CEM infrastructure for the experimental application of quantum technologies

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Based on macroscopic quantum effects
- Josephson effect
- Quantum Hall effect

Based on subatomic quantum effects
- Ion trap

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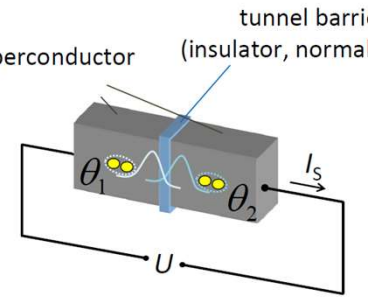
Josephson effect: Cooper pair tunneling

Predicted by Brian D. Josephson in 1962



$U \neq 0$: AC current with frequency $f_J = 2eU / h$

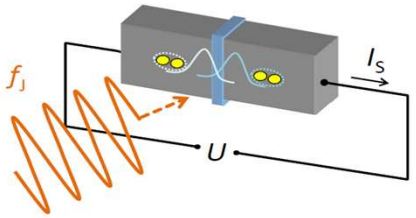
$$I_S(t) = I_{Smax} \sin(\varphi(t))$$

$$\frac{\partial \varphi(t)}{\partial t} = \frac{2e}{\hbar} U$$

AC Josephson effect

Josephson voltage standard

Inverse of the AC Josephson effect



$$U_n = n \frac{h}{2e} f_J = \frac{n f_J}{K_J}$$

$K_J = \frac{2e}{h}$ Josephson constant

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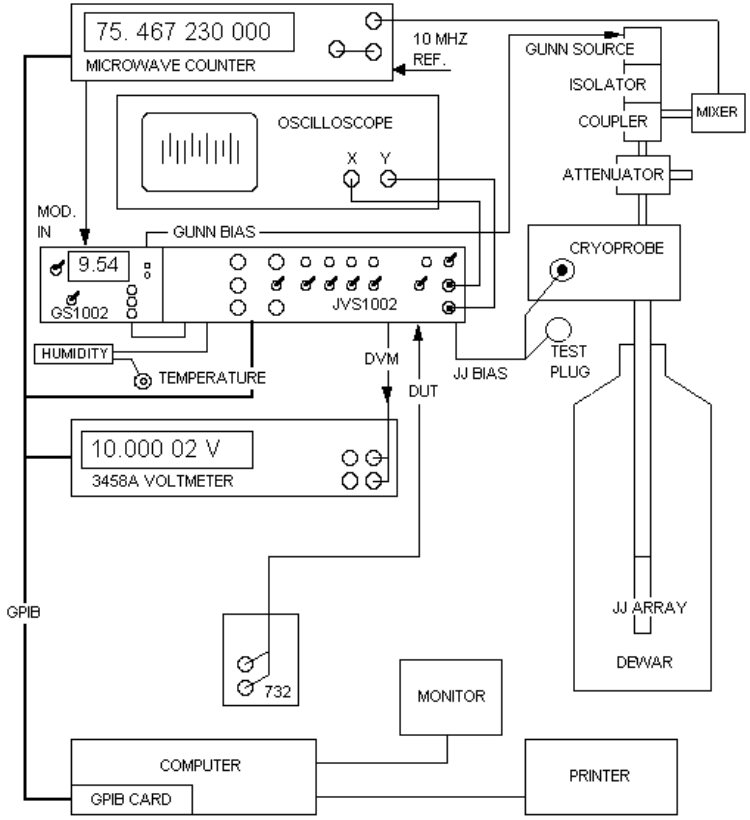

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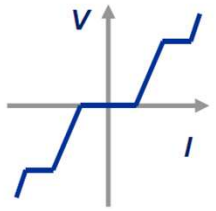
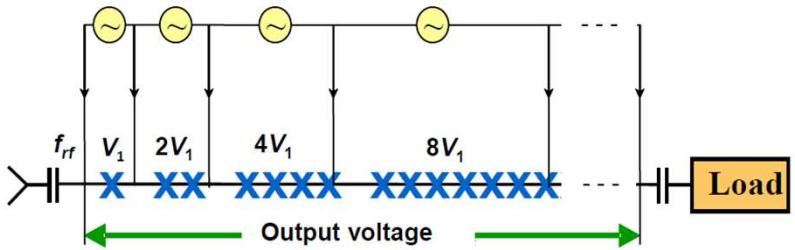
D/A converter

