

Report on Electromagnetic Metrology Activities at JV, Norway Prepared for the 34th Meeting of the CCEM 2025

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During the last two years Helge Malmbekk has left JV for a job at **Institute for Energy Technology (IFE)** as Research Manager in Solar Cell Technology and was replaced as group leader by Bjørnar Karlsen who took over the lab and research responsibilities. Lars Kristian Skaar and Pascal Sado were hired in 2023-24 as part of taking over responsibilities related to DCI/DCV and ACI/ACV calibration responsibilities (LKS) and for automation of the electro (EL) labs at JV. During the last two years, our group has focused on research related to resistance standards, Josephson standards, power & energy, and automation of labs.

Current EPM Projects:

1. **2023:** In June 2023 the EPM project True8DIGIT started, focusing on the development of a digitiser with a state-of-the-art ADC, operating from DC to 100 kHz, to meet the demands for linearity, noise, and overall accuracy of current applications in NMIs and research which cannot be met using currently available DMMs, digitizers or ADCs.
2. **2024:** Metrology for superconducting qubits (MetSuperQ) is a Joint research Project of the European Partnership on Metrology, that started 1st June 2024. This project concerns the metrological aspects of superconducting qubits, such as qubit materials, peripheral devices, characterisation of operation and round-robin comparison.
3. **2024:** Wideband AC quantum traceability (WAC) is a Joint research Project of the European Partnership on Metrology, that started 1st June 2024, and JV is the leader of WP3. This project furthers the development started in previous projects such as TracePQM and QuantumPower, and aims to develop its own wideband quantum voltmeters (WBQV) to be used as an alternative to thermal converters and thermal transfer standards. The WBQVs consist of high-precision digitizers and PJVS and make use of a differential sub-sampling method to make it usable for frequencies up to 100 kHz.
4. **2024:** Quantum anomalous Hall effect materials and devices for metrology (QuAHMET) is a Joint research Project of the European Partnership on Metrology. During 19-21st June of 2024, the QuAHMET project kick-started, and JV is coordinating this project. The project will focus on the traceable measurement and characterisation of quantum anomalous Hall effect (QAHE) materials as devices and primary resistance standard candidates. The QuAHMET project consortium consists of 14 partners and gathers 7 leading European national metrology institutes (NMIs), a Japanese NMI for metrology, complemented by 6 globally recognized institutes from academia and applied

research. Within the project, the partners will explore and understand in-depth a new but scientifically grounded methodology for developing metrology grade QAHE devices, and to achieve higher operating temperatures and currents compared to the current state-of-the-art.

5. **2024:** Metrology for electric vehicle charging systems (Met4EVCS) is a Joint research Project of the European Partnership on Metrology, that started 1st July 2024. The project aims to develop metrology concerning electric vehicles in terms of grid disturbances, metring accuracy and energy transfer efficiency, on-site verification and standardisation.

Completed EMPIR and TC projects 2023-24:

1. In 2024, we completed the EMPIR project [QuantumPower](#), coordinated by Dr. Bjørnar Karlsen, where the overall objective of the project is to develop a quantum sampling standard for electrical power which is open to the whole Metrology community and provides direct traceability to the new quantum SI. The use of quantum standards in sampling of electrical power enables direct traceability not only for power measurements, but also for PQ and phasors. The project has developed the open-source design for a multiplexer, which has been used and synchronised with the sampling system. The multiplexer switches the inputs of the analogue-to-digital convertors (ADCs) between the voltage, current and PJVS channels to provide real-time calibration of the ADCs and substantially decrease the uncertainties of the power measurements. The multiplexer enables using a single PJVS chip for measurement of both current and voltage components of the electric power using differential sampling, or to provide calibration of ADCs before and after the direct sampling of electric power.

The software for performing the measurements is open source and can be found here: <https://github.com/KaeroDot/QPsw>. It is based on three separate components, which can be operated together or on their own:

1. The sampling software TWM first developed during the TracePQM project samples data from commercial digitizers such as the HP3458A or NI5922.
2. The algorithm toolbox QWTB performs waveform analysis on the sampled data.
3. The newly developed QPScontrol sets up commercial PJVS bias source hardware such as the NPL bias source, the Supracon AC Quantum Voltmeter and configures commercial trigger hardware.

A YouTube-channel has been created to share information about the project: <https://www.youtube.com/@quantumpowerempirproject9560?themeRefresh=1>

2. During the last few years, we have been discussing technical solutions for calibration and control of fast DC charging of electrical vehicles. We have also acquired test equipment for on-site measurements of electric vehicle chargers. A Nordic cooperation on the legal metrology issues related to this (NordCharge) and a EURAMET project ([LegalEVcharge](#)) has been initiated to investigate the issues related to fair and correct billing of electrical vehicle charging as well as coordinated work on providing a standard for testing of DC charging stations. The work has resulted in a [guide for metrological requirements for EV charging stations](#). In addition, we are developing measurement equipment for calibration commercial test equipment used for measurement systems at DC charging stations. This will be tested at EV charging stations operated in arctic winter condition. Proposed end date of the project was December 2024.

Infrastructure: Soon, we plan to gradually start investing in cryostat for QHE standard based on Graphene and to customise existing cryostat and samples for investigating the Quantum Anomalous Hall Effect (QAHE). We also intend to expand on our capabilities within operation of Josephson arbitrary waveform synthesizers (JAWSs) using cryocooled photodiodes to generate current pulses to bias Josephson junction arrays (JJAs).

During the last EPM calls we have participated in multiple project proposals involving small current metrology. While none of the proposals were accepted, **we remain deeply interested in developing our traceability in small current metrology** to serve the need for traceability down to the femtoampere range, particularly for applications in quantum technology.

Finally, the resistance calibration lab is currently undergoing upgrades to improve automation and digitalisation lead by Dr. Sado. The upgrades focus on improving or replacing current or outdated workflows, introduces automated scheduling, execution and analysis of calibrations and integrating these with established systems for order-and inventory tracking to improve processing times, reduce manual labour and avoid mistakes.

Publications and presentations

1. Technical Committee on Electromagnetism Contact person meeting. Technical talk: "EPM project: quantum anomalous Hall effect maybe real devices for metrology", S. Kumar Oct. 2024
2. EMN-Q General meeting. Technical talk: "EPM project: quantum anomalous Hall effect maybe real devices for metrology", S. Kumar Oct. 2024
3. [N.J. Huang et al., Quantum anomalous Hall effect for metrology, Appl. Phys. Lett. 126, 040501 \(2025\)](#)
4. [L. Callegaro et al., QuAHMET: Quantum anomalous Hall effect materials and devices for metrology. Measurement: Sensors, 2024, 101437](#)