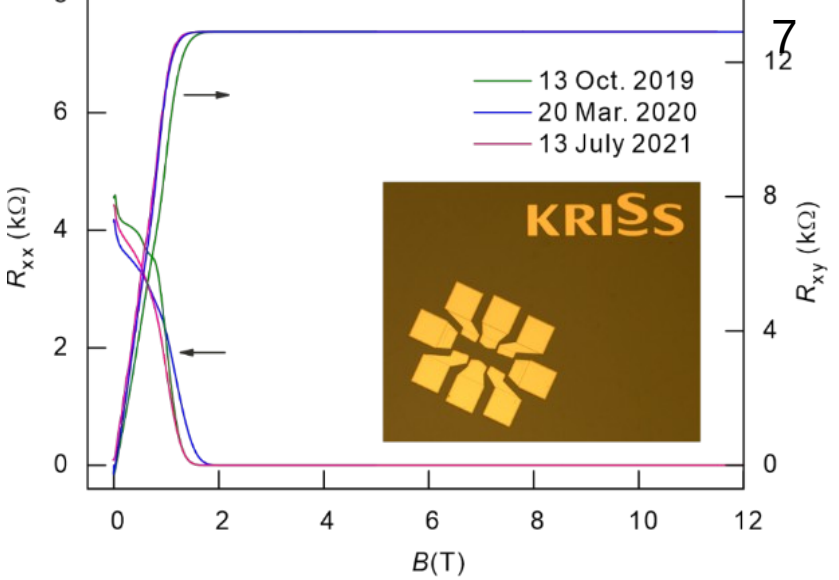


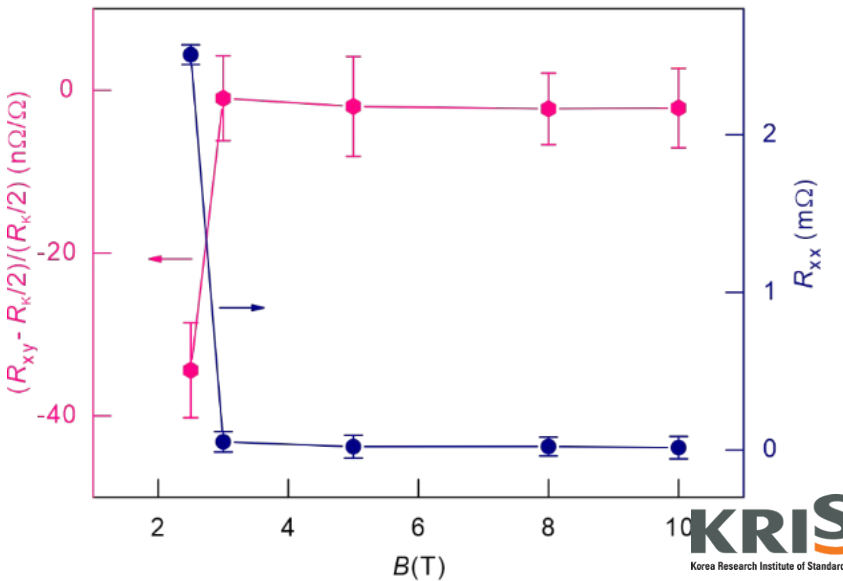




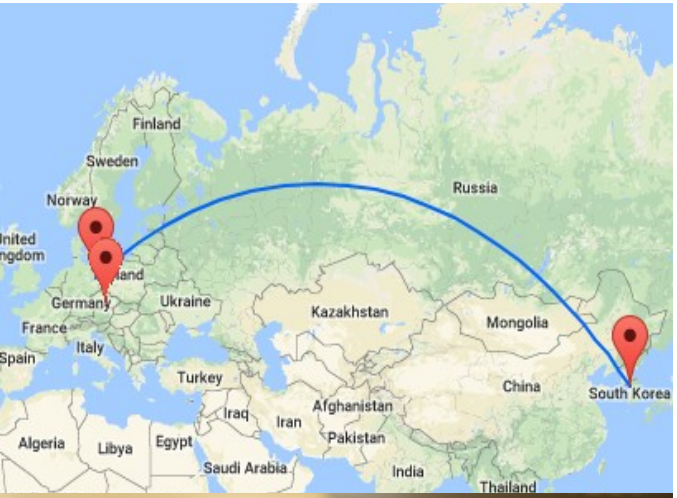
The devices: DC accuracy

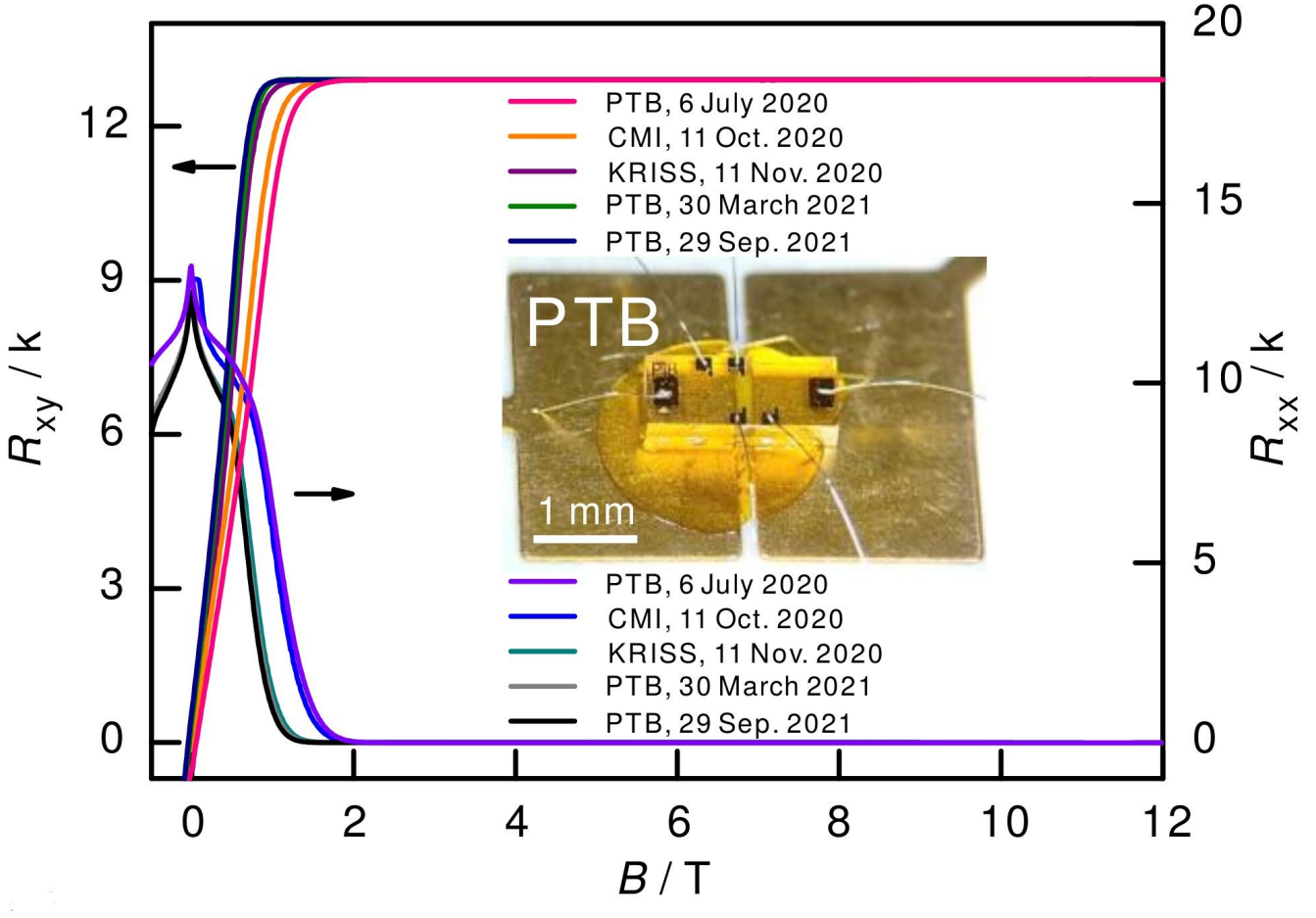




