SPECIFICATION SHEET

Supply, installation and starting-up of a Microwave Impedance Microscope system for the Pilot Line PIXEurope at ICFO

FILE NUMBER: ICFO-2026-022

Contents

CLAUSE 1. Object of the contract

The purpose of this contract is the supply, installation and starting-up of a Microwave Impedance Microscope system for the Pilot Line PIXEurope at ICFO for ICFO's laboratory.

The types of items supplied are linked to the CPV (Common Public Procurement Vocabulary), **38000000-5** Laboratory, optical and precision equipment (except glasses).

CLAUSE 2. Needs to satisfy

The Microwave Impedance Microscope (MIM) system will allow to characterize electrical properties at the nanoscale. The system is a combination of a MIM module with an Atomic Force Microscope (AFM) that will also allow to look at morphological structures via AFM scan. This is the technique of choice for:

- Local mapping of the electrical properties of materials (conductivity, permittivity, complex impedance)
- The study of semiconductor structures, dielectrics, and advanced materials
- Direct correlation between AFM topography and electrical properties
- Analysis of nanometric and sub-surface structures

MIM directly probes microwave impedance, which is sensitive to free carriers and dielectric response, the properties that determine electro-optic and thermo-optic performance of devices on PIC.
In the frame of the PIXEurope project the Microwave Impedance Microscope system is planned to be used for:

- The characterization of PIC devices especially electro-optic devices: Map carrier depletion/accumulation under applied bias, Visualize the active modulation region, Correlate electrical activity with optical mode location
- The characterization of dielectric and EO material: Local permittivity variations, inhomogeneities in EO polymers, oxides, or ferroelectrics
- The study of interface quality in heterogeneous PIC integration
- The study of carrier dynamics and microwave behaviour, by probing Local RF impedance, conductive vs capacitive response and carrier mobility and loss mechanisms in modulators and photodetectors.
- The study of Metal–semiconductor interface quality, as MIM is sensitive to Contact resistance variations, Schottky vs ohmic behaviour and interfacial defects under metal pads. It is critical for PICs where contacts limit the bandwidth.
- Enabling failure analysis and process control in photonics integrated circuits fabrication.

CLAUSE 3. Technical requirements

Technical proposal structure

The proposal has to follow as much as possible the structure of this technical requirements document to facilitate evaluation. Any optional accessories not included in the proposal will have to be put in a separate section, and not mixed with the included items.

Machine / Process overview

The system will be used as a microwave impedance microwave and multiphysics measurement system at the nanoscale for the following measurements:

- Permittivity, conductivity, complex impedance measurements
- Topography measurements
- Mechanical measurements
- Electrical measurements

The microwave impedance microscopy module (MIM) will be integrated into an atomic force microscope (AFM) supplied as part of the contract.

The system must allow to measure different sample forms and sizes, thus requiring an adaptive sample handling.
The measurement must be reproducible with time, and calibrated to be uniform within the sample area (XYZ calibrated, flatness and orthogonality).
To comply these requirements the machine must allow a minimum noise and a reduced drift with time.
All the following technical specification must have already been proven by results obtained with the system. These data must be included into the technical presentation of the system.

1. MIM capability

The MIM technique must be based on the injection and detection of microwave signals via the AFM tip. It must allow local measurement of complex impedance (resistive and capacitive parts). The operation must occur without direct electrical contact with the sample

a) Microwave will be injected to the sample through the end of the tip
b) The tip will acquire the Reflected microwave from the sample
c) The system will perform a phase comparison between injected microwave and reflected microwave
d) The In-phase signal will give MIM-Re (~ Resistance) and out-of-phase signal: MIM-Im (~ Capacitance) with a high sensitivity to local variations in these electrical properties
e) The system will allow to apply AC voltage to signal which is wanted to be measured
f) It must be possible to perform surface and subsurface measurements.
g) The MIM measurements must be stable and repeatable over long acquisitions.
h) Simple and reproducible alignment of the microwave signal on the tip
i) The lateral resolution for MIM measurement must be in the nanometer range, limited by the AFM tip.

