Indigenous Development of Scanning Electron Microscope

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Scanning Electron Microscope (SEM) is a scientific instrument that uses a finely focused beam of electrons to provide information about topography, elemental contrast and characterization of a specimen. Over the past few decades, it has proved to be an indispensable tool for research and education in material science, chemistry, biological sciences, life sciences, forensics and nanotechnology. SEMs are currently imported at costs unaffordable for most educational institutions in India. Bhabha Atomic Research Centre, Mumbai has developed an indigenous SEM. The SEM comprises mostly of in-house designed and developed subsystems and a few commercial off-the-shelf components. With growing impetus for indigenous development of technology under the flagship of the *Make in India* initiative by the Indian Government, development of SEM is expected to contribute significantly towards technological advancement in the country.

SEM Electron Gun & HV power supply

- Tungsten filament based thermionic triode electron gun.
- Self-Biased electron gun HV power supply integrated with grid bias voltage and floating filament heating supplies.

- Max acceleration voltage : 30 KV
- Acceleration voltage ripple : 10 ppm
- Acceleration voltage stability : 100 ppm/hr
- Max electron emission current : 300 µA
- Max grid bias voltage : 2 KV

Electromagnetic Lenses

- Total Design demagnification : 10,000
- Demagnification and focusing of electron beam achieved using multiple rotationally symmetric Iron clad magnetic lenses.
- Magnetic core material : Pure Iron
- Deflection coil assembly: X & Y dipoles with Mn-Zn ferrite core
- Octopole for astigmatism correction

Secondary Electron Detector
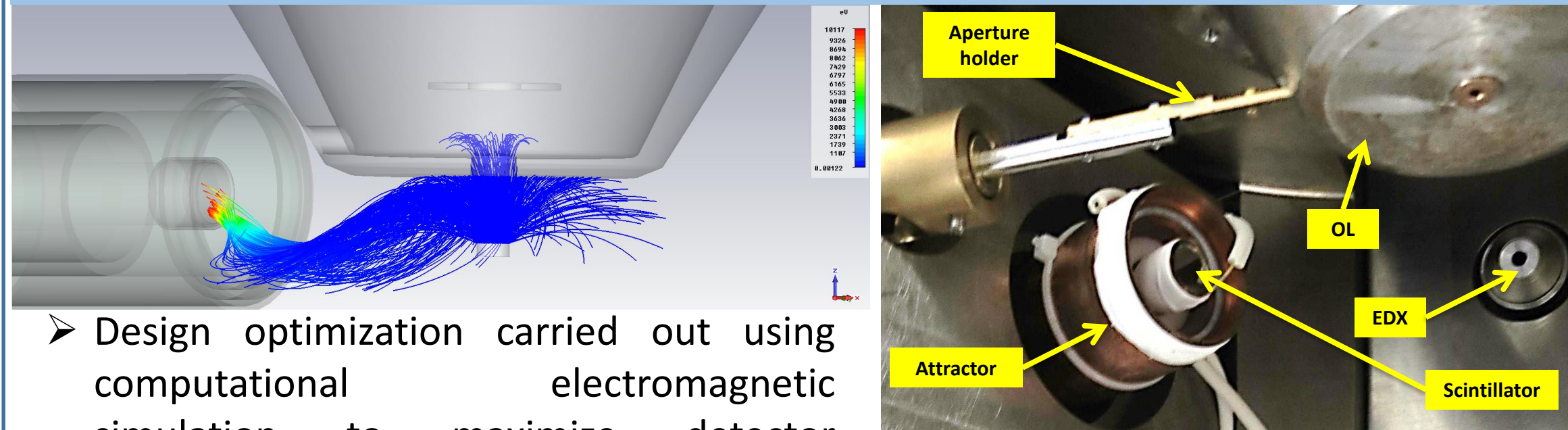
- Design optimization carried out using computational electromagnetic simulation to maximize detector collection efficiency
- Simulation results
  - Collection efficiency at WD=8mm: 50 %
  - Collection efficiency at WD=40mm: 99 %

- SE Detector Type : ET-type
- Scintillator : YAP:Ce
- Scintillator voltage : +10kV
- Faraday cage voltage : ±1kV

