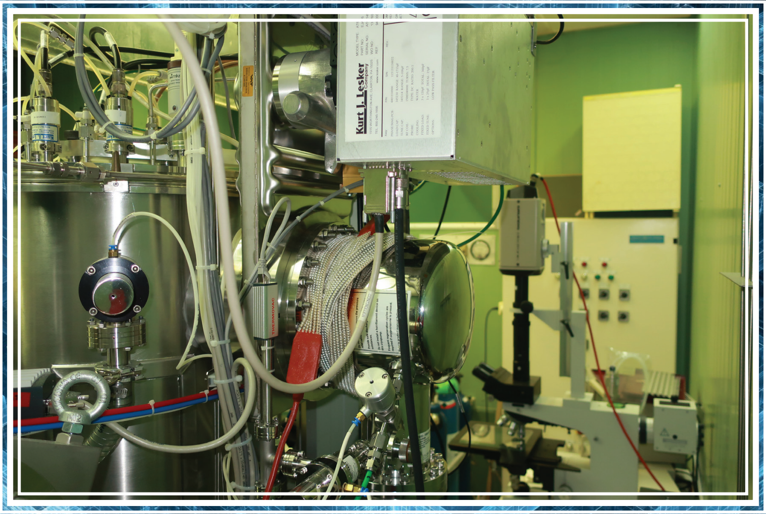
Kotelnikov Institute of Radioengineering and Electronics of Russian Academy of Sciences

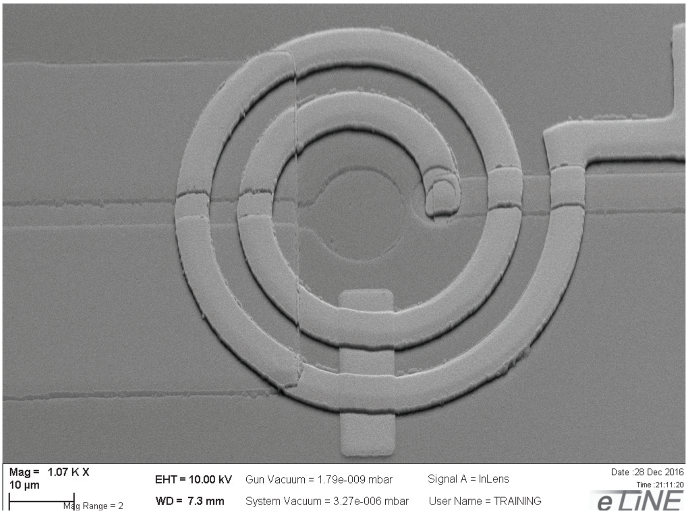
Laboratory of Superconducting Devices for Signal Detection and Processing

Thin Film Oxide Electronics Laboratory



Large-scale research facilities «Technological and measuring research facilities for the creating of superconducting nanosystems based on new materials» (LSRF "Cryointegral")

LSRF Cryointegral



LSRF "Cryointegral" is a complete technological line of full-cycle devices and equipment that allows the development, production and measurement of nanostructures with a dimension of up to 50 nanometers. Cryointegral is used for research, development and fabrication of new generations of devices and their components based on micro- and nanotechnologies, in particular: development of new nanostructures for operation in the terahertz range; development, fabrication and research of superconducting integrated circuits; development of technology for the fabrication of epitaxial thin oxide films and heterostructures.

Large-scale research facilities (LSRF) is a special type of scientific infrastructure that functions as a single whole, created in a single version with technical characteristics that have no analogues in the Russian Federation, and which allows obtaining significant world-class scientific results that cannot be achieved on mass-produced scientific instruments and equipment.