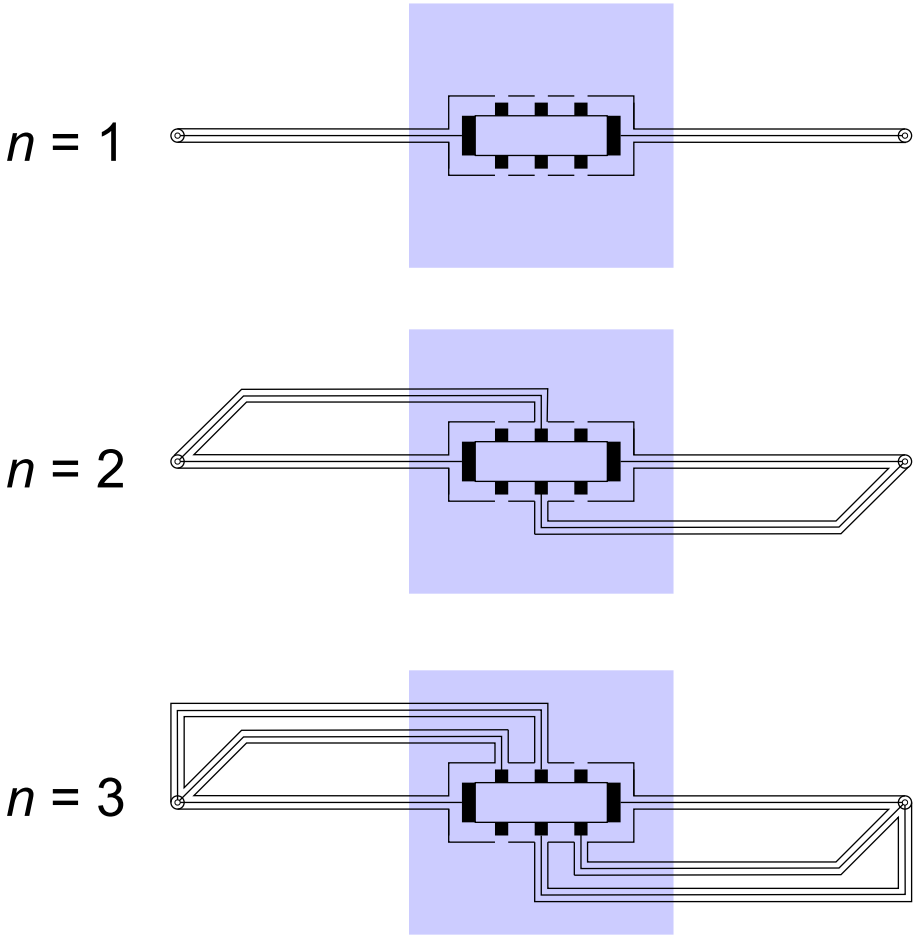


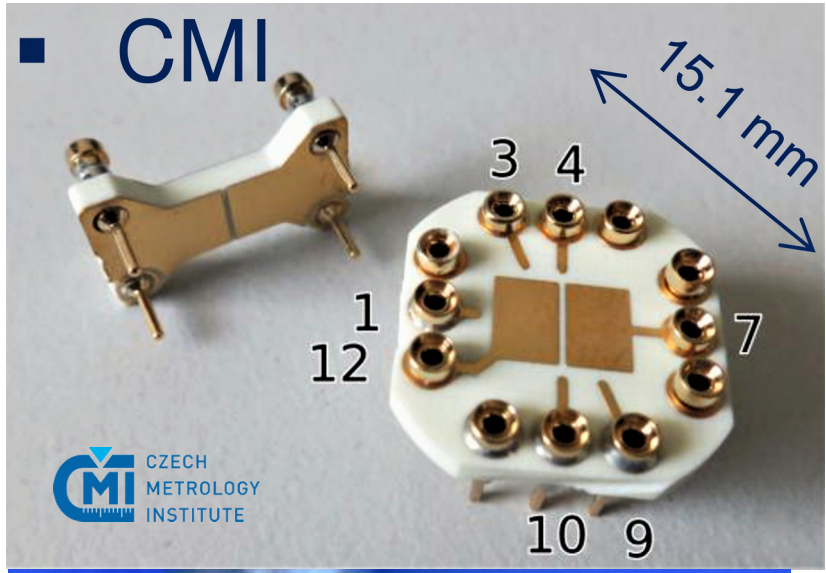
The devices: stability and reliability



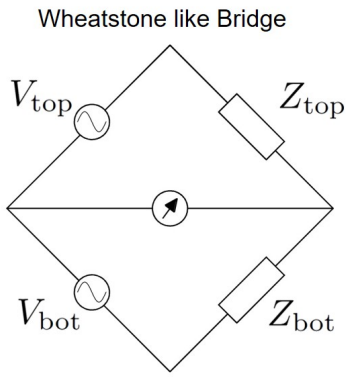


Cryogenic environments

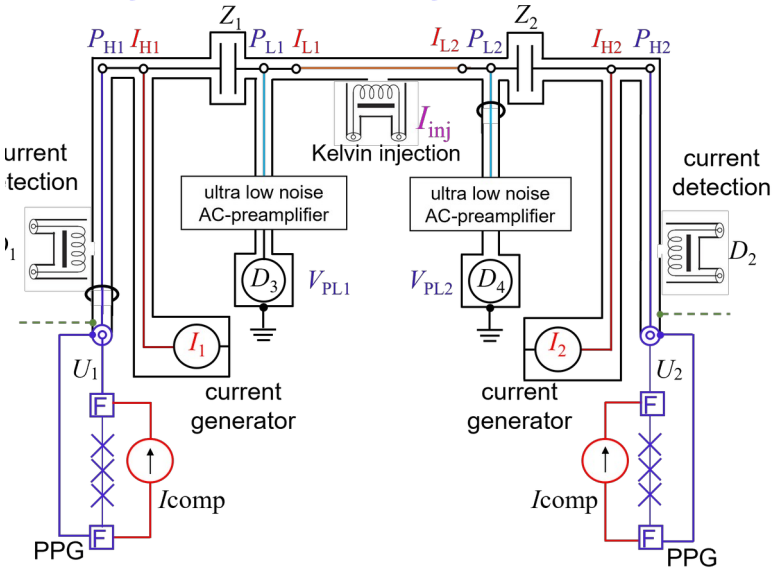


