
SPECIFICATION SHEET

SUPPLY, INSTALLATION AND COMMISSIONING OF “AN AUTOMATED CONFOCAL RAMAN MICROSCOPY SYSTEM FOR THE CHARACTERIZATION OF TWO-DIMENSIONAL MATERIALS AND VAN DER WAALS HETEROSTRUCTURES” FOR ICFO

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CLAUSE 1. Object of the contract

The purpose of this contract is the supply, installation, commissioning, and testing associated with an automated confocal Raman microscopy system for ICFO's laboratory.

The system shall provide state-of-the-art Raman spectroscopy and Raman imaging capabilities for the characterization of two-dimensional (2D) materials, van der Waals heterostructures, and other quantum materials. The instrument shall enable the investigation of structural, vibrational, optical, and electronic properties through high-resolution spectroscopic measurements and spatially resolved Raman mapping.

The system will form part of an integrated platform dedicated to the fabrication and characterization of layered materials and heterostructures. It shall therefore be suitable for operation within a controlled-atmosphere glove box and for integration with automated characterization workflows. The instrument shall support both standalone measurements and future implementation of automated, high-throughput characterization protocols associated with robotic assembly and AI-assisted process optimization.

CLAUSE 2. Needs to satisfy

ICFO is establishing a research platform dedicated to the fabrication and characterization of two-dimensional (2D) materials and van der Waals heterostructures, including graphene, transition metal dichalcogenides (TMDs), magnetic materials, superconductors, topological materials, and other layered quantum materials. These materials constitute the building blocks of a new generation of electronic, photonic, optoelectronic, and quantum devices.

The scientific and technological development of such devices requires advanced characterization techniques capable of providing detailed information on the structural, vibrational, optical, and electronic properties of atomically thin materials. Raman spectroscopy is one of the most important characterization methods for this purpose because it enables the non-destructive investigation of crystal quality, layer number, defects, mechanical strain, doping, crystal orientation, interlayer coupling, and other fundamental material properties.

A major challenge in the characterization of 2D materials is that the physical phenomena of interest often manifest themselves through extremely small variations in Raman peak position, linewidth, intensity, and symmetry. Accurate interpretation of these measurements therefore requires a system capable of delivering high spectral fidelity, high sensitivity, and excellent measurement reproducibility.

Particular importance is placed on the measurement of low-frequency Raman modes associated with interlayer coupling in van der Waals materials and heterostructures. The system shall therefore provide access to Raman shifts sufficiently close to the excitation line to permit characterization of shear modes, layer-breathing modes, twisted-layer structures, and other low-energy collective excitations.

Accurate interpretation of Raman spectra further requires that the instrumental spectral response does not introduce significant distortion or asymmetry into measured Raman peaks. The system shall therefore provide high spectral fidelity suitable for quantitative peak-shape analysis and precise determination of spectroscopic parameters.

Furthermore, many of the phenomena under investigation occur at length scales ranging from a few hundred nanometers to several millimeters. The system must therefore combine high spatial resolution with the ability to perform rapid spectroscopic mapping over large sample areas. This capability is essential for identifying localized

defects, grain boundaries, strain fields, interfacial phenomena, and spatial inhomogeneities, and for correlating these features with the optical and electronic properties of the material.

In addition to standalone characterization, the Raman system will form part of an automated platform for the fabrication and characterization of van der Waals heterostructures. The platform will include automated optical microscopes for flake identification, laser patterning, and robotic assembly of layered materials inside a controlled-atmosphere glove box. The Raman system shall therefore be capable of integration into automated workflows and shall support the rapid, non-destructive characterization of materials and heterostructures at multiple stages of the fabrication process. This capability is essential for establishing closed-loop fabrication and characterization workflows in which spectroscopic information can be used to assess material quality, guide process decisions, and verify the properties of assembled structures. Furthermore, the system shall support high-throughput characterization and automated measurement sequences, enabling spectroscopic feedback to be incorporated into autonomous fabrication workflows and future AI-assisted process optimization strategies.

