Requirements / Specification Document

National Institute of Standards and Technology
U.S. Department of Commerce

TITLE: **Optical Access Dilution Refrigerator**
NB686100-26-02139

Requesting Laboratory / Division / Group:

Physics Measurements Laboratory
Applied Physics Division
Quantum Nanophotonics Group

General Statement of Need:

We require a cryostat capable of cooling superconductive circuits, optical quantum dots, acoustical resonators and associated hardware to temperatures below 15 millikelvin. To perform these measurements, we require free space optical access enough cooling power to maintain continuous operation below 15 mK and to accommodate two 4 kelvin amplifiers, attenuated coaxial input lines, and an experimental volume specified below. Optical access dilution refrigerator with a vector magnet and 18 GHz bandwidth rf wiring. Notionally, this system will be set up as a flexible research and development platform for quantum computing circuits, optical quantum dots, and quantum acoustical resonators operating from 3-18 GHz so larger experimental volumes, lower base temperatures, and flexible/optional upgrades will be prioritized.

Item Specifications and Quantities:

Item 1:	Cryogenic system	
Quantity:	1	
Specifications:		**Base cryostat specifications:**
	1.1	The cryostat system shall have a base temperature of less than 15 mK at the coldest stage.
	1.2	The system must be equipped with a pulse tube cooler with greater than 1.3 W cooling power at 4.2 K (second stage) with low vibration remote motor.
	1.2	The cryostat system shall include all thermometry, support structures, pumps, and heaters necessary for continuous operation below 15 mK. As well as PID (or similar) controlled heater for continuous operation at intermediate temperatures up to 30K.
	1.3	The cryostat system shall include a line-of-sight port running normal to and through the center of all plates with unobstructive optical access to the mixing chamber from the top of the cryostat.
	1.4	The cryostat system shall have a thermal radiation shield at approximately 45 K and 4 K and base temperature stages. All vacuum cans and radiation shields must accommodate routine assembly/disassembly when the system is placed in a laboratory with 2.9 m floor-to-ceiling height. It must be possible for the vacuum can and shields to be removed and replaced when the cryostat is permanently mounted on its frame.
	1.5	The cryostat system shall be cryogen-free, that is, no additional cryogens shall be added by the user after delivery (excluding external liquid nitrogen trap(s)).
	1.6	The cryostat system shall have a water-cooled compressor. The cryostat system shall have flexible lines between the compressor and the cold head that are at least 5 m long
	1.7	No oil-based pumps shall be used in the helium-circulation path.
	1.8	The cryostat system shall include a dry vacuum pump and parts which are sufficient to evacuate the cryostat before cooldown to a pressure of 1e-4 torr.
	1.9	The cryostat system shall include all software necessary for automated cooldown, operation, warmup procedures with computer-controlled valves and pumps. The time to cool the system down with all ordered wiring (thermometry, coaxial, DC) shall not exceed 24 hours.
	1.10	The cryostat system shall have demonstrated a cooling power greater than or equal to 250 microwatts at 100 mK when loaded with (at a minimum) the included diagnostic thermometry, heater wiring, and coaxial cabling.
	1.11	The cryostat system shall have a gold-plated oxygen-free-high-conductivity (OFHC) copper base temperature plate to provide an experimental volume larger than 250 mm in height and greater than 125 mm in diameter.
	1.12	The dilution unit shall not have any soft solders. Soft solders are known to develop micro-fractures and cold leaks over time.
		Wiring Specifications
	2.1	The cryostat shall be electrically isolated from the compressor.
	2.2	The cryostat shall include wiring from 300 K to 4 K and thermal anchoring appropriate for powering at least two HEMT amplifiers
	2.3	At least 5 input microwave coaxial lines with bandwidth of 18 GHz and user-specified attenuation are required
	2.4	At least 2 18 GHz bandwidth output lines with minimal attenuations are required. Output lines shall be SP CuNi / CuNi and UT85 from 4K to 300K and NbTi/NbTi UT85 from the mixing chamber to 4K. SMA connectors shall be used.
	2.5	The cryostat system shall have a total of 24 resistive phosphor bronze dc wires; the resistance per wire shall be less than 50 ohms; the wires shall be in a single looms of 24 wires each; the loom shall be terminated in a 25-pin microD connector at 4K and base temperature
	2.6	The cryostat system shall have low resistance DC wiring capable of driving three cryogenic nanopositioners.
	2.7	All wiring listed above shall be properly heat sunk such that the cooling power remains greater than 250 uW at 100 mK fully wired.
	2.8	When fully wired the cooldown time with no magnet shall be less than 15 hours.
		General Specifications
	3.1	The cryostat system must be an established commercial product with at least one unit operating successfully in the field. Experimental or prototype items are not acceptable.
	3.2	The cryostat system shall be a new (not refurbished or reconditioned) item covered by the original manufacturer's full warranty. The use of "gray market" components not authorized for sale in the U.S. by the proposer is not acceptable.
	3.3	Manufacturer will test system on their site before shipping and send all temperature and pressure data for verification.
		Option A: upgrade to vector magnet; includes all of above and:
	A.1	The cryostat system shall have a superconducting magnet that controls a three-dimensional magnetic field at the sample position being held at < 15 mK.
	A.2	The magnet shall generate at least 1 Telsa in any direction determined by the user at the sample position.

