TT 38: Superconducting Electronics: SQUIDs, Qubits, Circuit QED I

Time: Wednesday 16:45–18:30 Location: H32

TT 38.1 Wed 16:45 H32

Microwave characterization of planar Josephson junction arrays — •Alexander Kirchner[1], Johanna Berger[1], Simon Feyrer[1], Narges Momeni[1], Matthias Kronseder[1], Michael Prager[1], Dieter Schuh[1], Dominique Bougeard[1], Nicola Paradiso[1], Christoph Strunk[1], and Leandro Tosi[2,1] — [1]Institut für Experimentelle und Angewandte Physik, University of Regensburg, 93040 Regensburg, Germany — [2]Centro Atómico Bariloche and Insitituto Balseiro, CNEA, CONICET, San Charlos de Bariloche, Río Negro 8400, Argentina

We present microwave characterization measurements of Josephson junction arrays (JJAs) based on a proximitized Al-InAs quantum well heterostructure. JJAs can be used to achieve high inductances, suitable for the implementation of quantum circuits. They also provide an excellent test-bed for studying the microscopic excitations of hybrid superconductor-semiconductor devices associated to the presence of Andreev states. By probing the low-energy plasmon modes of these devices, we have been able to derive the Josephson inductance and to demonstrate its tunability in out-of-plane magnetic field, following the Fraunhofer diffraction pattern of planar Josephson junctions. Furthermore, the temperature dependence of the inductance provides information about the induced superconducting gap in the two-dimensional electron gas.

TT 38.2 Wed 17:00 H32

Niobium-trilayer based Dimer Josephson Junction Array Amplifiers — •Bhoomika R Bhat, Asen L Georgiev, Fabian Kaap, Victor Gaydamachenko, Christoph Kissling, Judith Felgner, Mark Bieler, and Lukas Grünhaupt — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Qubit readout and other quantum technologies using microwave signals at low powers of a few fW benefit from amplification with the least possible added noise. Josephson parametric amplifiers are a well-established class of devices meeting this condition. We design a Dimer Josephson Junction Array Amplifier (DJJAA) [1], which has several pairs of modes, so-called dimers, in the 4 GHz to 12 GHz range. In principle, each of these dimers can be used to achieve non-degenerate amplification using the four-wave mixing regime. Our devices, consisting of arrays with 600-1200 dc-SQUIDs, are fabricated in Nb/Al-AlOx/Nb trilayer technology. We present finite element simulations of our design as well as the fabrication process and the first experimental results of our devices.

[1] P. Winkel et al., Phys. Rev. Appl. 13, 024015 (2020).

TT 38.3 Wed 17:15 H32

Towards a traveling-wave parametric amplifier with two-octave bandwidth — •Christoph Kissling, Victor Gaydamachenko, and Lukas Grünhaupt — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

Traveling-Wave Parametric Amplifiers (TWPAs) are among the leading technologies for amplifying weak microwave signals. They provide a gain of 15-20 dB over a bandwidth of more than 1 GHz while keeping the added noise close to the quantum limit. Although TWPAs are widely used in quantum computing, certain applications in fields like radio astronomy require amplifiers with broader bandwidth, ranging from e.g. 4 to 12 GHz. In this work, we present a TWPA consisting of ca. 2400 rf-SQUIDs, which operates in the three-wave mixing regime and achieves a 3-dB bandwidth of 3.6 to 8.3 GHz. Our device provides a gain of 20 dB and has a saturation power of around -90 dBm. By incorporating this TWPA as the first amplifier in our readout chain, we attain a total system noise of 2-3 photons across the entire bandwidth. Finally, we discuss strategies to extend the bandwidth to two octaves and improve the flatness of the gain profile.

TT 38.4 Wed 17:30 H32

Mitigating phase velocity mismatch in flux-pumped Josephson traveling wave parametric amplifiers — •Daniil Bazulin[1,2], Lars Aaron Anhalt[1,2], Kevin Kiener[1,2], Matthias Grammer[1,2], Niklas Bruckmoser[1,2], Leon Koch[1,2], Matthias Althammer[1,2], Stephan Geprägs[1,2], Stefan Filipp[1,2,3], and Kirill G. Fedorov[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), 80799 Munich, Germany

Josephson traveling wave parametric amplifiers (JTWPAs) play a key role in enabling fast readout of multiple qubits in scalable superconducting quantum processors. These amplifiers utilize wave-mixing processes in extended nonlinear media, to achieve broadband amplification with noise performance close to the standard quantum limit. Flux-pumped JTWPAs, employing the SNAIL-based nonlinear media, are particularly interesting due to their potential to eliminate the problem of pump depletion and mitigate upconversion losses. However, these devices exhibit a phase velocity mismatch between pump and signal modes, which suppresses a maximum achievable amplification gain. This issue can be addressed by using materials with high dielectric constant or kinetic inductance, like $SrTiO_3$ and NbTiN, respectively. Here, we present our progress in millikelvin characterization of these materials and their prospects in the flux-pumped JTWPAs.