The Raman system will be permanently integrated within a glove-box-based fabrication and characterization platform used for handling air-sensitive materials and devices. The system must therefore be suitable for reliable long-term operation in a controlled atmosphere and shall permit integration with automated sample handling, positioning, and characterization workflows while minimizing maintenance and optical realignment requirements.

The research activities also require polarization-resolved Raman measurements for the determination of crystal orientation, vibrational symmetry, optical anisotropy, and other direction-dependent material properties. In addition, the system must permit precise control of the optical excitation conditions in order to minimize laser-induced heating and measurement artefacts, particularly when investigating atomically thin materials.

The equipment specified in this tender shall address these challenges and provide the capabilities required for state-of-the-art research on graphene, transition metal dichalcogenides, van der Waals heterostructures, and other quantum materials.

CLAUSE 3. Technical requirements

Raman microscope architecture

- The system shall consist of a fully integrated confocal Raman microscopy platform designed for the characterization of two-dimensional materials and van der Waals heterostructures.
- The system shall support both point spectroscopy and spatially resolved Raman imaging.
- The optical architecture shall be optimized for high-throughput Raman measurements while maintaining high spectral fidelity and spatial resolution.
- The system shall employ a fiber-coupled optical architecture linking the microscope, excitation sources, and spectrometer modules. The optical design shall permit future upgrades and reconfiguration without requiring fundamental modifications to the microscope body.
- The system shall be suitable for operation within a controlled-atmosphere glove box and shall be compatible with the spatial constraints associated with glove-box installation.
- The system shall be designed for reliable long-term operation with minimal optical realignment and maintenance requirements.
- The system shall support automated measurement workflows, including automated focusing, automated sample positioning, automated mapping, and automated data acquisition.
- The system shall support high-throughput characterization and automated measurement sequences suitable for closed-loop fabrication and characterization workflows.

- The system shall provide software-controlled operation of all motorized components and measurement functions.
- The system shall permit future expansion toward additional characterization modalities through modular hardware and software architecture.
- The complete system, including microscope, spectrometer, detectors, excitation sources, control electronics, and software, shall be supplied as a fully integrated platform by a single manufacturer or supplier.

Spectrometer

- The system shall include a high-throughput imaging spectrometer optimized for confocal Raman microscopy.
- The spectrometer shall provide high spectral fidelity and high wavelength reproducibility suitable for the characterization of two-dimensional materials and van der Waals heterostructures.
- The spectrometer shall support operation with the excitation wavelength supplied with the system and shall permit future expansion to additional excitation wavelengths without replacement of the spectrometer.
- The spectrometer shall incorporate a motorized grating turret accommodating at least three diffraction gratings.
- The system shall be supplied with at least three diffraction gratings optimized for low-resolution, medium-resolution, and high-resolution Raman measurements. At least one diffraction grating shall provide a groove density of 1800 grooves/mm or greater.
- The spectrometer shall permit software-controlled selection of diffraction gratings.
- The system shall support automated wavelength calibration procedures without requiring manual optical realignment. The wavelength calibration mechanism shall include an internal calibration source, calibration lamp, or equivalent solution enabling automated wavelength calibration and verification. The system shall support automatic verification of wavelength calibration before or during automated measurement sequences.
- The system shall permit Raman measurements at Raman shifts down to 10 cm^{-1} from the excitation line in both the Stokes and anti-Stokes spectral regions. The low-frequency Raman capability shall be available using the excitation wavelength supplied with the system. The low-frequency Raman performance shall be suitable for the investigation of interlayer vibrational modes in two-dimensional materials and van der Waals heterostructures, including shear modes, layer-breathing modes, and related collective excitations. The low-frequency Raman capability shall support characterization of multilayer and twisted-layer structures through the measurement of low-energy vibrational modes associated with interlayer coupling. The low-frequency Raman functionality shall be fully integrated into the instrument control software and shall be compatible with automated measurement workflows and Raman mapping experiments.
- The spectrometer shall provide sufficient spectral stability and reproducibility for the characterization of strain, doping, defects, interlayer coupling, and other phenomena in two-dimensional materials and van der Waals heterostructures.
- The spectrometer shall provide a highly symmetric instrumental spectral response function across the operating spectral range.
- The optical design shall minimize instrumental distortion of Raman peak shapes and shall not introduce significant asymmetry into measured spectral features.
- The instrumental response shall be suitable for accurate determination of Raman peak position, linewidth, peak splitting, and peak shape parameters.
- The system shall be optimized for quantitative spectral analysis and curve fitting of Raman peaks acquired from two-dimensional materials, van der Waals heterostructures, and related quantum materials.
- Suppliers shall describe the measures implemented to ensure high spectral fidelity and minimal instrumental peak distortion.