SEM vacuum chamber & Sample Stage
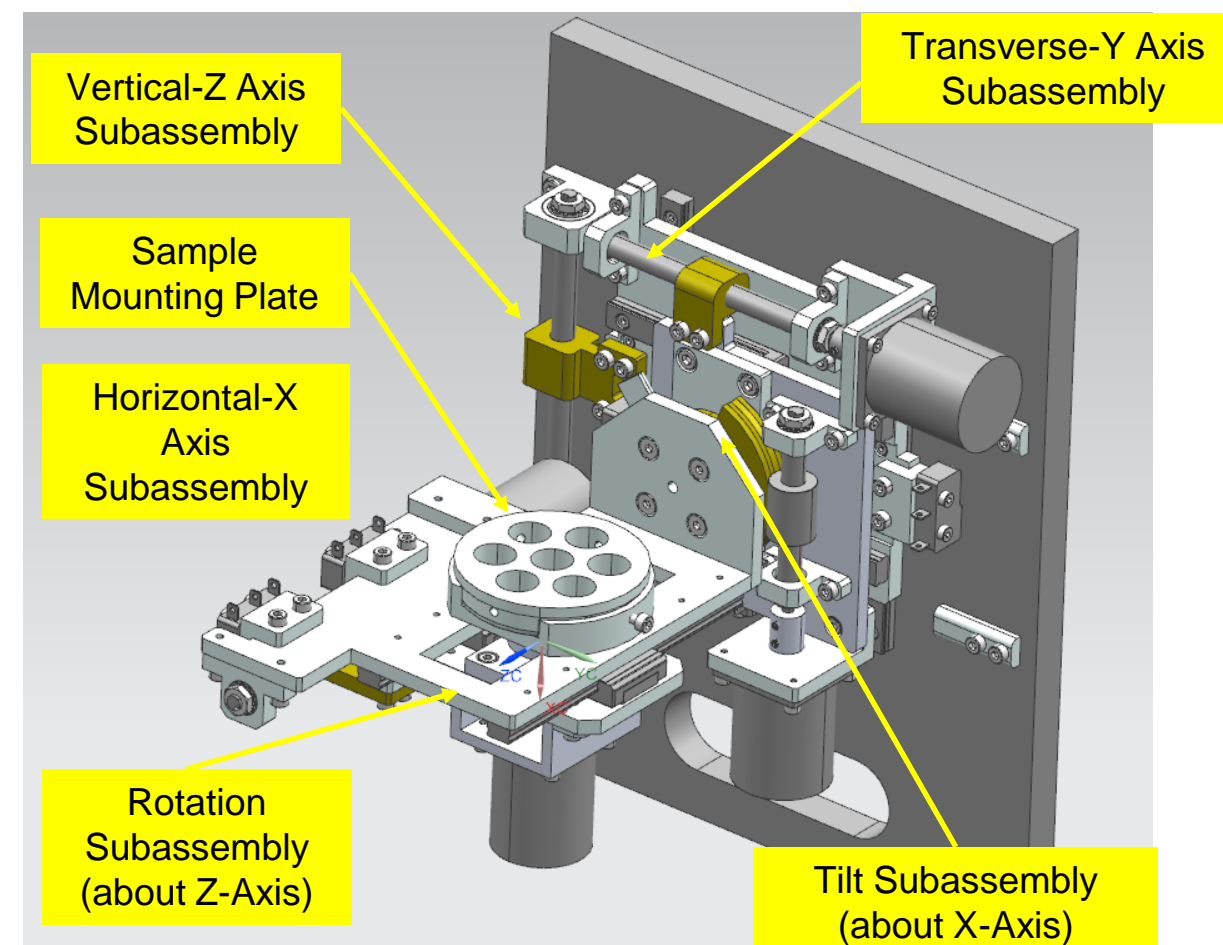
- Material : AISI 1018
- No. of ports : 8
- Surface passivation : Ni plating
- Sliding door mechanism holds the sample stage

- 5-DOF : Motorized
- X : ± 20 mm
- Y : ± 20 mm
- Z : 8 - 40 mm
- Tilt : ± 45º
- Rotation : 360º

BARC Developed SEM

BARC SEM Specifications

- Electron Source : Thermionic Tungsten Filament
- Vacuum pressure : 10^{-6} Torr.
- SEM Resolution : < 20nm
- Magnification : 50x to 1,50,000x
- Acceleration Voltage : 1 kV to 30 kV
- Sample Stage : 5-axis Motorized
- Sample size : 50mm dia., 40mm height
- In-house Detector : Secondary Electron
- Optional attachment : EDX Detector (Commercial)
- Software for centralized control and Image post-processing

