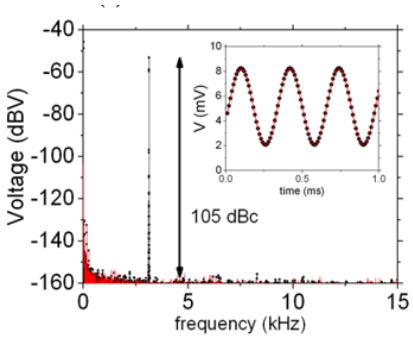
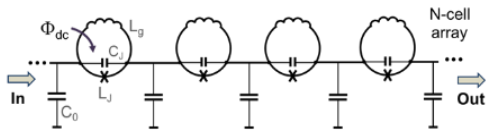
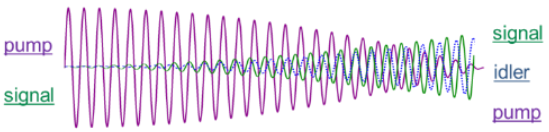
National Physical Laboratory

News from NPL for the CCEM, 28-29 March 2019



In the EMPIR project QuADC "Waveform metrology based on spectrally pure Josephson voltages", NPL has developed an optoelectronic pulse drive for Josephson junction arrays. The synthesis of quantum-accurate waveforms up to frequencies of 300 kHz has been demonstrated (https://ieeexplore.ieee.org/document/8540847). The system has several advantages over the electrical pulse drive equivalent including lower cost and easier future commercialisation and scalability. In collaboration with PTB, CMI, Signal Conversion, Applicos and INTI, NPL has demonstrated proof of concept for the real-time quantum-accurate characterisation of voltage waveforms, using a novel FPGA (Field Programmable Gate Array)-based system combined with the optoelectronic pulse drive. PTB brought a quantum voltage synthesiser to NPL in order to develop validation methods for the system.



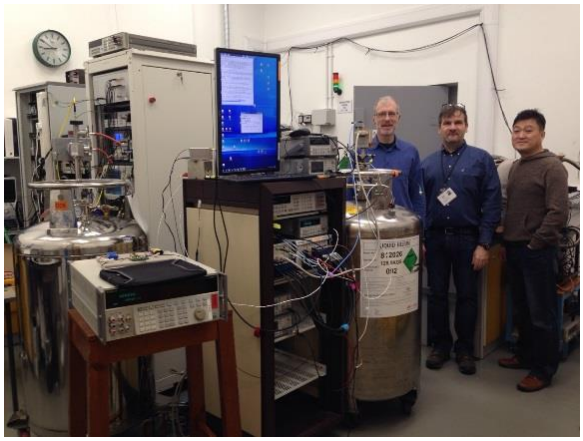


NPL is working on a the three year project "Josephson Traveling Wave Parametric Amplifier and its Application for Metrology" involving two other NMIs and two universities in the EMPIR Fundamental call. The project aims to deliver a program of research and development surrounding a new type of quantum limited microwave amplifier for the amplification of extremely small electric and photonic microwave signals with sufficiently large gain, wide bandwidth and with the lowest possible added noise. NPL will contribute to all work packages and will lead the work package on quantum amplifier metrology whose aim is to carry out fundamental metrology of the amplifier at the single-photon limit.

NPL is also active in the EMPIR Joint Research Project, TEMMT - "Traceability for electrical measurements at millimetre-wave and terahertz frequencies for communications and electronics technologies" in the 2018 SI Broader Scope targeted programme of research. The project is being led by NPL and involves a total of 19 partners: 9 NMIs, 5 research institutes, and 5 industrial companies (as unfunded partners). The project is focusing on precision electrical metrology in the frequency range from 50 GHz to 1.5 THz. This will be delivered across four technical work packages, involving traceable

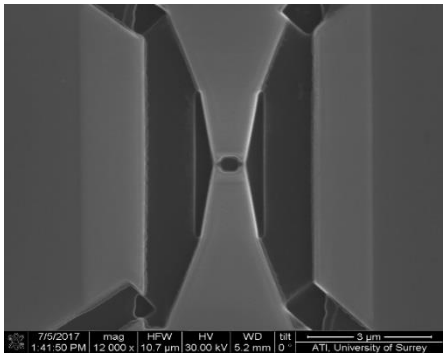
measurements of: (i) connectorised S-parameter; (ii) planar S-parameters; (iii) power; and (iv) materials properties (i.e. complex permittivity of dielectric materials).

Prof Tian Hong Loh (NPL) has been appointed to the IET (Institution of Engineering and Technology) Technical and Professional Network (TPN) Committee on Antennas & Propagation (AP) between 2018 and 2020.
The IET is the largest multidisciplinary professional engineering institution in the world. Its worldwide membership is currently in excess of 167,000.
The IET AP TPN Committee brings together engineers working in the field of Antennas and Propagation on application areas such as 5th Generation (5G) communications, Internet of Things (IoT), Autonomous Vehicles, etc.



Stéphane Solve from the BIPM and Mun-Seog Kim from KRISS visited NPL for three weeks in February 2018 to carry out a pilot comparison of AC Quantum Voltage. Agreement between the NPL AC Quantum Voltmeter and the BIPM travelling system was obtained at the level of 1 μV for sinusoidal voltages of 1 V peak amplitude for three different measurement frequencies using two different calibrator instruments as a go-between. Both systems utilised arrays of Josephson junctions operating at liquid helium temperatures to provide a quantum reference for the measured voltages. The application of Josephson junction voltage standards to waveform metrology is still a research topic and this comparison is an essential part of the ongoing process to move the work from research to measurement services underpinned by CMCs.

The uncertainty for calibrating 100 MΩ and 1 GΩ resistors using the NPL high-resistance CCC bridge has been re-evaluated, resulting in combined uncertainties of ~0.1 μΩ/Ω^{-1}, considerably smaller than the CMC entries of 0.4 μ μΩ/Ω^{-1} and 1.6 μ μΩ/Ω^{-1} respectively. Details of this work are now published in Metrologia 56 (2019) 015014.



A SEM image of the NanoSQUID made by Xe FIB. NanoSQUID loop size is ~ 500 nm.

SQUIDs based on nanobridge junctions have shown increasing promise for single particle detection. The Quantum Detection group at NPL has recently published a paper with title 'Investigation of Dayem Bridge NanoSQUIDs Made by Xe Focused Ion Beam' by T. Godfrey, J. Gallop, D. Cox, E.J. Romans, J. Chen and L. Hao, IEEE Trans. on Appl. Supercon. v. 28, 1100605, 2018 (DOI: 10.1109/TASC.2018.2854624). This paper describes development of improved and reproducible nano-bridge junctions fabricated by focused ion beam (FIB) milling from niobium thin films. Although the very low noise properties of nanobridge SQUIDs are well known, the nature of the milling process is little understood at the level of local superconducting properties. In this paper we report the results for nanobridge Josephson devices and SQUIDs which we believe are the first to be made by Xenon (Xe) FIB milling.

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29 March 2019