Detector

- The system shall include a thermoelectrically cooled scientific detector optimized for Raman spectroscopy.
- The detector shall provide high quantum efficiency throughout the visible spectral range.
- The detector shall provide low-noise operation suitable for the measurement of weak Raman signals from atomically thin materials.
- The detector shall support acquisition rates suitable for rapid Raman mapping and automated measurement workflows.
- The detector cooling system shall maintain stable operating conditions during extended measurements.
- The detector shall be fully integrated into the instrument control software and shall support software-controlled acquisition parameters, including integration time, readout mode, and acquisition sequencing.

Excitation sources

- The system shall be supplied with a 532 nm laser excitation source optimized for Raman spectroscopy.
- The excitation source shall provide a minimum optical power of 30 mW before attenuation.
- The delivered laser power at the sample shall be software adjustable over a wide dynamic range suitable for sensitive two-dimensional materials.
- The optical architecture shall permit future integration of additional excitation wavelengths without requiring replacement of the microscope or spectrometer.
- The software architecture shall support operation with multiple excitation wavelengths should such wavelengths be added in the future.
- The system shall permit automated laser power selection as part of user-defined measurement sequences and automation workflows.
- The excitation system shall be fully integrated into the instrument control software and accessible through documented third-party software interfaces, including APIs, SDKs, scripting interfaces, or equivalent mechanisms.

Microscope optics and confocal imaging

- The system shall include a research-grade microscope optimized for confocal Raman spectroscopy and Raman imaging.
- The microscope shall provide reflected-light imaging capabilities suitable for the inspection of two-dimensional materials, van der Waals heterostructures, and other layered quantum materials.
- The microscope shall include a reflected-light illumination system suitable for Köhler illumination.
- The illumination source shall be LED-based and optimized for stable, homogeneous illumination during optical imaging and Raman measurements. The illumination intensity shall be software controllable and accessible through automated measurement workflows.
- The microscope shall support future expansion to additional optical contrast modalities, including darkfield and differential interference contrast (DIC) microscopy.
- The microscope shall support both optical imaging and Raman measurements through the same objective lens to ensure accurate spatial correlation between optical and spectroscopic data.
- The microscope shall include a motorized objective turret accommodating at least five objectives.
- The system shall be supplied with a set of objectives with the following characteristics (magnification, numerical aperture NA, working distance WD): 10x, NA>0.2, WD>10 mm; 50x, NA>0.7, WD≥1 mm; 100x, NA≥0.9, WD≥1 mm.
- The microscope shall provide software-controlled objective selection.