SEM Micrographs

Samarium Cobalt sample — 3500 x

Standard grid calibration sample — 5000 x

Etched Stainless Steel sample — 8000 x

Standard gold on carbon sample — 1,50,000 x
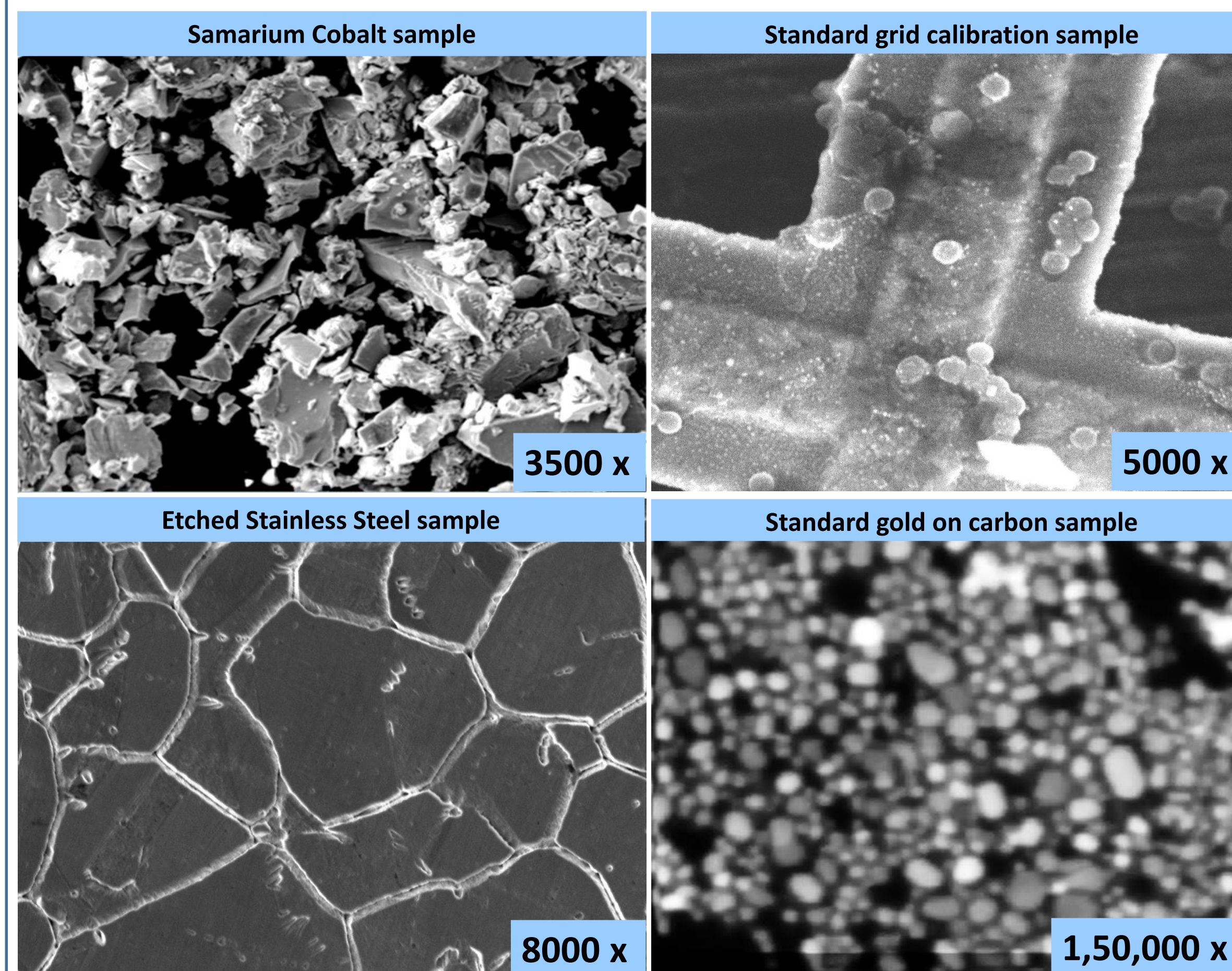
Vacuum System & Vibration Isolation Platform

- Vacuum level : 10^{-6} Torr.
- Rough vacuum pump : Rotary
- Fine Vacuum pump : TMP
- Isolator : Passive air
- Isolator air pressure : 25 psi
- Max. Vertical Attn. : 20 dB
- Aluminium Honey-Comb damper

Beam Collimating Apertures

- Material: Molybdenum
- Thickness : 25um
- Spray aperture size : 1mm dia.
- Final variable aperture with 350, 200, 100 µm dia.
- Circularity: 2%