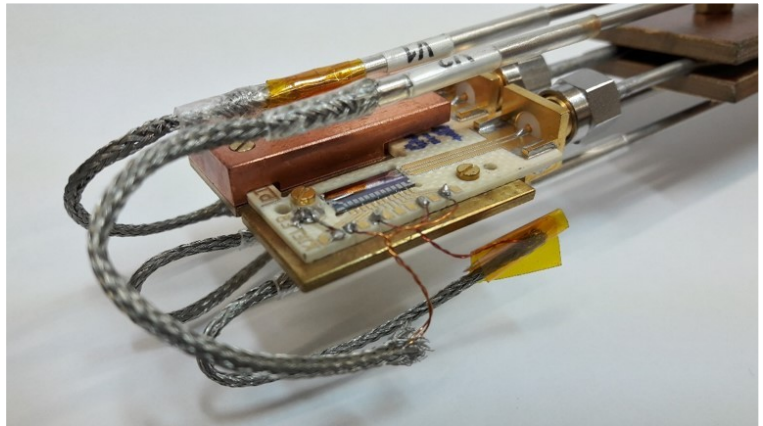


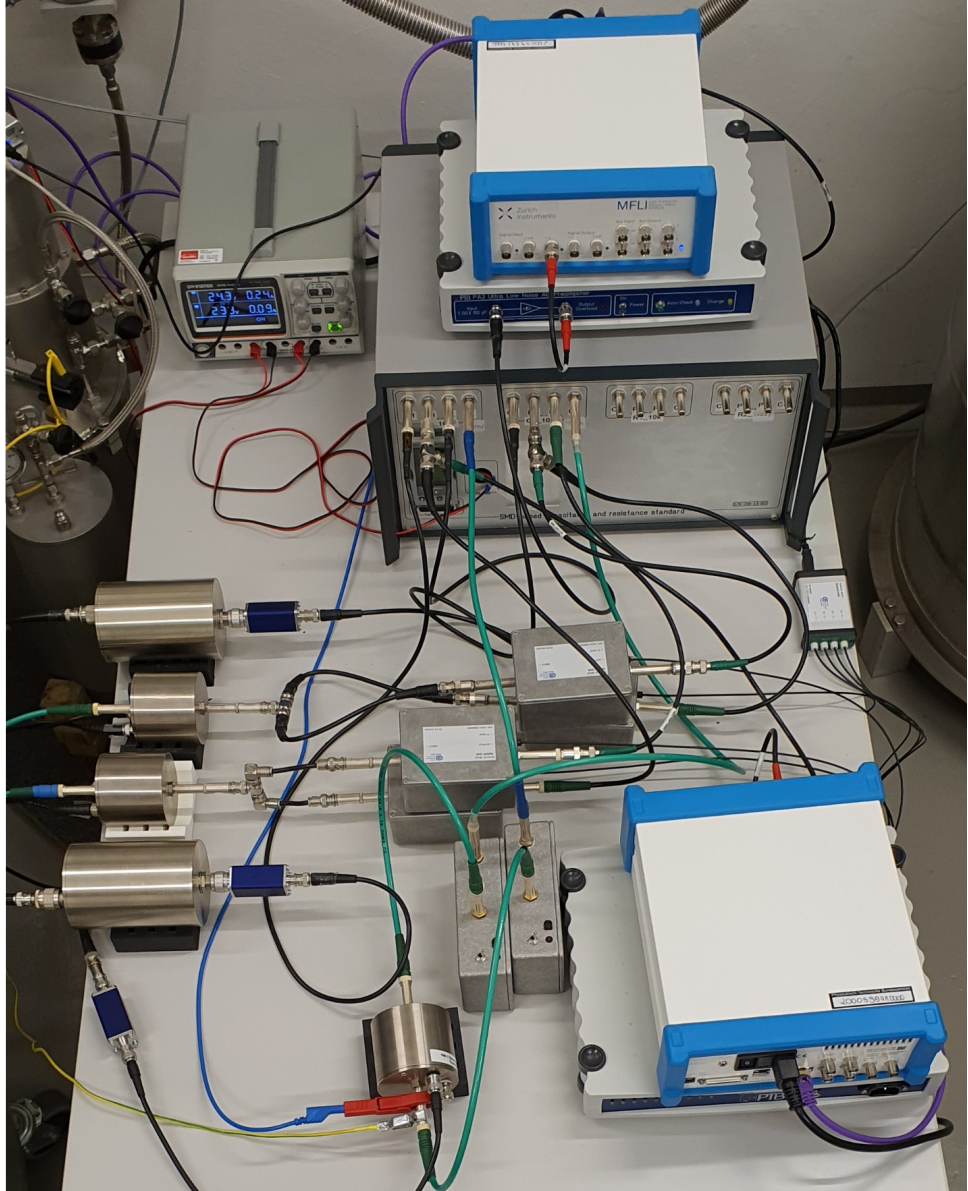
Josephson digital bridges



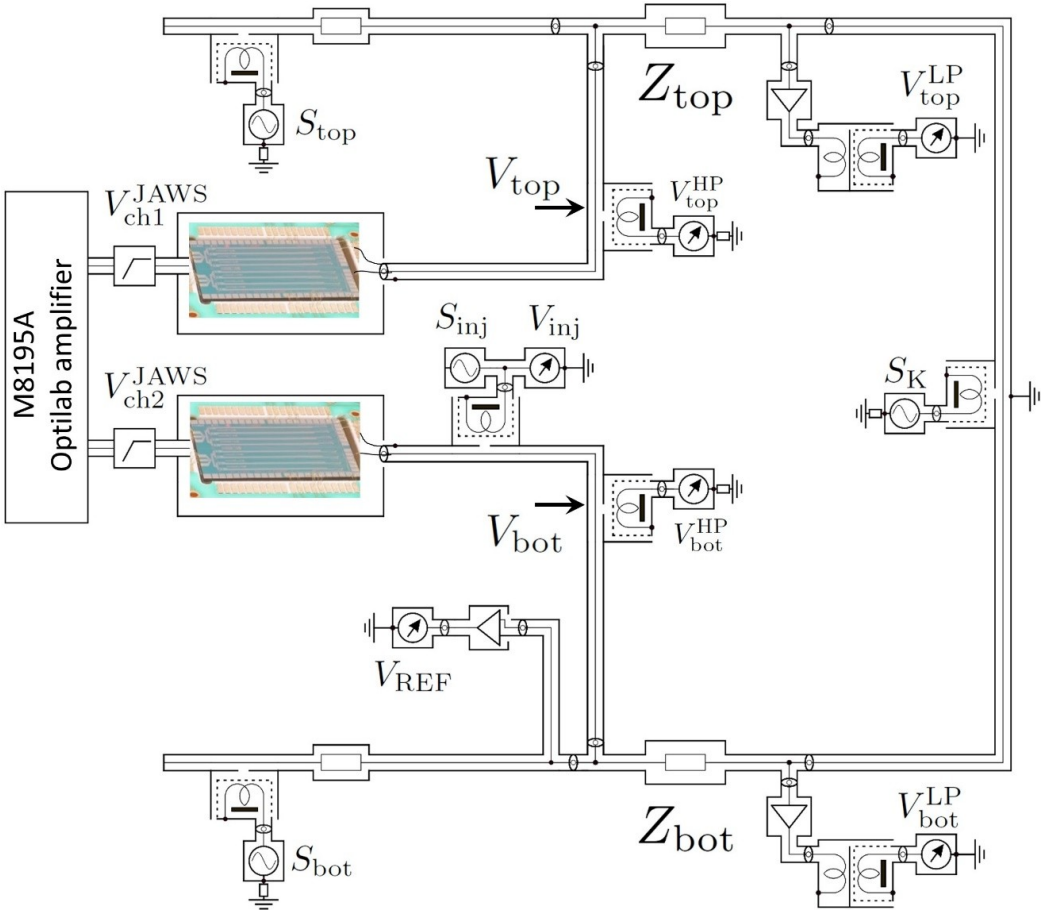
$$\frac{V_{top}}{V_{bot}} = -\frac{Z_{top}}{Z_{bot}}$$