- The microscope shall include an integrated confocal optical system for rejection of out-of-focus light and optimization of spatial resolution.
- The microscope shall provide motorized and software-controlled field and aperture diaphragms for Köhler illumination. Field diaphragm and aperture diaphragm settings shall be accessible through the instrument control software and through documented APIs, SDKs, scripting interfaces, or equivalent mechanisms. Diaphragm settings shall be configurable as part of automated measurement workflows and user-defined measurement recipes.
- The system shall automatically compensate for field-of-view offsets arising from objective changes or shall provide equivalent functionality ensuring reproducible relocation of measurement positions following objective changes.
- The system shall support automated focus compensation or equivalent functionality when switching between objectives having different working distances. The autofocus system shall be suitable for low-contrast samples and atomically thin materials.
- The microscope shall include a digital imaging system suitable for sample navigation, optical inspection, focusing, and image documentation. The camera shall support live imaging during Raman measurements, mapping experiments, and automated positioning routines.
- The system shall support automatic focusing and software-controlled focus adjustment.
- All optical-path configuration functions required for automated operation shall be motorized and software controllable. This shall include objective selection, field diaphragm and aperture diaphragm selection for Köhler illumination, brightfield/Raman beam-path switching, camera/spectrometer beam-path selection, filter or reflector selection, polarization control, and other optical-path configuration functions required for automated measurements.
- No manual intervention shall be required to switch between optical imaging and Raman measurement modes during automated measurement sequences.
- All motorized optical-path functions shall be accessible through the instrument control software and through documented APIs, SDKs, scripting interfaces, or equivalent mechanisms.

Motorized sample positioning and Raman mapping

- The system shall be equipped with a motorized XY sample stage suitable for automated Raman measurements and spectroscopic mapping.
- The stage shall provide a minimum travel range of 150 mm x 150 mm.
- The stage shall provide a step size of 50 nm or better and a high displacement reproducibility.
- The stage shall provide closed-loop position control and encoder-based position feedback, or equivalent technology.
- The stage shall support automated point measurements, line scans, area scans, and large-area Raman mapping.
- The stage shall permit relocation of previously measured positions using stored coordinates.
- The system shall include a motorized Z-axis positioning system with a travel range of at least 30 mm.
- The Z-axis positioning system shall provide a positioning resolution of 10 nm or better.
- The Z-axis positioning system shall support software-controlled motion and automated approach procedures.
- The Z-axis positioning system shall be fully integrated into automated measurement workflows.
- All Z-axis positioning functions shall be accessible through documented software interfaces, including APIs, SDKs, scripting interfaces, or equivalent mechanisms.
- The system shall support automated raster scanning for hyperspectral Raman imaging.
- The system shall support automated focusing capabilities suitable for long-duration mapping experiments.
- The system shall support unattended operation during automated mapping and measurement sequences.

- The system shall permit user-defined measurement recipes combining optical inspection, autofocus, stage positioning, Raman acquisition, and data analysis without operator intervention.

Polarization-resolved Raman spectroscopy

- The system shall support polarization-resolved Raman spectroscopy over a broad spectral range.
- The optical design shall minimize polarization-dependent variations in spectral response arising from diffraction gratings or other optical components. The supplier shall describe the measures implemented to achieve this objective.
- The system shall permit the control and analysis of both excitation and scattered-light polarization states.
- The system shall include motorized polarization components enabling automated polarization-dependent measurements.
- The system shall include a motorized polarization analyzer in the detection path.
- The system shall include a motorized polarization rotator, half-wave plate, or equivalent component enabling software-controlled adjustment of the excitation polarization state.
- The polarization components shall support continuous angular adjustment over 360° or an equivalent range sufficient to perform polarization-dependent Raman measurements.
- The system shall permit automated acquisition of Raman spectra as a function of polarization angle.
- The system shall support user-defined polarization measurement sequences without requiring manual intervention.
- The system shall permit polarization-resolved Raman mapping.

