	INDIAN INSTITUTE OF TECHNOLOGY BOMBAY MATERIALS MANAGEMENT DIVISION Powai, Mumbai 400076

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Detailed Technical Specifications for Integrated IR Atomic Force Microscope

Nanoscale spectroscopic information at using an Atomic Force Microscope (AFM) cantilever and Tunable IR laser as source. System must provide simultaneous measurement of IR absorption and sample topography from the amplitude and frequency of the AFM cantilever oscillation. The system must be subsequently upgradable to include conductive AFM, KPFM and thermal-conductivity measurements, at later stage. The system should be able to include/upgrade and use with an temperature controlled stage (-20 - +80 deg C) at a later stage. The system should include a 3-years comprehensive warranty, on-site installation and 6 training sessions spread over the first two years. Full-time, free upgrade for the software associated with the equipment should be made available. Further, any data-analysis software employed should have licenses for use in at least 5 computers. Peer reviewed scientific publications should be provided for proof of all capabilities listed. Details of installation and user-testimonials from at least 5 reputed international labs and universities.
System must provide simultaneous measurement of IR absorption, sample topography and mechanical properties from the amplitude and frequency of the cantilever oscillation.

1. **AFM Specification**

    1. AFM Head/Scanner Material should be made from material for best thermal stability. Invar would be preferred.
    2. AFM Deflection Laser wavelength ~ 920 nm or equivalent
    3. System z-noise floor < 100 pm rms
    4. AC beam deflection detector noise < 80 fm/(root Hz) above 200 kHz. Any other noise value should be given at appropriate frequency and be compatible with this.
    5. Detector Bandwidth: 6 MHz.
    6. Operational Mode: ambient or open liquid cell
    7. Standard modes of operation include – Contact, Tapping, Lateral Force, Force Modulation, Phase Imaging.
    8. Provide Tapping mode based and contact mode based, photothermal technique/PiFM providing IR spectra chemical imaging covering requested Laser range
    9. Technique should directly correlate to FTIR libraries for polymeric materials with proven examples.
    10. Alignment of laser source with the tip/sample is computer controlled over the entire laser tuning range with no manual adjustments required.
    11. AFM head incorporates a parabolic mirror controlled by 3D piezo motor/scanner, allowing the laser to excite the sample and tip from top side. The range of parabolic mirror is 1 mm × 1 mm × 0.8 mm (stepping mode) and 15 µm × 15 µm × 15 µm (scanning mode) with 10 nm resolution, the NA of parabolic mirror is ~0.5. Any other equivalent technology is acceptable.

12. Inverted optics for photo-induced force microscopy with a 3D piezo objective scanner with ability to accept up to 1.45NA objective lens. Any other equivalent technology is acceptable.
13. The system must be able to generate both fixed wave number images and spectrum with the same laser/s. The spectrum on PES (polyethersulfone) must be generated and shown good agreement with a published FTIR spectrum. Spectra should cover the entire range requested in this tender
14. Sample size: 25 mm diameter and 10 mm height or better.
15. 200 number of tips for use in AFM-IR.
16. Scanner:
    a. XY range - 50µm x 50 µm or more
    b. Dual Z feedback – The AFM feedback mechanism must drive both the sample Z with ≥ 7 µm range or better and fast tip Z piezo with ≤ 1 µm with 20kHz bandwidth or better. The Z-range for measurement should be aminimum of 6 microns or better. Piezo elements to produce the best AFM feedback while maintaining the tight focus of the excitation laser on the tip apex region. Any other equivalent technology is acceptable.
    c. Scanner operation Closed loop with capacitive sensors in XY &Z
    d. Sensor Noise for XY scan sensors < 0.4 nm rms @ 1 kHz bandwidth. Any other noise parameters should be given at the appropriate frequency matching these specifications.
    e. XY-Scanner Linearity < 1% of range
17. Positioning system
    a. Coarse positioning range of tip in Z > 10 mm.
    b. XY positioning type of sample at minimum of 6 mm x 6 mm motorized with absolute position sensor
    c. The system shall include an integrated optical microscope coupled to a 5MP digital camera and computer display. The optical imaging shall be in top view (i.e., looking down on the cantilever), with minimum spatial resolution of 1.5 m
    d. XY sample positioning repeatability < 1 µm
    e. Sensor resolution for position sensor < 100 nm rms