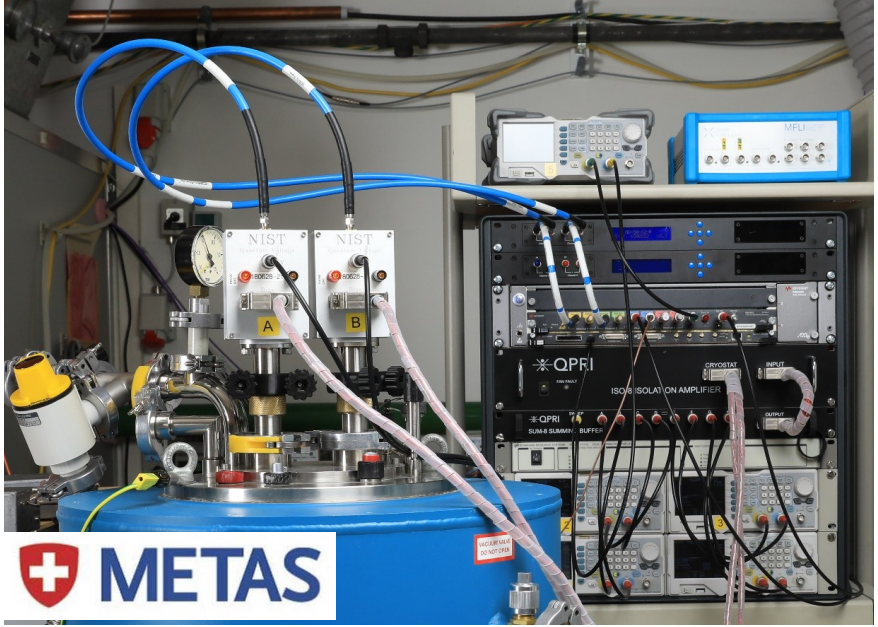


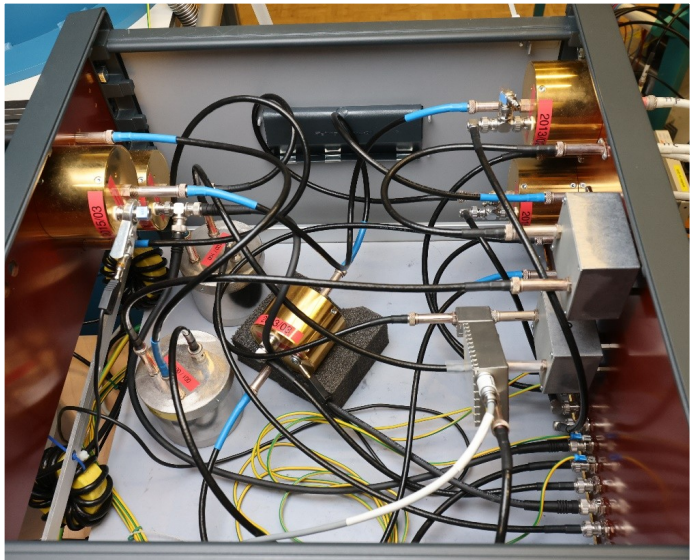




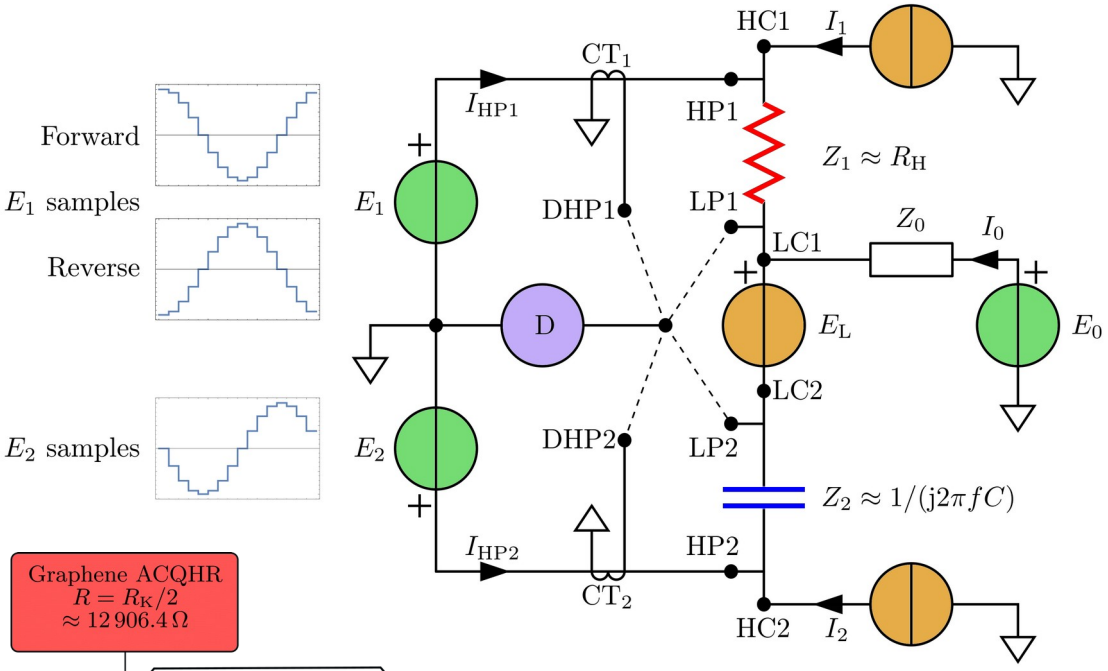
Josephson digital bridges

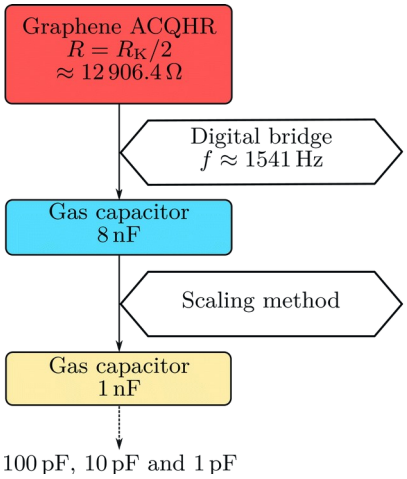