More information about Cryointegral are available on the portal of the Russian Ministry of Education and Science

https://ckp-rf.ru/

Development of the component base of superconducting electronics

The Laboratory of superconducting devices for signal detection and processing, thanks to which Cryointegral was created and successfully operates, is one of the leading research teams in the field of superconducting electronics in Russia. The Laboratory team develops new types of multi-element superconducting circuits of submicron sizes and fabricates single elements and integrated structures for superconducting electronics. The quality of the obtained fundamental and applied results meets the standards of leading scientific centers around the world. Some achievements of the team, for example, the Superconducting Integrated Receiver of the THz range, are marked as unique.

The line of technological equipment for the manufacture of integrated superconducting structures includes ISO Class 6 cleanrooms with ISO Class 5 working areas. Cleanrooms are equipped with ventilation, cleaning and air conditioning systems, exhaust ventilation system and water purification systems.

The level of publications of the laboratory staff meets the highest international standards:

https://nanolith.ru/publications.html

Scientific collaboration

The Laboratory team's developments using the Cryointegral are in demand both in Russia (receiving devices are being created for ground-based radio astronomy telescopes and future space missions, including the Millimetron RSA project), and abroad – projects are being carried out jointly with the Netherlands Institute for Space Research, German Aerospace Center, University of Tübingen (Germany), Nanjing University (China), Purple Mountain Observatory (China), Chalmers University of Technology (Sweden), University of Stellenbosch (South Africa), Institute of Astrophysics and Geophysics in Sao Paulo (Brazil), and others.

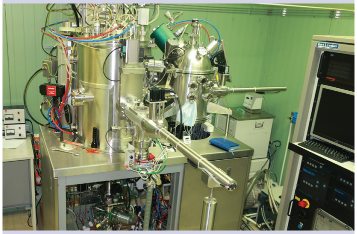
Electron-beam lithography

The e_LiNE electron lithography system combines a scanning electron microscope and an electron lithography system from Raith (a laser interferometric platform and a digital-to-analog converter to control the deflection of the electron beam). The size of the electron beam is 2 nm for an accelerating voltage of 20 kV. The minimum structure size for HSQ resist is 20 nm. The electron lithography system can be used both to study the topography and electronic properties of micro- and nanoobjects, and to create objects with a limiting size of ~20 nm in the direct lithography mode and in the photomask mode.

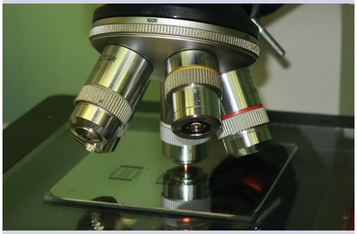
Superconducting nanostructures fabrication technology

The cleanrooms are equipped with all the necessary equipment for creating a resistive pattern, deposition of thin films of materials, etching and subsequent processing of microcircuits. Each technological step can, if necessary, be monitored using electron microscopy.

The high-vacuum magnetron plant Kurt J. Lesker allows magnetron deposition of thin-film coatings in vacuum on samples with a diameter of up to 76.2 mm at a pressure in the chamber better than $5*10^{-8}$ mbar.



Optical microscopes for visual research and control of samples in reflected and transmitted light; equipped with a set of image contrast tools and a digital camera.

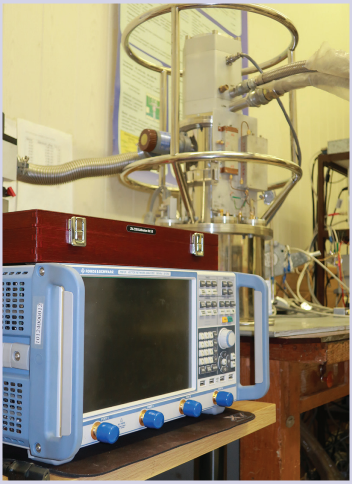


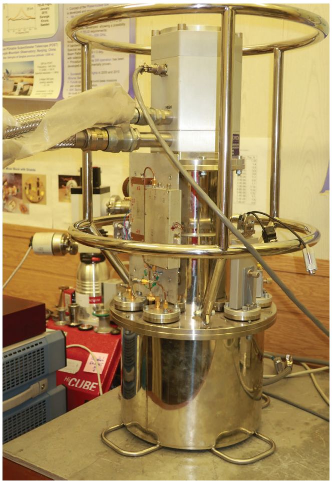
Plasma-chemical etching through the resist mask is carried out using two different plasma-chemical etching plants: Secon XPE II (SF_6); March Jupiter II (CF_4). A new modern etching system will be installed in the near future.