TT 38.5 Wed 17:45 H32

Towards superconducting quantum-accurate arbitrary waveform generators for microwave frequencies — •Michael Haas, Abdulrahman Widaa, Oliver Kieler, Shekhar Priyadarshi, Marco Kraus, Ralf Behr, Johannes Kohlmann, and Mark Bieler — Physikalisch Technische Bundesanstalt, Braunschweig, Germany

The Josephson Arbitrary Waveform Synthesizer (JAWS) consists of an array of Josephson Junctions being driven by electrical pulses to produce quantum-accurate output signals with high spectral purity and low noise [1]. It has been subject of research for many years and is well established at output frequencies in the kHz and low MHz range. However, the extension to GHz frequencies, which could prove to be very important for quantum applications and metrology, has just recently started [2, 3]. This effort requires completely new circuit designs. Moreover, at high frequencies part of the input signal is fed through to the output signal and it is essential to accurately determine and minimize this so-called feedthrough error. We will present the status of the GHz-JAWS development at PTB, including new approaches to circuit design and feedthrough reduction.

[1] O. Kieler, Encyclopedia of Condensed Matter Physics, 2e 1 Oxford: Elsevier (2024). DOI: 10.1016/B978-0-323-90800-9.00001-9
[2] C. Donnelly et al., IEEE Trans. Appl. Supercond. 30 (2020). DOI: 10.1109/TASC.2019.2932342
[3] A. Babenko et al., IEEE Trans. Appl. Supercond. 32 (2022). DOI: 10.1109/TASC.2022.3201188

TT 38.6 Wed 18:00 H32

Characterization of stacked Josephson junction arrays for the Josephson Arbitrary Waveform Synthesizer with integrated on-chip power dividers — •Omar M. Aladdin[1], Oliver Kieler[1], Abdulrahman Widaa[1], Hannes Preissler[1], Erasmus Wolf[2], Marco Schubert[2], Johannes Kohlmann[1], and Mark Bieler[1] — [1]Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany — [2]Supracon AG, An der Lehmgrube 11, 07751 Jena, Germany

The Josephson Arbitrary Waveform Synthesizer (JAWS) is based on pulse-driven Josephson junction (JJ) arrays and provides precisely controlled, spectrally pure quantum-based AC voltages with low noise and no drift. Being widely used at National Metrology Institutes, increasing the output voltage of JAWS might significantly expand its application range. In this contribution, we describe our current efforts towards reaching JAWS output voltage of 1 V RMS. We are improving the existing on-chip RF power dividers enabling up to 8 parallel JJ arrays to operate simultaneously per chip with sufficient operation margins. Additionally, we are increasing the number of active junctions by means of fabricating of up to 5-stacked SNS-type JJ with Nb_xSi_{1-x} as barrier material. The target is to integrate about 50 000 to 60 000 JJ per chip. The circuit layout with integrated on-chip power dividers, the fabrication technology and first measurement results will be presented at the conference.

TT 38.7 Wed 18:15 H32

High-temperature superconducting Josephson junctions for optical neuromorphic computing — •Elena Vinnemeier[1], Sebastian Schaper[1], Malik Ayachi[2], Vincent Humbert[2], Javier Villegas[2], and Ursula Wurstbauer[1] — [1]Institute of Physics, University of Münster, Münster, Germany — [2]Laboratoire Albert Fert, CNRS, Thales, Université Paris-Saclay, Palaiseau, France

Josephson Junctions (JJ) offer a promising platform for neuromorphic computing, owing to their inherent ability to emulate key neuronal behaviours such as spiking and bursting. When coupled with high-temperature superconductors and reconfigurable interconnects, these junctions present a viable alternative to traditional CMOS-based approaches, providing a low-power solution that is both faster and more efficient. The integration of high-temperature superconductors into the JJs enhances energy efficiency while exploiting their sensitivity to external stimuli. The currently missing integrated memory element is addressed by replacing passive interconnections with active links, which can be tuned by external stimuli. Our goal is to achieve optical modulation of the critical current I_C through light irradiation. To explore this capability, we characterize semiconducting materials from the transition metal dichalcogenide (TMDCs) family in combination with superconducting JJs using Raman spectroscopy and photoluminescence (PL), contrasting their properties as a function of environmental conditions.

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