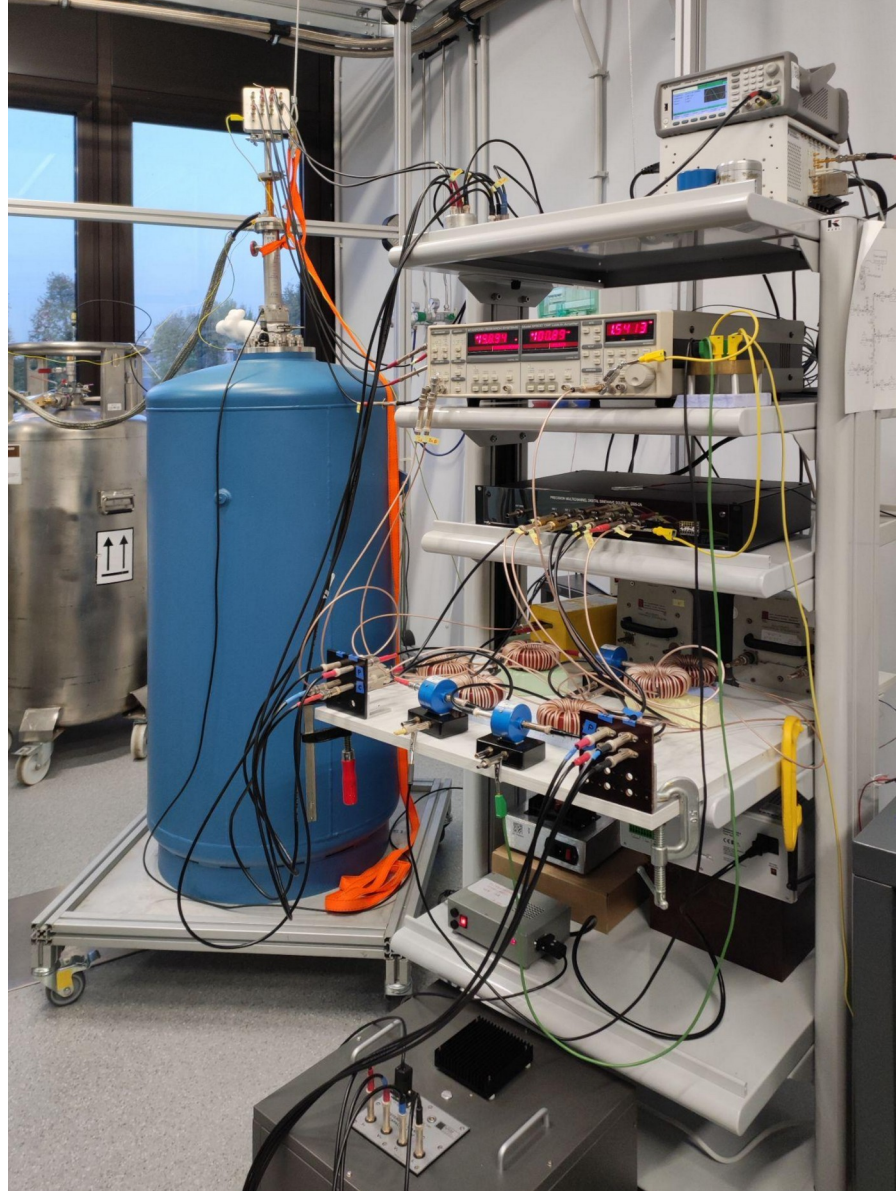




Electronic digital bridges







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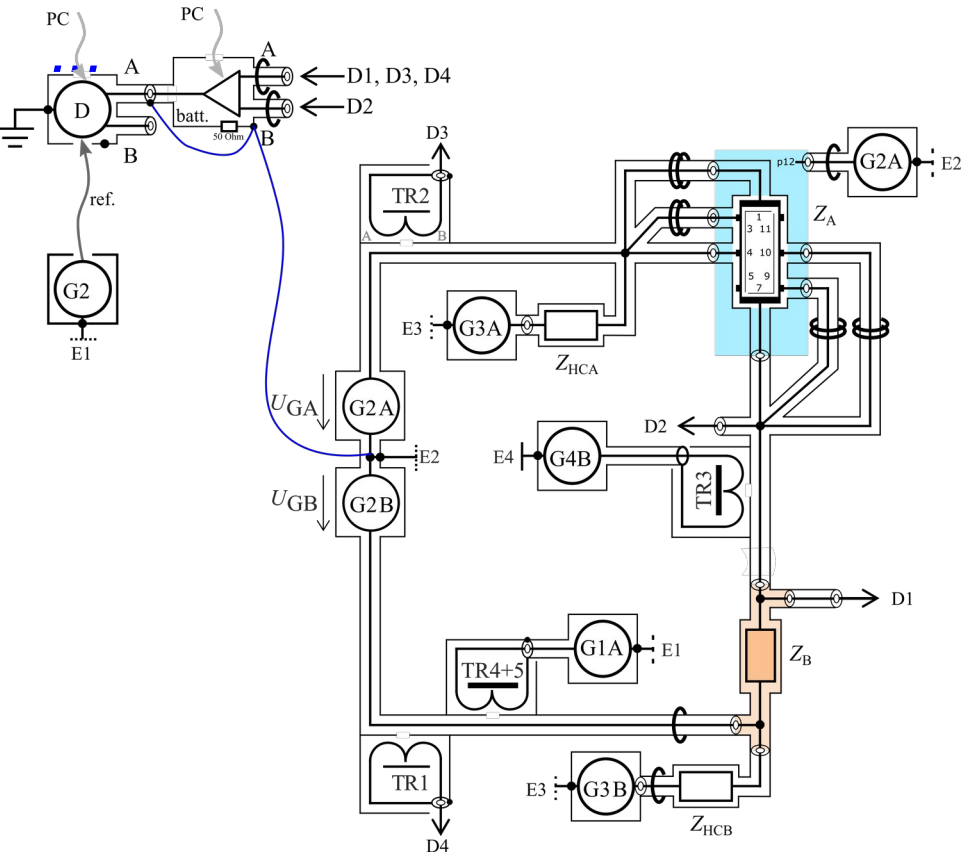
