ORDERING SPECIFICATIONS
FOR AN EXTREME HIGH RESOLUTION ANALYTICAL FIELD EMISSION SCANNING ELECTRON MICROSCOPE

1. RESOLUTION AND SPOT SIZE:
The secondary electron resolution shall be:
0.6nm at 15kV guaranteed
0.7nm at 1kV guaranteed
1.0nm at 0.1kV guaranteed
3.0nm at 15kV, 10mm WD (EDS WD), 5nA probe current guaranteed
Guaranteed values are demonstrable at the customer site and are measured using edge method.
A plot of probe size vs. kV vs. probe current should be provided for 1kV and 15kV.

2. MAGNIFICATION:
The magnification range shall be 10X to 1,000,000X (120x90 mm photo), up to 3,000,000X (1280x960 pixels display)
The magnification shall be microprocessor linked to changes in kV and WD.
Any magnification can be preset and instantly recalled.

3. ACCELERATING VOLTAGE:
The kV shall be variable from 0.01kV (<u>10 Volts</u>) to 30kV with 10V steps between 0.01kV and 2.9kV and 100V steps between 3kV and 30kV.

4. PROBE CURRENT:
Probe current of >500 nA should be achieved at 30kV
Probe current of >20nA should be achieved at 1kV

5. ELECTRON GUN:
The electron source shall consist of a Schottky type thermal field emission gun.
The emitter shall be a Zr/O tungsten tip with up to 100uA emission.
The gun shall be positioned in the field of the first condenser lens to maximize the current generated into the probe.
The anode must be of conical design to minimize image shift and gun alignment when changing accelerating voltage.
A battery back up power supply shall be standard and eliminate the need for gun bake-out and realignment even after an extender power outage.
Emitters shall be guaranteed for 3 years and fully covered under the normal service contract, with typical lifetime of the gun expected to be over 6 yrs.

6. AUTOMATION:
The microscope shall employ an auto-alignment correcting procedure (NeoEngine) that automatically presents all the lens parameters for ultimate imaging and analytical performance. By pressing an AUTO button the user should be able to auto-focus, auto-stigmate and automatically adjust the brightness/contrast ratio of the image.

7. LENS SYSTEM:
The lens system shall consist of a zoom condenser lens to allow changes in beam current with minimal focus change, coupled with an aperture angle control lens (ACL) to minimize system Cs and optimize the convergence angle to ensure optimum performance at all beam currents. The ACL shall be computer controlled and fully automatic to provide the smallest probe diameter at low beam currents (largest optimum alpha angle) and the optimum probe geometry for high resolution analytical performance at high beam currents (smallest optimum alpha angle).The beam current delivered to the sample shall range continuously between <1pA and >500nA.The objective lens (OL) aperture strip shall contain four externally selectable, X/Y alignable apertures plus an open position. The apertures should be in the front

focal plane, so as to maintain the optimum spot size as a function of beam current. The objective lens shall be highly conical so as to allow high tilt at short WD.
The OL shall be a super hybrid type lens with both electrostatic and electromagnetic components for ultra high-resolution imaging with beam acceleration and deceleration within the lens to reduce aberration and improve probe diameter. The in column detectors must not reside within the OL field but be placed above the lens outside the lens field. There must be no OL electromagnetic leakage flux below the lens allowing imaging of magnetic or paramagnetic samples at short working distance and preventing pattern distortion while doing EBSD.
There shall be a lens setting for ultra long depth of focus.
It should be possible to perform both EDS and WDS with a take-off-angle of >30° at the analytical WD.
It must be possible to add an automated Faraday cup into the column just below the objective lens aperture (without altering the column length) for the purpose of measuring the probe current with readout in the GUI.
A port for an optionally available beam blanking system shall be provided and be located in the column just below the OL aperture assembly. It should be automated to provide either beam blanking or beam current monitoring (Faraday cup). This electrostatic blanker should have a rise time of less than 10ns.
The column shall have an acoustic dampening coating.