A.3	All necessary power supplies, control electronics, and software for generating and controlling the magnetic field will be supplied.
A.4	With magnet, cool down from 300K to base will be less than 24hrs.
	Option B: Low-noise amplifiers and circulators; includes all of above and:
B.1	The cryostat shall include at two LNF HEMT amplifiers (bandwidth 4-8GHz, gain 38dB) properly heat sunk to the 4K stage connected in series with one amplifier on each output line.
B.2	The cryostat shall include at two LNF cryogenic circulators (bandwidth 4-8GHz) properly heat sunk to the mixing chamber stage connected in series with one circulator on each output line.

Procurement Support Information and Ancillary Services:

Section	Requirements/Specifications
Planning Considerations ☒ N/A	☐ List any visits required to allow potential vendors to see site specific constraints. ☐ US citizen required on-site (foreign nationals require pre-registration 30 days prior to visit.) ☐ Vendor Representative On-Site more than three (3) days. ☐ Other Considerations:
Shipping & Delivery ☐ N/A	Shipping Address: ☒ NIST-Boulder ATTN: Kevin Silverman Mail Stop: 686.04 325 Broadway Boulder, CO 80305 ☐ NIST-Gaithersburg ATTN: Mail Stop: 100 Bureau Dr Gaithersburg MD 20899 ☐ [Alternate Shipping Address] Shipping Criteria: ☐ Partial Delivery Acceptable ☐ [Enter Shipping and Delivery information by item.] ☐ Direct Delivery to OU Building Required [Explain Need for Requirement] Building /Room Number: [Enter Building/Room Number] ☐ Building has Loading Dock Containerization Preference: [Enter Container Type] Other Requirements: [List Any Other Requirement] Delivery Date Criteria: ☐ Delivery Shall Be Competed No Later Than: Click or tap to enter a date. ☐ Delivery Shall Be Made No Earlier Than: Click or tap to enter a date. ☐ Scheduled Deliveries: Item Number | Due Date ☐ Other: Delivery expected 6 months after receipt of order
Electronic Media ☐ N/A	☒ Software ☒ Electronic Manuals; All manuals shall be provided electronically. ☐ License Key ☐ Other: [List Any Other Electronic Media Requirements] ☐ US Government Email Address for Software Delivery: [Enter Address]
Installation ☐ N/A	☒ Vendor Technician on Site ☐ Rigging ☒ Uncrating / Unpackaging ☐ Removal of Packaging Material ☒ Equipment Set Up ☐ Start-Up Services ☐ Turnkey Installation ☐ Other: [Enter Details] NOTE: TPOC shall be the coordination POC.
Facility / Utility Considerations ☒ N/A	[List Site Specific Utility Considerations by Item] ☐ OFPM Work Order Numbers [List Work Order Numbers] ☐ Power Available Voltage: [Enter voltage] (V) Maximum Current: [Enter max current draw] (A) Phase: [Choose Phase] Frequency: [Typically 60Hz] (Hz) NEMA Plug Type: [Enter Plug Type] (i.e.: NEMA L5-20P) Environment: [Choose Environment] Other Power Considerations: [List Any Other Power Considerations.]