Measuring equipment

For low-temperature measurements, helium cryostats are used - both liquid helium cryostat production by Infrared Lab (USA) and closed cycle based on the Cryomech Inc cryocooler (USA). All cryostats are equipped with windows for optical measurements at temperatures in the range of 4.2 - 325 K and a stability of +/-0.01 degrees.High-vacuum pumping stations Pfeiffer Vacuum (Germany) of the HiCube 80 series based on turbomolecular pumps make it possible to obtain deep vacuum in vacuum chambers and gas cells of various sizes.The following equipment is used for high-precision measurements: Rohde&Schwarz ZNB20 vector 4-port network analyzer (Germany) up to 20 GHz; Keysight (USA) and Rohde&Schwarz spectrum analyzers up to 26.5 GHz, microwave signal generators up to 40 GHz; Keithley source meters (USA) and Agilent digital multimeters. There is also a set of specialized low noise battery packs, some of which were designed and assembled in the electronic workshops of the Space Research Institute of the Netherlands.

Equipment for low-temperature measurements.





Compliance with the world level

Cryointegral specifications	Current value	Target value	Best value in the world
Accuracy of Pattern Formation in Plasma-Chemical Etching of Niobium Films	100 nm	50 nm	50 nm (1)
Minimum feature size for contact lithography	1 um	0,6 um	0,6 um (2)
Minimum feature size for laser lithography	1 um	0,6 um	0,6 um (3)
Film thickness resolution (profile height) of measured structures	20 nm	2 nm	1-2 nm (4)
Spread of parameters in the fabrication of superconducting integrated structures of the THz range	10 %	5 %	unknown (5)
The minimum reproducible area of tunnel structures in the THz range with a deviation of not more than 5%	0,8 um^2	0,5 um^2	0,5 um^2 (6)
Tunnel current density of superconducting tunnel structures in the THz range	20 kA/cm^2	50 kA/cm^2	50 kA/cm^2 (7)
The lowest noise temperature of sensitive elements for receiving systems in the 211-275 GHz range	75 K	20 K	30 K (8)
The lowest noise temperature of sensitive elements for receiving systems in the 800-930 GHz range	400 K	~180-200 K	200 K (9)

(1) To fabricate superconducting tunnel structures based on niobium films;

(2) For contact lithography at a wavelength of 405 nm;

(3) For fabrication of superconducting tunnel structures;

(4) For thickness (height) measurements with a profilometer;

(5) Manufacturers of superconducting structures do not indicate this technological parameter in open sources;

(6) For superconducting tunnel structures in the THz range with high current density (above 20 kA/cm^2);

(7) For structures manufactured for use in highly sensitive receivers;

(8) At the ALMA International Radio Telescope in Chile, band 6;

(9) At the ALMA International Radio Telescope in Chile, band 10.

Contacts

Mokhovaya 11-7, Moscow, 125009, Russia
Phone: +7 495 629-34-18
e-mail: nanolith@yandex.ru
www: https://nanolith.ru/
Portal: https://ckp-rf.ru/usu/352529/

LSRF Cryointegral was established in 2005 and successfully operates on the basis of the Laboratory of Superconducting Devices for Signal Detection and Processing and the Thin Film Oxide Electronics Laboratory of Kotelnikov Institute of Radioengineering and Electronics of Russian Academy of Sciences.

LSRF Cryointegral includes a full range of equipment for the fabrication and research of high-quality superconducting structures based on tunnel junctions with a high current density and integrated circuits of a medium degree of integration.

Head of the LSRF Cryointegral: **Prof. V.P.Koshelets**