2. **QCL IR Source**

1. Tuning range should cover at least ~ 800 cm^{-1} to >1800 cm^{-1} and 2250 - 4400 cm^{-1} or equivalent. This can be a combination of Quantum Cascade Lasers or OPOs, but should have a minimum spectral line width < 2 cm-1, or equivalent or better. In case of utilizing OPOs, the laser source should have the specifications given in point no 3, given below.
2. Spectral Accuracy/Repeatability: < 2 cm^{-1} or equivalent or better.
3. Average Power: 1 - 15 mW over the entire tuning range
4. Power Stability: < 5% pulse-to-pulse (typical)
5. Pulse Repetition Frequency: up to 3 MHz;
6. Pointing Stability: <1mrad in full tuning range and 40 msec tuning speed in full range to support fast spectrum acquisition with 0.1 s per spectrum and hyperspectral IR imaging with a spectrum over full range in every pixel.
7. Cooling Water cooling for silent operation. Appropriate chillers should be included in the quotation.
8. Required multiplexer / tuners should be included to cover the complete range of the source as mentioned above.
9. Beam steering: 3D peizo motor/scanner/Motorized tip/tilt

10. With the Pulsed QCL laser source it should be possible to operate in
    a. hyper spectral imaging and spectroscopy in the complete tunable range

3. OPO Laser:

1. OPO Single Housing Picosecond Laser
2. 87 MHz ± 5 MHz PRR;
3. 70 ± 10 ps pulse duration;
4. Tuning ranges; 2250 cm^{-1} – 4400 cm^{-1}
5. Spectral resolution: < 4 cm^{-1} or equivalent or better
6. Acoustic-optic modulator to allow heterodyne AFM measurements with non-contact AFM cantilevers; Any other equivalent technology is acceptable.
7. Material: single crystal optical germanium or equivalent.
8. A/R coating: 2.4 – 4.3 microns or equivalent.
9. Static optical insertion loss: <4 percent;
10. Center frequency: 80 MHz or better or equivalent;
11. Frequency shift range: 70-90 MHz or better or equivalent;
12. Active aperture height: 2mm or better or equivalent;
13. Optical rise time: 117nsec/mm beam diameter or better or equivalent;
14. Beam separation: 34.9 / 61. mrad (2.4 / 4.2 microns, 80 MHz) or better or equivalent;
15. Bragg angle: 17.5 / 30.5 mrad (2.4 / 4.2 microns, 80 MHz) or better or equivalent;
16. Diffraction efficiency: 85 percent or better or equivalent;
17. RF drive power: 1.5 / 4 watts (2.4 / 4.2 microns, 80 MHz) or better or equivalent;
18. Optical polarization: horizontal (parallel to base) or better or equivalent;
19. Input impedance: 50 ohms or better or equivalent;
20. RF connector: BNC or better or equivalent;
21. Water cooling: 250 ml/min approximately 23°C or better or equivalent; appropriate chillers to be provided
22. Modulator driver
23. Motorized laser multiplexer to accommodate OPO and QCL lasers with available additional ports.
24. Automatic switching between OPO and QCL sources should be possible (if applicable).

4. Optical access top view for position observation
    1. Top optics (for position observation) 10x, 0.2 NA Lens or better or equivalent
    2. **Tip-Sample Approach:** Automated engagement via 3 stepper motors or equivalent;
    3. **Illumination:** Software controlled LED
    4. CCD camera: > 5MP, with pixel image resolution of 500 nm (optical resolution < 1.5 micron) or better or equivalent.