Electronic digital bridges



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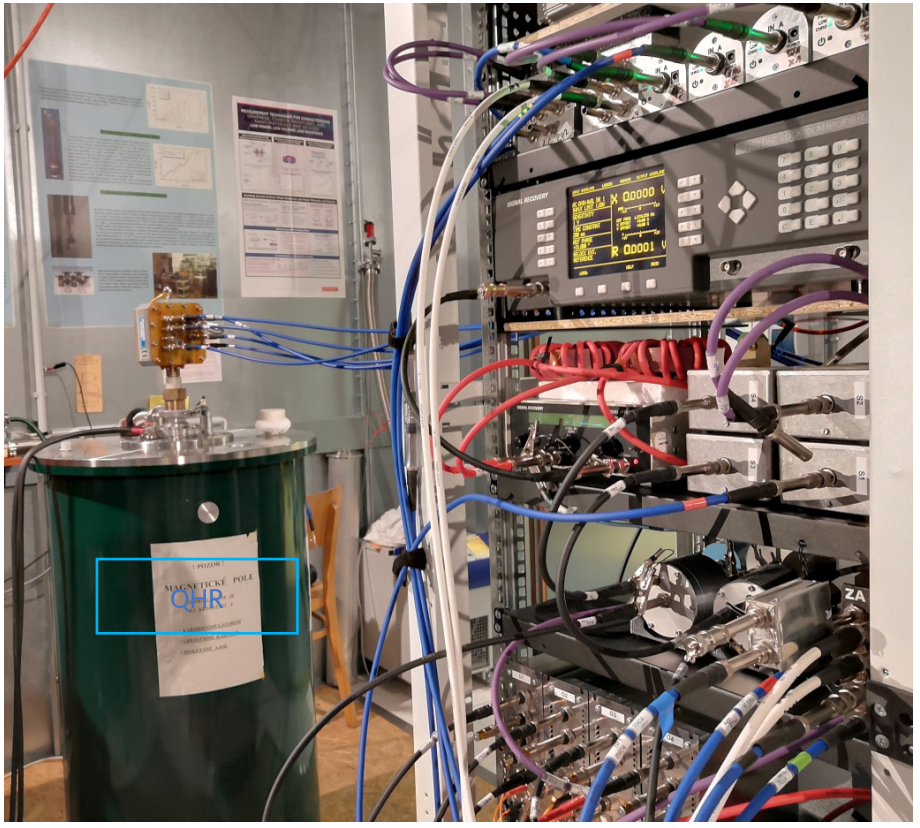
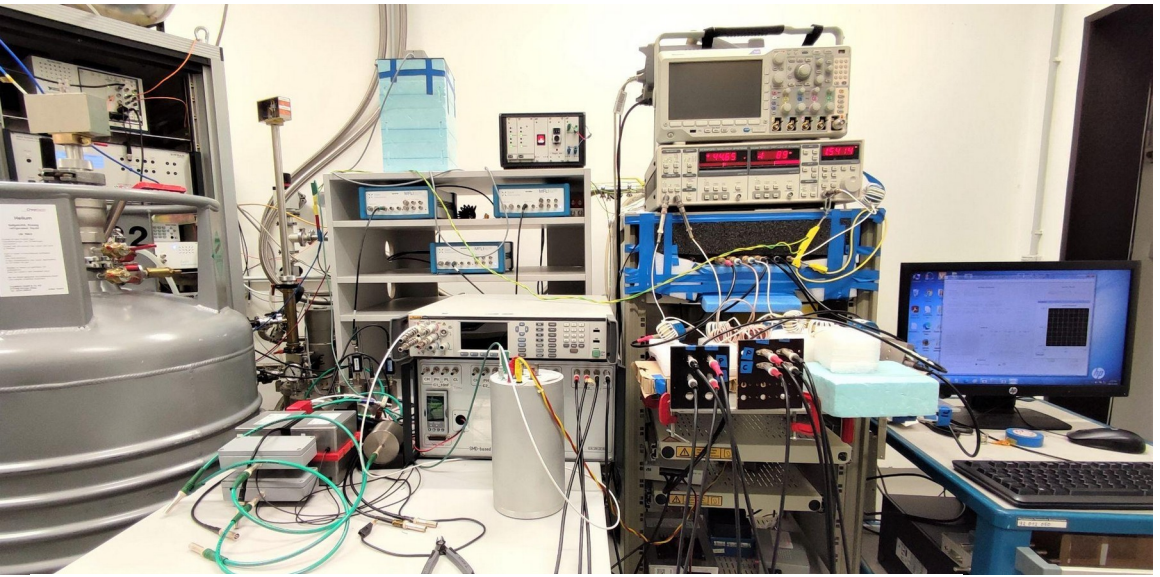