8. ELECTRON DETECTOR SYSTEM:
Standard Detectors must include:
LED (Lower Electron Detector) - A secondary electron detector system consisting of an in the chamber E-T type detector shall be standard. The user shall have control of the collector cage voltage in a minimum of 5 steps for both SE and BSE imaging.
UED (Upper Electron Detector) - A through the lens detector with a user controllable energy filter for collection of topographic (SE) contrast or atomic number (BSE) contrast shall be standard.
STEM (Scanning Transmission Detection) – The microscope should be capable of producing STEM images utilizing a STEM converter holder which should be included as standard with the system. The STEM imaging resolution should be 0.8 nm.
SRBED (Short Working Distance Retractable Solid State BSE Detector) - The backscattered electron detector must be a pneumatically retractable (from the GUI) solid state design that does not block SE signal or limit the collection of X-Rays and allows a working distance as short 2.0 mm when inserted. This detector shall produce pure compositional images with a resolution of 0.1Z at Z=29 and be operational at or below 1kV.

Optionally Available Detectors must include:
USD (Upper Secondary Detector) - A dedicated in column low energy SE detector
STEM (Transmission Electron Detector) – The chamber must be capable of accepting a dedicated STEM detector (either a scintillator /photomultiplier BF/DF transmission electron detector or a solid state BF/DF).

All of the above detectors must be capable of being installed simultaneously.
It shall be possible to image with up to four of these detectors simultaneously
It shall be possible to mix in real time up to four of these detectors.

9. SPECIMEN STAGE:
The sample stage shall be a large goniometer with mechanically fully eucentric tilt at all Z positions..
Stage movement should be at least 70mm in X, 50mm in Y and 40mm in Z.
The stage shall be eucentric at all Z positions and tilts.
The tilt range must be -5° to +70° with the tilt axis perpendicular to dedicated EDS and EBSD Ports.
All 5 stage Axes (X, Y, R, T, Z) shall be motorized and automated and include computer eucentric rotation.
The stage shall be capable of meeting all resolution specifications without a stage lock or clamp.
The combination of specimen chamber design and objective lens shape must be optimized for an analytical geometry of the sample at 0° Tilt at 10mm WD with an EDS take off angle not less than 30°.
The chamber must also be capable of accommodating multiple EDS detectors simultaneously and accommodating EDS, WDS, and EBSD simultaneously. The EDS and EBSD detectors shall be co planar.
The stage tilt shall be perpendicular to the dedicated EBSD port.
The sample substage shall be electrically isolated and a sample current feed thru shall be provided to measure absorbed current (or true probe current when a Faraday cup is mounted on the sample holder).

The stage shall be capable of having a bias voltage of up to 5kV.
Beam deceleration shall be able to be applied at any gun accelerating voltage.
The stage automation system shall be controlled through mouse control, programmable trackball and magnification linked touch pad and allow the following functions:
a. Computer eucentric rotation
b. Continuous movement with the speed linked to magnification.
c. Mouse drag and drop movement
d. Snap shot image capture for sample survey (up to four images)
e. Step distance defined by user
f. Field by field with user defined % overlap.
g. Click center and zoom
h. Points table and on screen graphics
i. Hard limits and soft limits linked to sample holder and user input of sample height offset.
j. Stage return to location of any stored image.

10. SPECIMEN EXCHANGE AIRLOCK:
A specimen exchange airlock shall be available to allow up to 6-inch diameter or 1-inch tall samples, (or 4" wide or 2 inch tall samples) to be loaded with a cycle time of less than 60 seconds.
The sample loading procedure shall require a single movement, be fail-safe and not require observation of the sample stage. The load lock shall be pumped to appropriate vacuum via vacuum gauge reading and not a timer. The airlock door shall open automatically upon reaching vacuum and shall remain part of the high vacuum region. There shall be an indicator showing the presence or absence of a specimen on the stage both on the airlock and on the software GUI. The airlock shall have 3 ports for installation of options such as an integrated color navigation camera, oxygen radical cleaner or environmentally isolated specimen holder. There shall also be an audible alarm if the air lock rod is activated while the stage is not at the exchange position.