5. High-Speed Electronics& Controller Module

1. FPGA-based control electronics has a section dedicated for high speed scanning probe microscopy or equivalent
2. Sampling Rate: >500 MHz for channels A & B; Channel A dedicated for photodiode detection for high speed AFM or better or equivalent
3. Lock-in Amplifiers (LIA): 4 independent 2-phase lock-in amplifiers (LIA0 to LIA3). LIA Operation Frequency: Up to 10 MHz. LIA Synchronization: fully synchronized from one clock source. Any equivalent technology is acceptable.

4. High Speed Sine Wave Generator: Two channels with 160 MHz sampling rates; one reserved for scan generator for high speed AFM. Any equivalent or better technology is acceptable.
5. Maximum Feedback Throughput: 1 Mps with Dual-Z feedback. Any equivalent technology is acceptable.
6. Integrated Synchronized Laser Driver. Any equivalent technology is acceptable.
7. Standard DAC Channels: 15 channels, 24-bit, 156 kHz data rate
8. Standard ADC Channels: 8 channel: 24-bit, 156 kHz data rate
9. Noise Floor for Scan HV-Amplifiers: 140 uVrms for 150V full range
10. TTL Signal Generator: Two flexible TTL signal generators (with 160 MHz sampling rate) with adjustable duty cycle and DC offset for direct current modulation of laser diodes or for input to Bragg cells
11. Flexible Lock-in Referencing: The LIAs can be phase locked to any other LIA or at any calculated frequencies from the other LIAs
12. Digital Counter Input: Input for APD and PMT for low-lighting imaging or equivalent.
13. Any other equivalent technology for any of these points is acceptable.

6. **Image Acquisition Software:** Supported modes/features include:
   1. Contact and AC AFM
   2. PLL feedback (for high Q sensors such as tuning-fork)
   3. Ultrafast Dual-Z feedback, if required.
   4. Q-control
   5. Bi-modal force gradient imaging for linear and non-linear PiFM or PTIR.
   6. Concurrent acquisition of 26 channels in Dual-Z configuration and 40 channels in Slow-Z configuration
   7. Concurrent acquisition of 4 channels for each spectroscopy mode which may include
   8. vs gap distance
   9. vs bias with and without feedback
   10. step response to voltage response with and without feedback
   11. Should have capability to locate and zoom in/out of pre-acquired images on the same sample.
7. **Computer:**
1. Mounted in a 19″ rack.
2. Minimum configuration includes 3.4GHz Quad Core, 256GB SSD and 2000GB HD combination, 26″ or larger monitor, 8X USB ports, Windows 10 Professional
8. **Environmental**
1. Suitable Active Vibration Isolation system with active bandwidth 0.6 to 200 Hz
2. Acoustic Enclosure with capability to keep temperature controlled to +/- 0.2C.
3. Dry Air filtration set up to provide quiet, clean, and water-absorption-free operation with customer provided compressed air connection.

9. Acceptance Criteria

All the lasers must be capable of AFM-IR by cantilever detection for both fixed wave number imaging and single and multipoint full range spectra. The spatial resolution of AFM IR should be at least 10 nm. The 10 nm spatial resolution must be demonstrated during the site acceptance test by imaging a PS-PMMA block copolymer with a half pitch of 21 nm or smaller; the PS block should be acquired at ~ 1492 cm-1 and ~ 2956 cm-1 and PMMA at ~ 1733 cm-1 and ~ 2853 cm-1 along with AFM topography and phase. Any other equivalent demonstration of spatial resolution and spectral resolution with other standard sample is acceptable. Vendor must also demonstrate single molecule layer sensitivity under AFM IR. The entire system should carry a comprehensive warranty for 3 years. Appropriate training for full operation of the system should be given at least twice a year during the period of warranty.