+QHR

FD DigiBridge

+DA

Assessment of digital impedance bridges

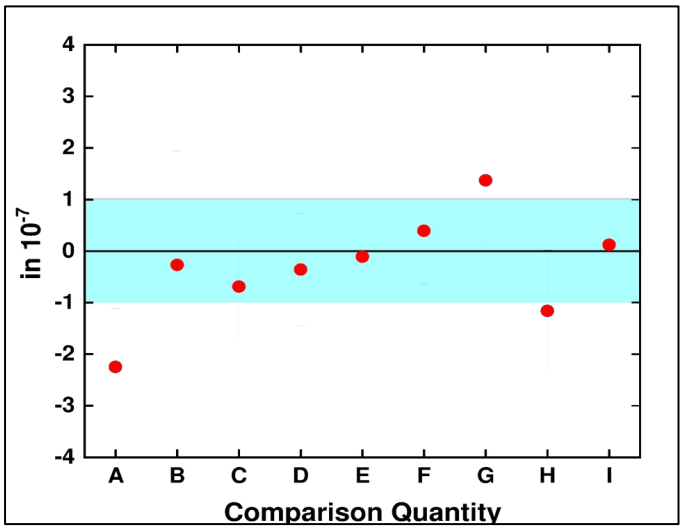


- R_1 = PTB 12.9 kΩ
- R_2 = INRIM 12.9 kΩ
- C_1 and C_2 = two PTB 10 nF

All the uncertainties are reported with a coverage factor $k = 1$.

Quantity	f/Hz	PTB	INRIM-POLITO	δ	Unit
$C_1/C_2 - 1$	1233	2.506(7)	2.731(111)	−0.225(114)	μF/F
$C_1/C_2 - 1$	2466	3.265(9)	3.292(221)	−0.027(221)	μF/F
$R_2/R_1 - 1$	1233	−21.633(9)	−21.564(102)	−0.069(103)	μΩ/Ω
$R_2/R_1 - 1$	2466	−21.808(11)	−21.772(108)	−0.036(109)	μΩ/Ω
$2\pi f R_1 C_1 - 1$	1233	10.311(9)	10.322(121)	−0.011(121)	μΩ/Ω
$R_{QHR}/R_1 - 1$	1233	−7.734(9)	−7.773(102)	0.039(103)	μΩ/Ω
$1/(2\pi f R_{QHR} C_2) - 1$	1233	0.266(9)	0.129(137)	0.137(116)	μΩ/Ω
$2\pi f R_1 C_2 - 1$	1233	7.504(9)	7.620(118)	−0.116(118)	μΩ/Ω
Triangle	1233	0.036(16)	0.024(194)	0.012(195)	μΩ/Ω

EURAMET Project #1501
Technical assessment of novel digital impedance bridges



Outlook: specialised cryostats

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Josephson + QHE
In the same cryostat

RISE

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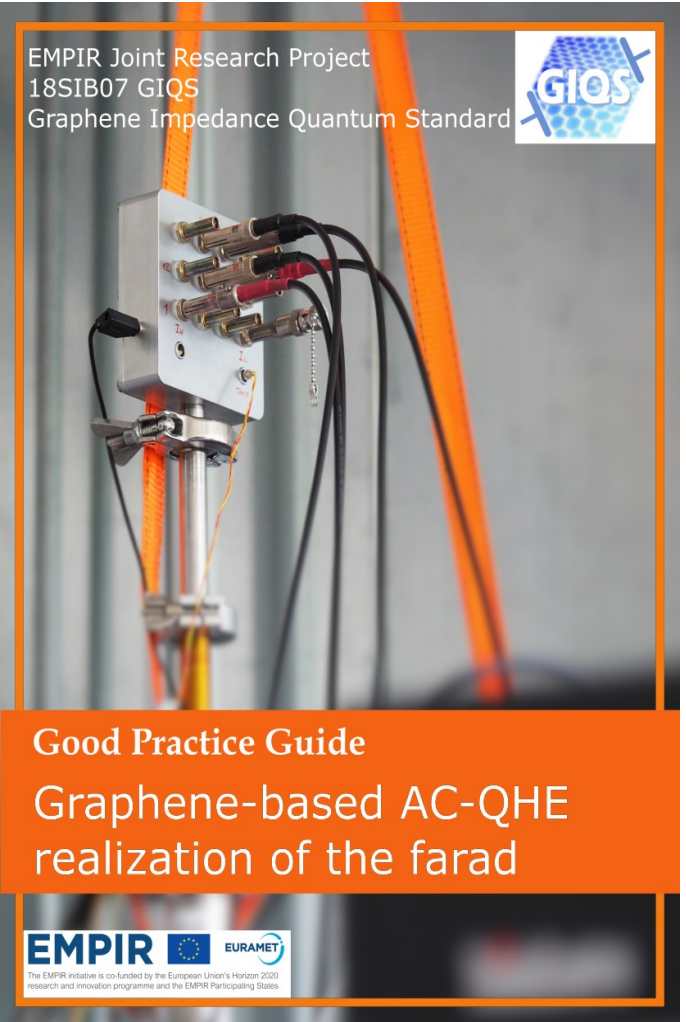
The Good Practice Guide



Contents

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83 references
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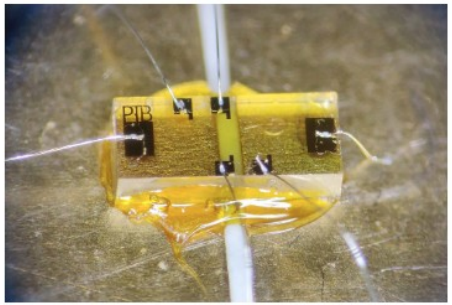
BIPM news [oct 2021]

Bureau International des Poids et Mesures

SIGN IN | Fra

"The transition from the actual GaAs-based QHR reference to a compact graphene-based reference, allowing relaxed operational conditions, is now underway at the BIPM and is planned to be effective in a few years' time."

ABOUT US | COORDINATION | LIAISON | TECHNICAL/SCIENTIFIC | PUBLICATIONS & EVENTS



Preparing for the transition from a GaAs to a graphene-based quantum Hall resistance reference at the BIPM

Check the website...

