Development of Nb NanoSQUIDs Based on SNS Junctions for Operation in High Magnetic Fields

Viacheslav Morosh[1], Benedikt Müller[3], Maria J. Martínez-Pérez[3], Oliver Kieler[1], Thomas Weimann[1], Jörn Beyer[2], Thomas Schurig[2], Alexander Zorin[1], Reinhold Kleiner[3], Dieter Koelle[3]

[1] Physikalisch - Technische Bundesanstalt (PTB), Bundesallee 100, 38116 Braunschweig
[2] Physikalisch - Technische Bundesanstalt (PTB), Abbestraße 2, 10587 Berlin
[3] Physikalisches Institut und Center for Quantum Science in LISA+, Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen

E-Mail: viacheslav.morosh@ptb.de

Abstract - **We present nanoSQUIDs developed for investigation of small spin systems. For this purpose, we fabricated sandwich type Josephson junctions (JJs) with lateral dimensions down to 80 x 80 nm^2 having Nb as a superconductor and HfTi as a normal metal barrier. The dc nanoSQUID are realized in a strip-line geometry, with two JJs connecting the top and bottom Nb lines.**

Nb current carrying lines have a width of ~100 nm and thickness ~200 nm. The geometrical pick-up loop area is ~ 0.005 µm^2 and the effective area ~0.03 µm^2, which is increased due to the flux focusing effect and finite London penetration depth. Electrical characterization of the JJs with critical current densities j_0~300 kA/cm^2 was carried out in the temperature range from 4.2 K to 250 mK and yielded noise-rounded overdamped current-voltage curves (IVC) down to 2.5 K. An increase of j_0 up to 1.1 MA/cm^2 leads to larger critical currents I_0 and to a sharper critical current corner in the IVC, but still without visible thermal hysteresis at 4.2 K. The former feature can be attributed to an improvement of the characteristic noise parameter $\Gamma = 2\pi k_B T/I_0\Phi_0 \approx 2.5 \cdot 10^{-3}$, i.e. a decrease of the ratio of thermal and Josephson energies. We also demonstrate that due to their miniature design our nanoSQUIDs maintain stable operation in sufficiently high magnetic fields up to 0.25 T. This property is particularly important in order to withstand the magnetic field required to manipulate small spin systems.

Voltage noise of the single JJs as well as flux noise of the complete sensors was investigated. We compare the experimentally measured voltage noise of our "intrinsically-shunted" JJs with the theory developed for conventional externally shunted SIS-type JJs. The observed rise of more than 50 % of the white-noise floor over the theoretical level presumably originates from imperfections of the measurement setup and/or from intrinsic dissipative processes in the HfTi barrier, including elevation (over the bath temperature level) of the electron temperature.

We also simulated the coupling between a point-like magnetic dipole and the nanoSQUID loop for our geometry, and by using the measured flux noise values we estimate spin sensitivity of our devices to be below 10 μ_B/Hz$^{1/2}$.

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Keywords (Index Terms) – **NanoSQUID, Fraunhofer-like pattern, effective loop area, flux-to-voltage transfer coefficient, magnetic field stability, flux noise, spin sensitivity, SNS sandwich-type junctions, voltage noise.**

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