2. MIM operation mode compatibility with AFM modes

a) The MIM mode will be compatible with standard AFM modes (contact and/or dynamic modes)
b) It must be possible to have simultaneous acquisition of :
    - Topography
    - Microwave electrical channels (at least capacitive and resistive components)
c) The system must have the possibility of spot measurements (local spectroscopy) and 2D imaging

3. Hardware integration between MIM and AFM

a) Full integration with existing AFMs
b) No degradation of standard AFM performance
c) Use of standard electrical or special AFM tips possible.

d) Compatibility with high vacuum measurements (10^{-6} mbar)
e) The MIM module can be used without major modification of the AFM system

4. Software integration between MIM and AFM

- Module control via the AFM interface or dedicated interfaced software
- Real-time visualization of MIM channels
- Tools for analysing and post-processing electrical data
- Data export in standard formats

<u>The supplied atomic force microscope (AFM) must have the following characteristics:</u>

5. AFM Scanners, Resolution /noise

a. Flexure-guided, decoupled XY-Scanner and Z-Scanner mechanically driven by piezoelectric materials to improve dynamic performance as well as stationary positioning and guarantees a high linearity and orthogonality
b. The Z-scanner, which controls the vertical movement of the SPM tip, is completely separated from the XY-scanner which moves the sample in the XY horizontal directions and has a scan range of 15 µm or better
c. The Z scanner must have high feedback speed with resonant frequency 9 kHz or better to allow for stable imaging conditions and for accurate, repeatable and reproduceable results which do not suffer from tip wear
d. Supplier must proof this capability by using a noncontact or tapping mode to image a reference sample
e. Detection of the cantilever deflection by using SLD (Super Luminescent Diode) or a laser
f. The XY scan range must be at least 100 µm and its out of plane motion must be less than 250 pm for the scan range of 100 µm. The XY closed loop scan must minimize the forward and backward scan gap to less than 0.15% of the scan range
g. An adaptive scan method that automatically adjusts the scan speed to the sample geometry
h. The Z detector noise must be less than 30 pm over a large bandwidth and the Z scanner non-linearity must be less than 0.5%.

6. Stage, samples size

a) A sample chuck that can host up to 4 magnetic holders, or more, to host samples fixed on a magnetic holder.
b) A motorized XY stage which is capable of addressing full 20 mm × 20 mm area, at least, and a motorized Z stage with a stage travel range of at least 25 mm
c) A motorized focus stage synchronized to Z stage
d) Z stage encoder resolution of 0.05 µm
e) X Y stage encoder resolution of 0.5 µm and stage position repeatability of 2 µm in unidirectional and 3 µm in bidirectional movement
f) The sample size acceptable on the system will be up to 50 mm x 50 mm, or more and up to 20 mm thickness, or more.
g) Voltage biases from at least -10V to 10V can be applied to sample chuck

7. Electronics / PC & software

a) Control electronics
b) AFM data size of at least 4096 x 4096 pixels
c) 24 DACs for signal generation, 4 high-speed 16-bit DACs, 20-bit DACs for X, Y and Z scanner positioning, 20-bit DACs for Aux output and Tip/Sample bias
d) 18 ADCs for signal acquisition, 4 high-speed 20-bit ADCs, 24-bit ADCs for X, Y and Z scanner position sensor, 20-bit for PSPD, Option and Aux signal
e) At least 8 channels of integrated digital lock-in amplifier
f) Integrated signal access ports for AFM signals (7 inputs and 3 outputs)
g) External signal access ports
h) 1 Gbps communication with the PC
i) The operating software and analysis software run on Windows 10 or 11 and can be installed on any number of PCs for data analysis. No license or dongle required

8. AFM/SPM modes

a. Non-contact more, Tapping mode and Phase imaging
b. Contact mode and LFM (Lateral Force Microscopy)
c. Mechanical properties spectroscopy including the acquisition of force vs. distance curves
d. Spring constant calibration by thermal vibration method
e. Force Modulation Microscopy
f. Scanning Thermal Microscopy
g. Electrostatic Force Microscopy (EFM) including Kelvin Probe Microscopy (KPFM) and Piezo-response Force Microscopy (PFM)

9. Data acquisition and analysis software

a) Auto mode to produce high quality AFM imaging with few clicks: the software automatically selects the oscillation frequency
b) Manual mode to control all the functions and settings for AFM scans
c) Program mode to execute multiple measurements, including approach, measurement, withdraw and move at a determined position
d) Automatic sequential imaging to allow sequenced scanning of the sample at the user-selected coordinates, comprising of image scan, cantilever retract, move to the next selected coordinate, tip approach, and repeat.
e) Adaptive scan option included in the software
f) Possibility of scripting for advanced automation: the data acquisition software must have built-in macros, which can be easily loaded and applied for repeating operations, such as moving the XY or the Z stage to a specific location or resetting the operation. Users can edit existing macros or create new ones as needed
g) Independent software for image processing, data analysis and data presentation support
h) Full Python control of the system must be possible.

10. Acoustic enclosure

a) Environmentally sealed acoustic enclosure to block external acoustic noise.
b) Ergonomic design for user convenience.
c) Active vibration isolation to cancel out the floor vibration
d) Active isolation frequency: 1 Hz to 200 Hz

11. Vacuum option
The system can include the option of performing the nanoscale electrical measurements above mentioned in high vacuum conditions, allowing high accuracy and resolution measurements with high signal to noise ratio in topography and electrical signal. In this case the vacuum chamber will have minimal inside dimensions of 250 mm x 300 mm x 250 mm, or more, in order to be able to host the AFM scanner and the sample holder in vacuum.