News & Events

Publications

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Scientific publications

Design and development of a coaxial cryogenic probe for precision measurements of the quantum Hall effect in the AC regime, M. Marzano et al., ACTA IMEKO 10 (2021)

Graphene quantum Hall effect devices for ac and dc electrical metrology, Kruskopf et al., IEEE TEM 68 (2021)

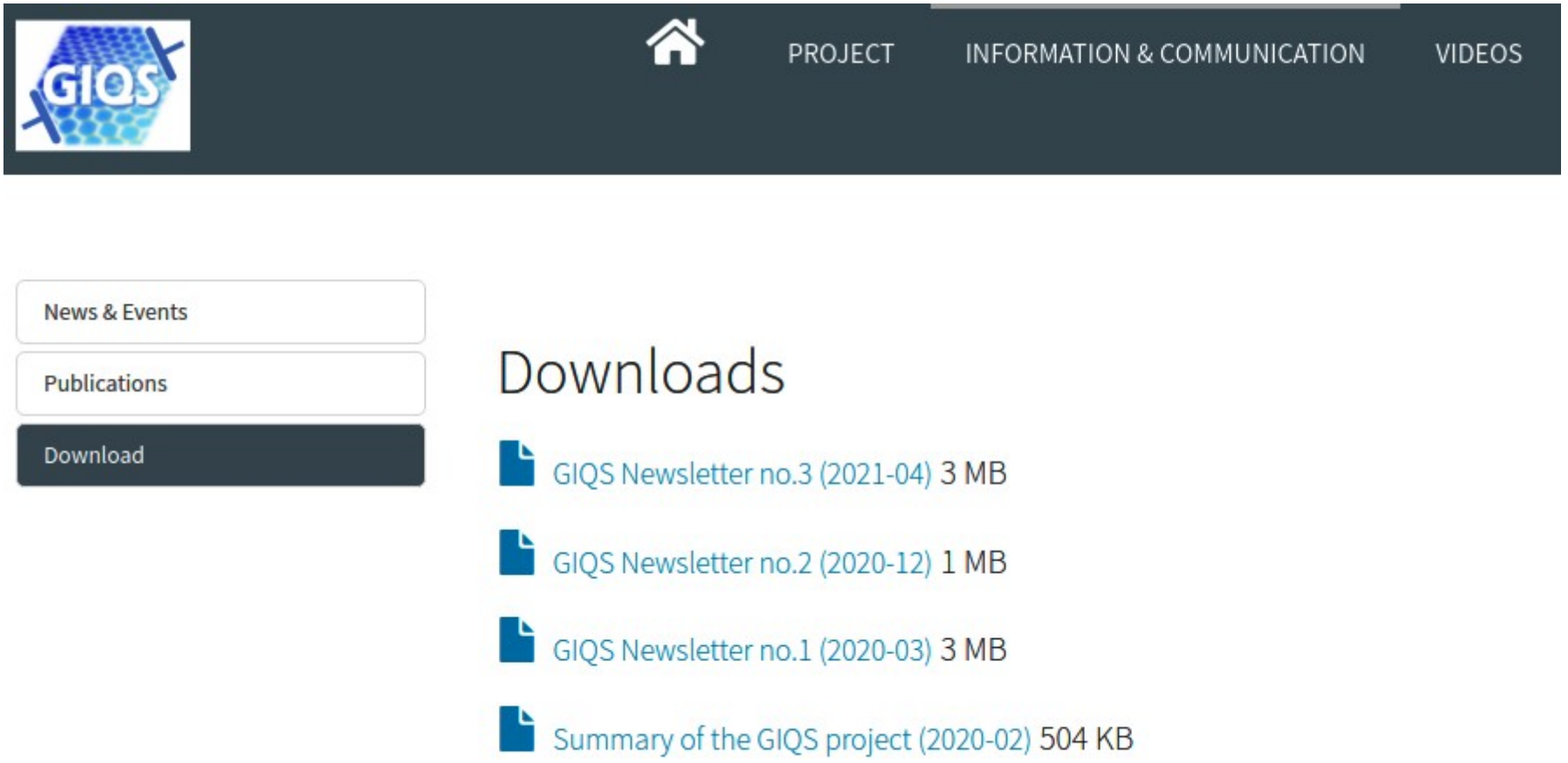
A four-terminal-pair Josephson impedance bridge combined with a graphene quantized Hall resistance, Bauer et al., Meas. Sci. Technol. (2021))

A fully digital bridge towards the realization of the farad from the quantum Hall effect, M. Marzano et al., Metrologia (2020)

Silicon Carbide Stacking-Order-Induced Doping Variation in Epitaxial Graphene, D. Momeni Pakdehi, Adv. Funct. Mater. (2020)

Realization of 5h/e2 with graphene quantum Hall resistance array, J. Park et al., Appl. Phys. Lett. (2020)

Check the website...



… and our social channels!

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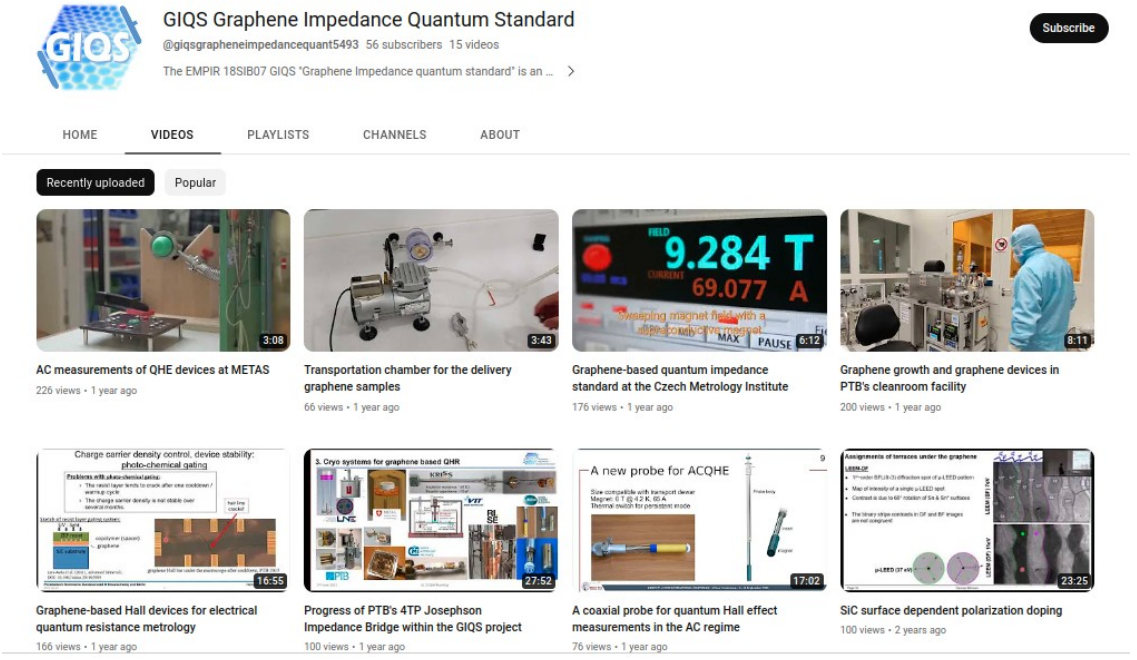
ResearchGate



Thanks to:
- the people of the consortium!
- the collaborators and stakeholders!

Thank you!