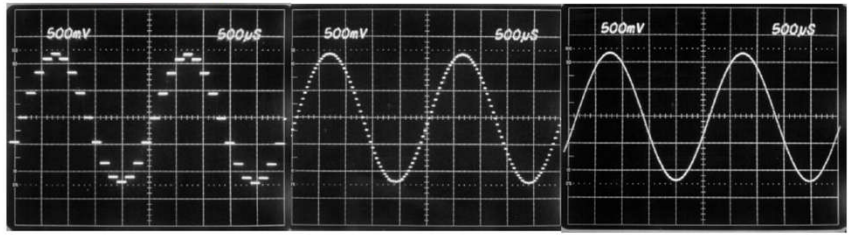


Computer-controlled current sources



C. A. Hamilton et al., *IEEE Trans. Instrum. Meas. 44 (1995) 223*

- 400 Hz, 13 binary bits



16 samples 64 samples 256 samples

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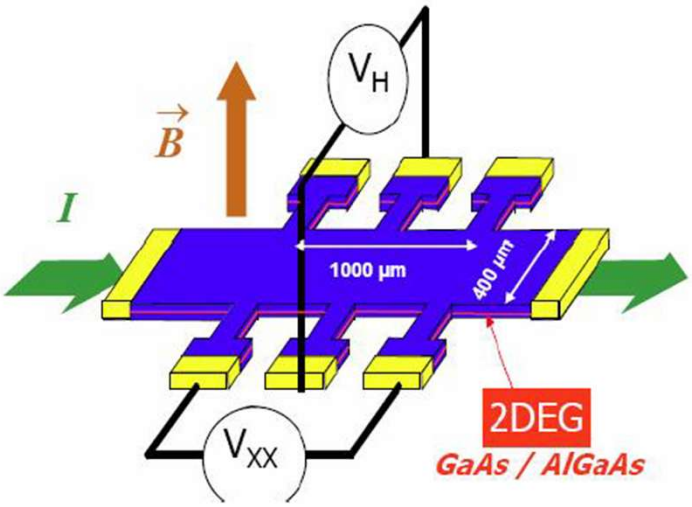
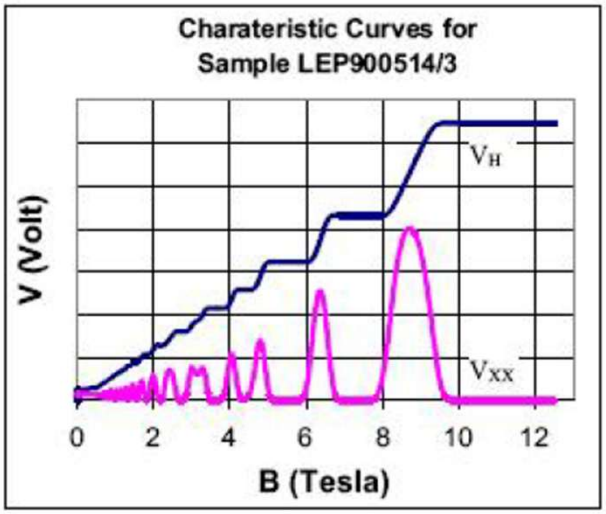
Quantum Hall Effect





In flat areas:

$$V_{xy} = \frac{h}{ne^2} I$$

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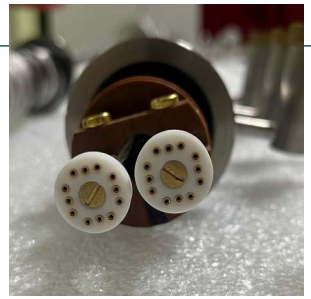
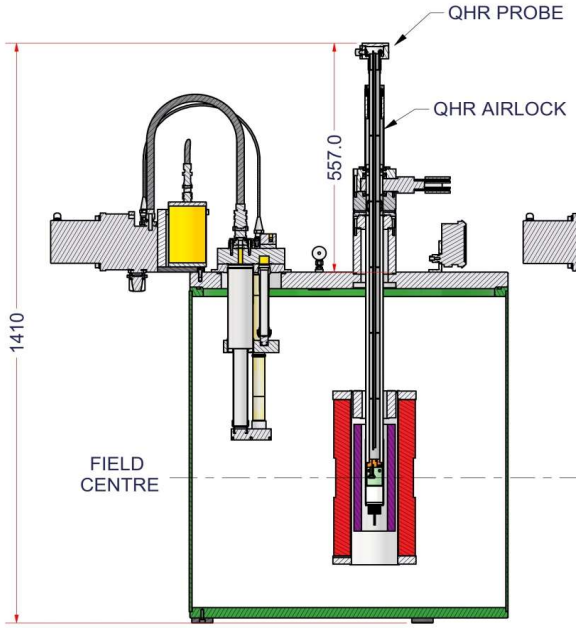
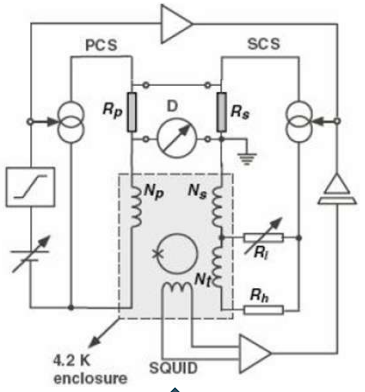
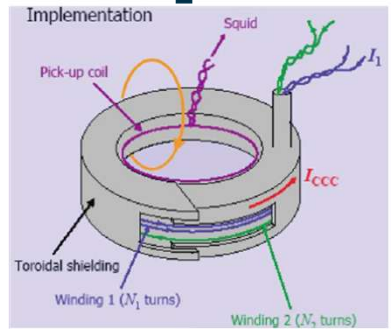
Cryogenic Current Comparator