Software, automation, and open interfaces

- The system shall be supplied with integrated software for microscope control, Raman data acquisition, instrument configuration, data visualization, and data analysis.
- The software shall provide control of all motorized instrument functions.
- The software shall support automated measurement workflows and user-defined acquisition sequences.
- The software shall permit the creation, execution, modification, and storage of user-defined measurement recipes combining optical inspection, autofocus, stage positioning, Raman acquisition, and data analysis.
- The system shall support unattended execution of automated measurement sequences.
- The system shall provide documented APIs, SDKs, scripting interfaces, communication protocols, or equivalent mechanisms enabling third-party software access to instrument functionality.
- The supplier shall provide all documentation necessary for the development of third-party software applications and automation workflows.
- Third-party software shall be capable of controlling all motorized instrument functions.
- The software interfaces shall permit real-time access to acquired spectra, Raman maps, optical images, instrument status information, and measurement metadata.
- The system shall support remote operation through standard communication protocols, including TCP/IP or equivalent mechanisms.
- The system shall permit the development and execution of automation routines using Python.
- The supplier shall provide documented Python interfaces, libraries, APIs, SDKs, or equivalent mechanisms enabling programmatic control of the instrument.
- Python-based software shall be capable of controlling instrument functions, executing measurement workflows, retrieving measurement data, and accessing metadata.
- Measurement data shall be stored in documented formats that permit access by third-party software.

- The software interfaces required by this tender shall be supplied with the system and shall not require additional proprietary software modules, hardware dongles, or optional licenses beyond those included in the tendered configuration.

Computer workstation

- The system shall be supplied with a dedicated workstation for instrument control, data acquisition, data processing, and data storage.
- The workstation shall be fully configured for operation of all hardware and software supplied under this tender.
- The workstation shall include at least 16 GB RAM, and a minimum 2 TB SSD for operating system and active datasets.
- The workstation shall include a dedicated graphics processing unit suitable for visualization and analysis of large Raman datasets.
- The workstation shall be supplied with at least one monitor of 27 inches or larger.
- The supplier shall provide all software licenses required for operation of the system, including instrument control, data acquisition, data analysis, automation, and programming interfaces.
- The workstation shall support the execution of user-developed Python software and third-party scientific software.
- The supplier shall provide administrator-level access to the workstation and shall not impose technical restrictions that prevent installation of user-developed software, scientific software packages, or automation tools.

Spectral fidelity demonstration

- Acceptance of the system shall include demonstration of spectral fidelity and instrumental peak symmetry using recognized Raman reference materials (e.g., diamond, cyclohexane, silicon, or equivalent standards). The supplier shall provide the measured spectra and fitting procedures as part of the acceptance documentation.

CLAUSE 4. Power distributions and safety

- The system shall be configured for EU (Spain) power grid (voltage, sockets, etc.) and be CE marked.
- The system shall be protected against unexpected power cuts and, in that case, should 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 start-up requirements** (**Unpack all system components; Assembly; Run system; Demonstrate scan range; Demonstrate resolution; During the installation process, instruction should be provided on proper procedures for operation and maintenance of the system**), clearly specifying temperature, pressure, humidity, vibration level, etc, for the specific configuration of the offered system.
- 1 copy of the Operating and maintenance manuals must be delivered in English.

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

- The proposal will include transportation to ICFO's facilities including insurance and all export/import and customs duties. **DAP incoterm will apply.**
- The system will be placed in the selected location by ICFO. Contract winner will cover all costs, organization and coordination of system placement, including any required specialized equipment or vehicle, and any required component disassembly and reassembly for system unloading and transportation inside the building to the target lab location. A spectral fidelity test on a Raman reference material will have to be performed.

CLAUSE 7. Warranty and Follow-on Support

- **1-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.

CLAUSE 8. Delivery and Installation Time

The system must be delivered at ICFO before 18th of December 2026.

Delivery time is defined as the time elapsed since the signature of the contract until the system delivery at ICFO facilities. It includes the manufacture of the system, the transportation, the installation and the acceptance test at ICFO's premises.

CLAUSE 9. Target price

- The target price for the system is 275.000,00 € (VAT excluded).
- Payment terms: after installation and acceptance - 100% total price

Castelldefels, on the date of its digital signature

Prof. Dr. Frank Koppens
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