12. Accessories

a) 20 non-contact probes
b) 20 dedicated probes for MIM.
c) Calibration grating for lateral/vertical calibration
d) Manuals: Operational, Maintenance and Software manual
e) Table and cabinet

CLAUSE 4. Power distributions and safety

- The system should be configured for EU (Spain) power grid (voltage, sockets, etc.) and be CE marked.
- The system will be fully protected against unexpected power cuts and, in that case, will be fully safe for the operators. A quick and easy turning on of the system has to be possible after a power cut.
- Component wiring routed to a centralized power distribution panel.
- EMO protection.
- Appropriate hardware and software safety interlocks. Extended error diagnostics.
    - The system will be fully protected against unexpected power cuts and, in that case, will be fully safe for the operators. A quick and easy turning on of the system has to be possible after a power cut.

CLAUSE 5. System layout and services

- The proposal will include a complete set of pictures, drawings and layouts of the system, including dimensions, location and details of the different components.
- The proposal **will include full installation and start-up requirements (Unpack all system components; Assembly; Pump; Run system to helium liquid production ratio; During the installation process, instruction should be provided on proper procedures for operation and maintenance of the system)**, clearly specifying connection type, tubing materials, pressures, flows, etc, for the specific configuration of the offered system.

- A set of documentation should be delivered in English or Català/Spanish including the following topics:
    - Complete set of manuals, drawings, schematics and layouts about system assembly and configuration (mechanical assembly, vacuum system layouts, electrical schematics, system modules interconnection, etc)
    - Complete system user manual, including routine servicing, troubleshooting and basic repairs
    - System components spare list, specifying quantity, manufacturer, part number, etc
    - All the above documentation will be supplied in English of Català/Spanish, in electronic format (CD/DVD) and in paper copy.
    - In case the system hosts refurbished optional items, they should be explicitly specified in the proposal. When possible, it should be detailed which refurbishment process they have been through.

CLAUSE 6. Transportation, installation, start-up and training

- The proposal will include transportation to ICFO's facilities including insurance and all export/import and customs duties. **DAP incoterm will apply.**
- The machine will be placed in the designated location by ICFO. The contract winner shall cover all costs, organization, and coordination related to the placement, including the provision of any required specialized equipment or vehicles, as well as any necessary component disassembly and reassembly for unloading and transportation inside the building, strictly following the route specified by ICFO. The machine will be equipped with its own wheels to facilitate transportation and with levelling pads to ensure a stable and properly levelled position once installed.

- Depending on the size, machine crate may need to be disassembled outside ICFO building. The contract winner will be responsible for taking accurate measurements of the transportation route outside and inside ICFO and plan in advance any required component dis-assembly and re-assembly. The contract winner will be responsible for checking the selected location and for taking any required measurements to guarantee the suitability of it for the offered system. The compatibility with the operation of the systems already installed in the lab and the mobility of users will have to be guaranteed as well. The system will be installed in a provisory location and should be moved within a duration of 4 years in a definitive laboratory. The contract winner will take care of the move to the final destination.
- Installation and start-up of the system, including system checking, functional tests and process qualification
- The contract winner will be responsible for the removal and proper disposal of the packaging when the machine is delivered and unpacked, or its storage during the warranty period in case the original packaging needs to be kept.

Process qualification

The flowing specifications will be demonstrated at the factory before shipment and at the side at the installation:

1. XY flatness of 2 nm over 100 µm
2. XY/Z orthogonality of less than 2 degrees
3. XY linearity error of less than 0.5% over 100 µm
4. Feedback speed Z resonant frequency major than 9 kHz
5. CrN film (so called TipCheck) sample, run the scan for at least 50 times using 1 single cantilever tip, and show no degradation in image quality and profile line generated
6. For the MIM part, test on twisted bilayer graphene, showing a Moire pattern with a period of 10 nm or less in capacitance and in resistance channels.
7. For the MIM part, test on a calibration n-type and p-type doped Si sample with doping levels ranging from 1.5e20 to 4e15 /cm3 and 1e21 to 4e15 /cm3 respectively. The MIM measurements must measure the calibrated values +/-5%.