- Two samples simultaneously
- Magnetic field up to 13 T
- Temperature below 1,5 K (0,3 K with He-3)

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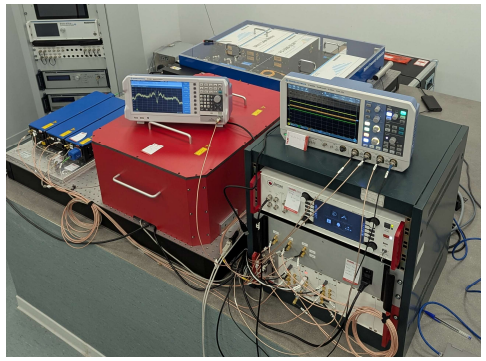
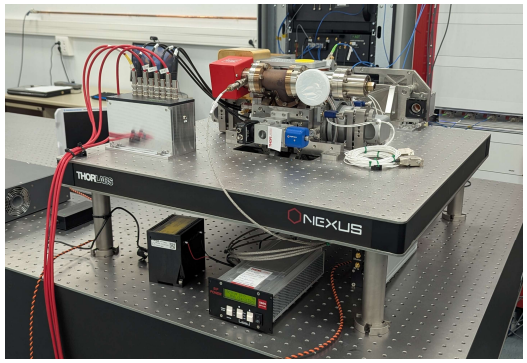
Second quantum revolution metrology

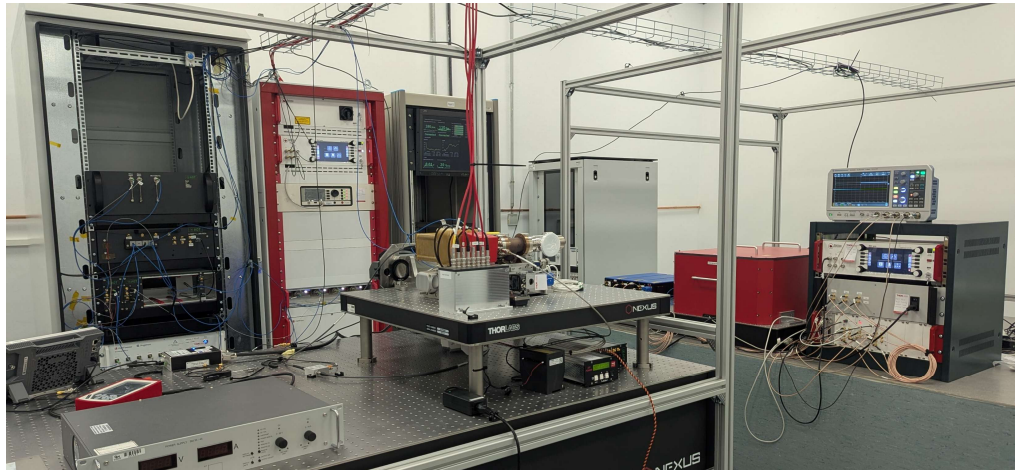
CEM has developed a laboratory to develop second-generation quantum metrology.