☐ Utility Connections:
[List Relevant Available Utilities, Pressure(s) and Flowrate(s).]
☐ Other Considerations:
[List Other Considerations to Ensure an Accurate Quote.]

Inspection and Acceptance
☐ N/A

[Inspection Requirements Per Item (Who, When, What, Where)]
☐ On-Site
☒ Acceptance Expected to Not to Exceed 7 Business Days
☐ Acceptance Expected to Exceed 7 Business Days:
[Duration]
☐ Inspection and Acceptance Plan:
[Explanation]
☐ Other:
[Enter Other Requirements]

Training
☐ N/A

Training Requirements (Who, When, What, Where)

☐ Number of Trainees: [Enter Number of Trainees]
☒ On-Site
☐ Off-Site Location: [Enter Location(s)]
Is Trainee Travel Required: [Choose Answer]

Scope of Training
☐ Operation ☐ Maintenance ☐ Troubleshooting
☐ Safety ☐ Other
[Enter Other Scope of Training Requirements]
☐ Training Materials to be Provided by Government:
[Describe Materials]
☐ Training Materials to be Provided by Vendor:
[Describe Materials]
☐ Other
[Enter Other Training Requirements]
NOTE: TPOC shall be coordination POC.

Warranty
☐ N/A

Base Manufacturer Warranty is acceptable
Warranty Length: 1 - year
What is included?
☐ Labor ☒ Parts ☐ Travel
☐ Cost and Liability for Returns
☒ Other
The cryostat system shall have a 1-year warranty.
☐ 1 Option Period
☐ 2 Option Periods
☐ 3 Option Periods
☐ 4 Option Periods (Maximum)

Calibration
☒ N/A

[Describe Calibration Requirements Per Item]
Calibration Plan Length: [i.e. 3 - Years]
What is Included?
☐ Labor ☐ Spare Parts ☐ Consumables
☐ Travel ☐ Cost and Liability for Shipment
☐ Software Updates ☐ Manuals
☐ Other
[Enter Other Requirements]
☐ Requirements:
[Enter Requirements] (i.e.: On-Site Within 72 hours, etc.)
☐ 1 Option Period
Length: [i.e. 1 – Year / 6 - Months]
☐ 2 Option Periods
☐ 3 Option Periods
☐ 4 Option Periods (Maximum)

Maintenance
☒ N/A

[Describe Maintenance Requirements Per Item]
Maintenance Plan Length: [i.e. 3 - Years]
What is Included?
☐ Labor ☐ Spare Parts ☐ Consumables
☐ Travel ☐ Cost and Liability for Shipment
☐ Software Updates ☐ Manuals
☐ Other
Requirements:
☐ [Enter Requirements] (i.e.: On-Site Within 72 hours, etc.)
1 Option Period
Length: [i.e. 1 – Year / 6 - Months]
☐ 2 Option Periods
☐ 3 Option Periods
☐ 4 Option Periods (Maximum)

☐ 4 Option Periods (Maximum)

Government Furnished Material / Equipment
☒ N/A

List Any Government Furnished Material / Equipment Per Item]
☐ Equipment which will leave Government Site
☐ Description: [Enter Description]
Serial Number: [Enter Serial Number]
NIST Property Number: [Enter NIST Property Number]
Other:
☐ Other: [Enter Other Details]

Travel ☒ N/A	[Describe any Travel Requirements Per Item] ☐ [Enter Justification / Requirement] Other: ☐ [Enter Other Requirements] [Enter Other Requirements] NOTE TO VENDOR: To the maximum extent possible, include travel requirement estimates as part of pertinent sections above (Installation, Maintenance, Repair, etc.). Otherwise, Travel will be a separate line item, reimbursable per the Federal Travel Regulation.