CLAUSE 7. Warranty and Follow-on Support

- **3-year Full Warranty** on all parts and components of the system irrespective of the manufacturer. The warranty will include the replacement of any faulty or damaged part(s) during normal use of the system, no matter the manufacturer of the component(s). It will cover any cost related with the disassembly, transportation, reparation and re-assembly of the damaged component(s), including all travelling and living costs of the required service engineer(s). An on-site repair, or a justified alternative to reduce the system down time to the minimum, will always be the first service option. A team of properly qualified and skilled service engineers will have to be available.
- System lifetime support:
- By phone and e-mail with a response within 3 hours, during business hours 8:30–17:30.
- Emergency on-site engineer dispatch after a system breakdown: within 10 working days hours or less after initial response and after possible remote diagnose
- Spare parts will be available during, at least, 10 years after system supply and, in case of failure, will be delivered within 10 working days
- An estimation of the cost of a warranty extension or available support contract options after warranty period will be included

CLAUSE 8. Training

- System training for ICFO personnel shall be included. The proposal must specify the number of training days and the approximate schedule with a minimum of 5 days. Training will cover both system operation and process use for ICFO users at ICFO facilities, as well as specific maintenance and advanced service training for ICFO lab technicians.

CLAUSE 9. Delivery and Installation Time

The machine must be delivered within **7 months from the formalization of the contract.**

For the purpose of this tender, delivery time is defined as the period from the purchase order (PO) issuance until system delivery at ICFO facilities, including manufacturing, transportation, installation, and acceptance tests.

Installations record

- Such a system must have been fabricated at least 3 times by the same provider with a proven record of installation. The record list should be provided upon request.
- For these systems, compliance with the specifications set out in paragraph “Process qualification” (clause 6) must be demonstrated.

CLAUSE 10. Target price

- The target price for the system is 300.000,00 € (VAT excluded).
- Payment terms:
  - Payment on order - 30% total price. This payment is optional for the contratist, but in case the contractor requests a payment of 30% of the contract, he will have to constitute a guarantee for an amount equivalent to the amount that was advanced. The payment of this amount does not imply conformity in the equipment, is an advance payment that the contractor must return in the event of non-compliance or deficient compliance.

  - Payment on delivery, commissioning and training – 100 % of total price, or 70% depending if optional payment on order is requested.

CLAUSE 11. Environmental clause

It is hereby stated that, in compliance with the provisions of the Recovery Plan, Regulation (EU) 2021/241 of 12 February 2021 establishing the Recovery and Resilience Facility, and its implementing regulations, in particular Commission Communication (2021/C58/01) Technical guidance on the application of the principle of “do no significant harm”, as well as the requirements of the Council Implementing Decision concerning the approval of the assessment of Spain’s Recovery and Resilience Facility (RDF), all financed actions carried out under this contract must respect the principle of not causing significant harm to the environment (the “Do No Significant Harm” principle). This includes compliance with the specific conditions set out in component 17, measure I1, under which this contract falls. During the execution of the actions covered by the contract, no significant damage will be caused to the environment, in accordance with Article 17 of Regulation (EU) 2020/852.

The activities carried out will not cause direct environmental impacts, nor will they have primary indirect impacts throughout their life cycle, understood as those that may materialize once the activity has been completed.

The activities carried out by the successful bidder under this contract will not generate waste that, in its long-term disposal, could cause environmental damage, as this is one of the situations excluded from funding by the Recovery, Transformation and Resilience Plan, in accordance with the Technical Guidance on the application of the principle of “not causing significant harm” under the Regulation on the Recovery and Resilience Facility (2021/C 58/01), the Council's Proposal for an Implementing Decision on the approval of the assessment of Spain's recovery and resilience plan, and its annex. The activities carried out by the successful bidder will be adapted, where appropriate, to the characteristics set for the measurement and sub-measure of the assigned component, and reflected in the Recovery, Transformation and Resilience Plan.

The activities carried out will comply with all applicable environmental regulations in force.

For the transport, installation, and commissioning of the equipment covered by this contract, the contractor will implement waste minimization measures and, should any waste be generated, will be responsible for its collection, preparation for reuse, recovery, or recycling, or appropriate treatment.

Methods for monitoring and controlling compliance with the conditions

With regard to compliance with environmental and social requirements, the contractor remains obligated to:

- The contractor must sign, before the contract is formalized, the declaration of commitment regarding the implementation of actions under the Recovery, Transformation, and Resilience Plan (RTRP) and compliance with the principle of not causing significant harm to the environment, included as Annex of the Special Administrative Clauses.

- Issue a manual detailing the dismantling instructions for the equipment, including the reuse, recovery, or recycling operations, or appropriate treatment, including the disposal of fluids and selective treatment, applicable to each of the materials or parts that comprise it. The manual must include a table summarizing, expressed as a percentage by weight, the expected fate of the materials that make up the equipment at the end of its useful life, according to the following options: reuse (including recovery and recycling), energy recovery, and rejection/disposal.

- For the transport, installation, and commissioning of the equipment covered by the contract, the contractor will implement waste minimization measures and, should any waste be generated, will be responsible for its removal and management.

Castelldefels, on the date of its digital signature

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Optolectronics