This includes an ion trap, a frequency comb, a set of lasers including an ultra-stable laser, and other needed devices. The purpose of this laboratory is

- Quantum optical frequency standard
- Collaborate in the redefinition of the second
- Quantum communications
- Research in fundamental physics
- Dissemination optical quantum frequency to CEM's laboratories







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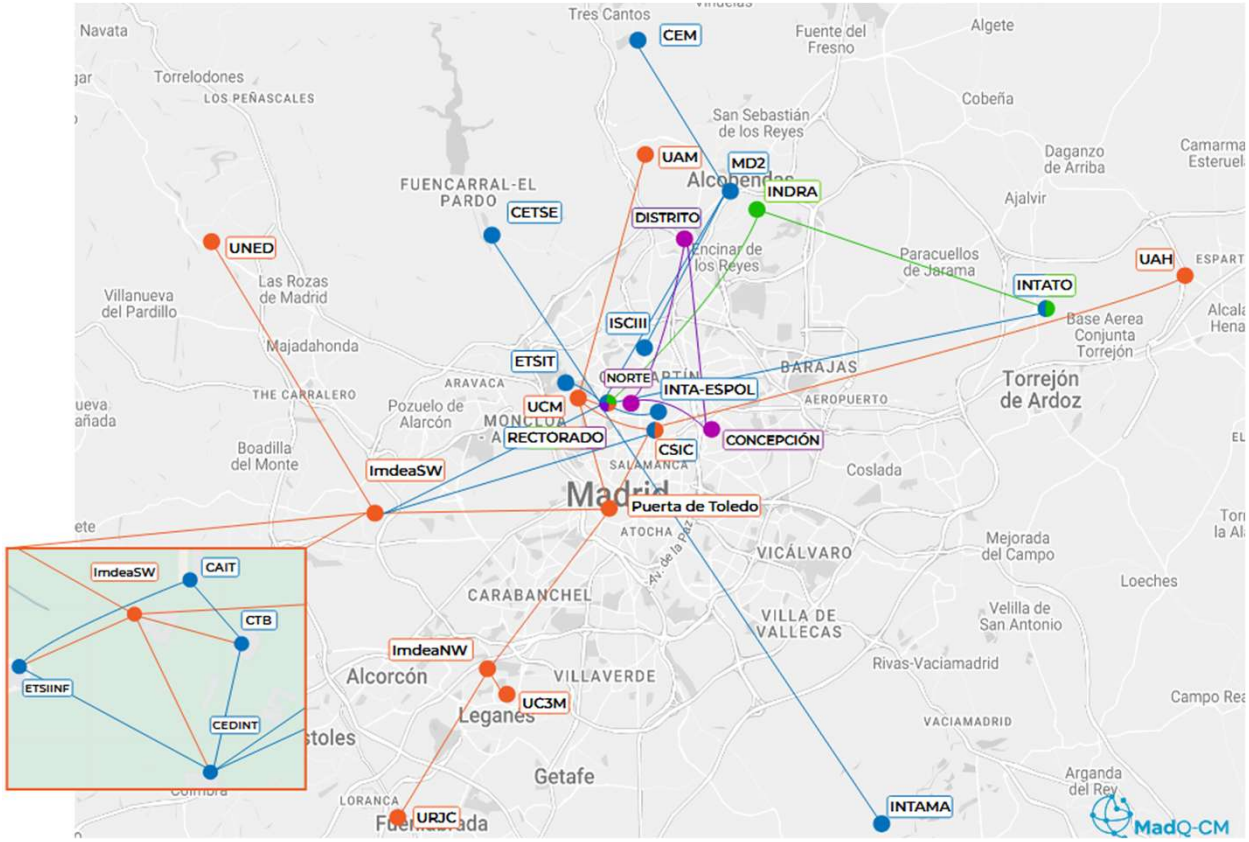
MADQuantum-CM project

Development of a quantum communications network in the Community of Madrid (MadQCI).

UPM is leading this project, which has the following partners: CEM, UCM, UAM, INTA, IMDEA-SW, IMDEA-Net, FVITHAS.

- 29 locations, 700 km

A common time and frequency reference is essential for synchronizing all network nodes. CEM will provide this frequency reference and be a node of the network.



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SRT-s03: Metrology for QKD to support quantum communication infrastructure deployments

European Partnership on Metrology
Call 2025 – Health, Integrated European Metrology, Regulation and Research Potential

Selected Research Topic number: **SRT-s03**
Version: 1.0

EURAMET

The main aims of the project are:

- Develop traceable methods for testing and certification of innovative QKD solutions, and also develop the metrological techniques required to establish efficient fiber links for long-haul distances.
- Facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain and **standards developing organizations (CEN CENELEC, ETSI, IEC, ISO).**

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