Control & Drive Electronics
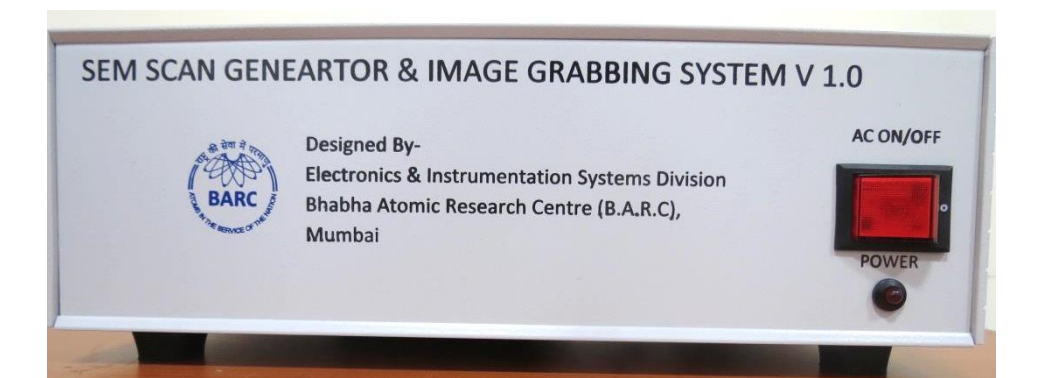
- Microcontroller based integrated SEM control & drive electronics.
- Lens drive modules
- Vacuum system control
- Detector control
- Data acquisition & Signal processing modules
- Sample stage motion control

- X-scan signal frequency: 5 KHz
- Y-scan signal frequency: 20 Hz
- Live rate: 10 fps (500 X 400)
- Acquisition rate: 2.5 mins/frm. (1000 x 800)
- No of acquisition channels : 2

Software
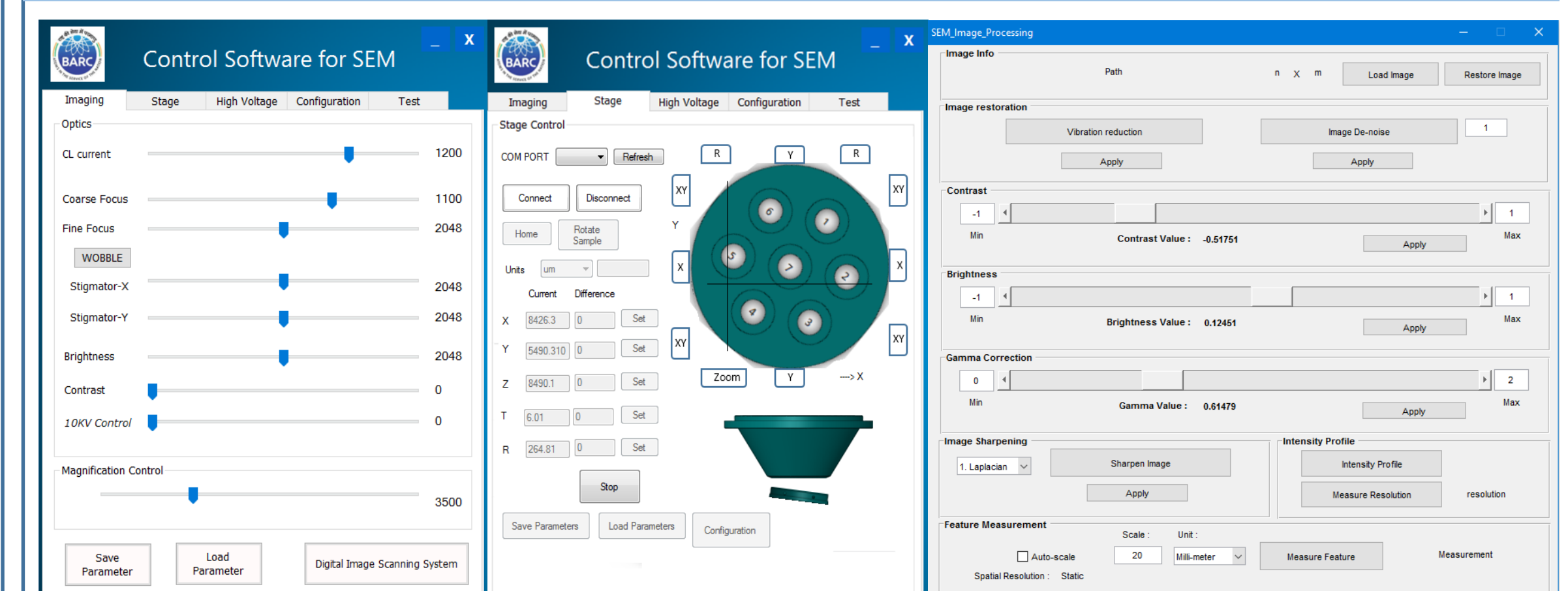
- Integrated GUI based software for imaging, stage motion and HV control
- Safety interlock provided for HV power supplies provided with vacuum level and voltage ramp rate.
- SEM image post-processing software with provisions for denoising, image enhancement and meteorology.
- Prototype auto-focussing software has been developed.