11. COMPUTER CONTROL SYSTEM:
All microscope functions shall be controlled through a Windows 10 PC based interface. This system should reside on a Xeon processor and be operated from a minimum 24-inch color wide screen format flat panel display with a pixel display resolution of at least 1920 x 1080.
The control graphical user interface (GUI) shall be easy to understand and use. The operation of the electron optics system shall be computer aided so that a minimum of fine tuning is required even when changing accelerating voltages.
This system shall also allow the following functions:
a. Image archiving and data base management with thumbnail display, search capability, montaging, percent area phase analysis, image filtration and kernel operators and a customizable report generator
b. Network interfacing
c. EDS integration (No additional hardware or software required on SEM)
d. Image processing
e. Mouse, keyboard, trackball, touchpad and digi-knob operation
f. Image annotation with: changeable fonts, colors & special characters. The on screen scalar measurement and annotation system must include: point-to-point with line end-point magnifying window, angles and lines, X & Y cursors including diagonal measurement, circle, square, arrow, line and text, calibration routine for standards, annotation can be saved; loaded and appended
g. On screen graphics of vacuum status, sample status, beam status and detector(s) status
h. Integrated HT Wobbler for beam alignment
i. A password protected master column and gun alignment with overriding user adjustments
j. No additional or optional software or hardware shall be required on the microscope to allow full control via 3rd party accessories such as EDS, WDS, and EBSD.

Image acquisition functions such as frame averaging, frame integration pixel integration, block integration, and pixel binning shall be built into the computer control system.
Auto functions such as Auto-Focus, Auto-Stigmation and Auto-Exposure shall also be included as part of the NeoEngine.

Stage automation shall include features such as eucentric rotation (about any point on the sample), snap shot sample review, click to center, and a programmable move by field or defined absolute amount button. The operation system shall have both standard “recipes” of common operating conditions for standard sample types as well as user created recipes for custom applications which can be stored and recalled. Recipes shall be tagged to user login.
Every saved image shall contain an automatically generated recipe of column and stage conditions which can be recalled and reset.

12. DIGITAL SCAN GENERATOR / IMAGING:
The digital scan generator shall be capable of high speed scanning and image acquisition of up to 5120 X 3840 pixels.
The live image shall be displayed on the display at 800 X 600 or 1280 X 960 resolution.
The system must allow for image acquisition at 8 or 16 bit resolution
The system shall provide for user selectable image acquisition parameters including time per frame, slow scan acquisition, frame averaging, frame integration, block integration mode (charge reduction mode) and pixel binning mode (charge reduction mode).
The system shall include a digital scan rotation feature that automatically corrects for accelerating voltage and working distance and any user entered angle of scan rotation to maintain orthogonal motion on the display.
The imaging software shall include dynamic focus to maintain focus on steeply tilted specimens.
Image display modes should include: normal display, full screen display, live image with user defined digital zoom window, User defined reduced raster, live horizontal or vertical split screen, live quad image display, signal mixing of up to 4 live signals (with individual live display simultaneously), dual color for mixed signals, pseudo color, and anaglyph stereo.
Image enhancement algorithms must be provided for gray scale manipulation on a stored and a live image as well as standard post processing kernel and sharpening routines.

13. REMOTE VIEWING AND REMOTE CONTROL
The SEM as configured shall be capable of live remote viewing and live external remote control of SEM operation via a standard high speed internet connection.

14. MISCELLANEOUS
The system shall operate on a 100V 40 Amp circuit.
The console shall have an emergency power off (EPO) switch mounted on the front of the instrument.
There shall be a low energy consumption mode (sleep mode) to reduce electrical cost during standby.
The SEM must allow installation of an optionally available, integrated & imbedded real time active feedback anti vibration system that must not be an external table.

15. INSTALLATION AND TRAINING
The system shall include installation start up training and proof of resolution at customer’s facility.
A one year warranty of all parts and labor for the FE SEM (3 years on the emitter) shall be standard. A minimum two day applications training for 1 person at provider’s facility. Unlimited technical support from trained applications specialists shall be available for the life of the instrument.