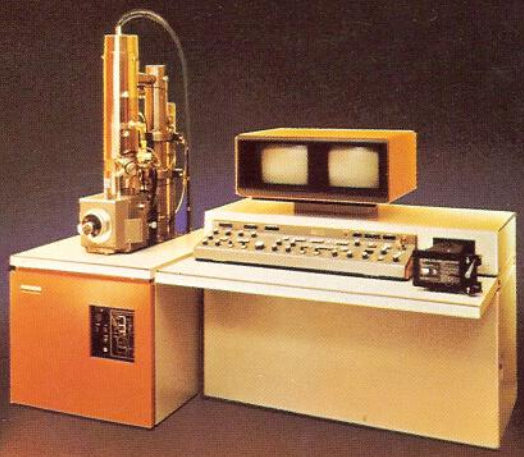
ISI DS-130

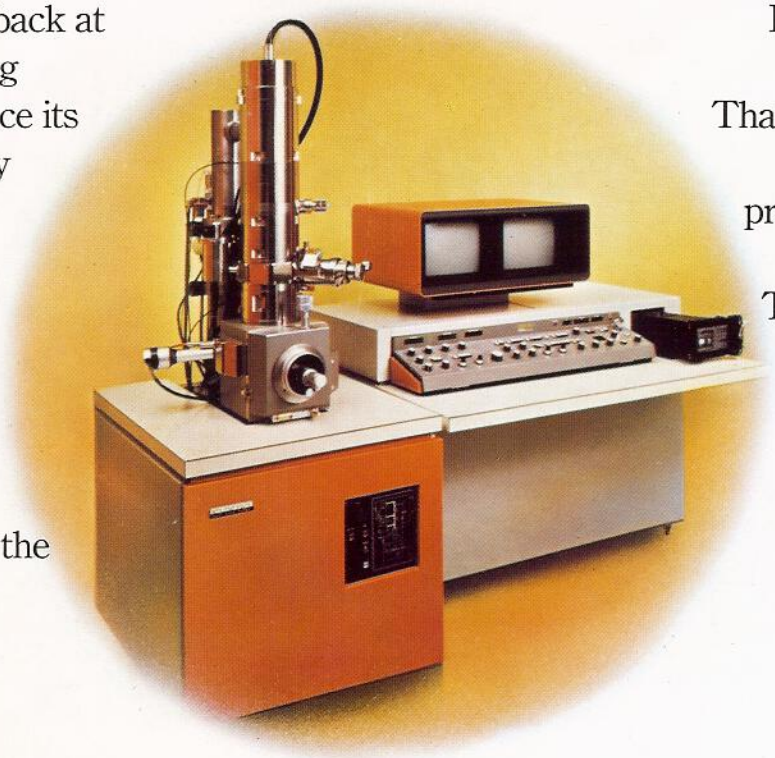
Research scanning electron microscope

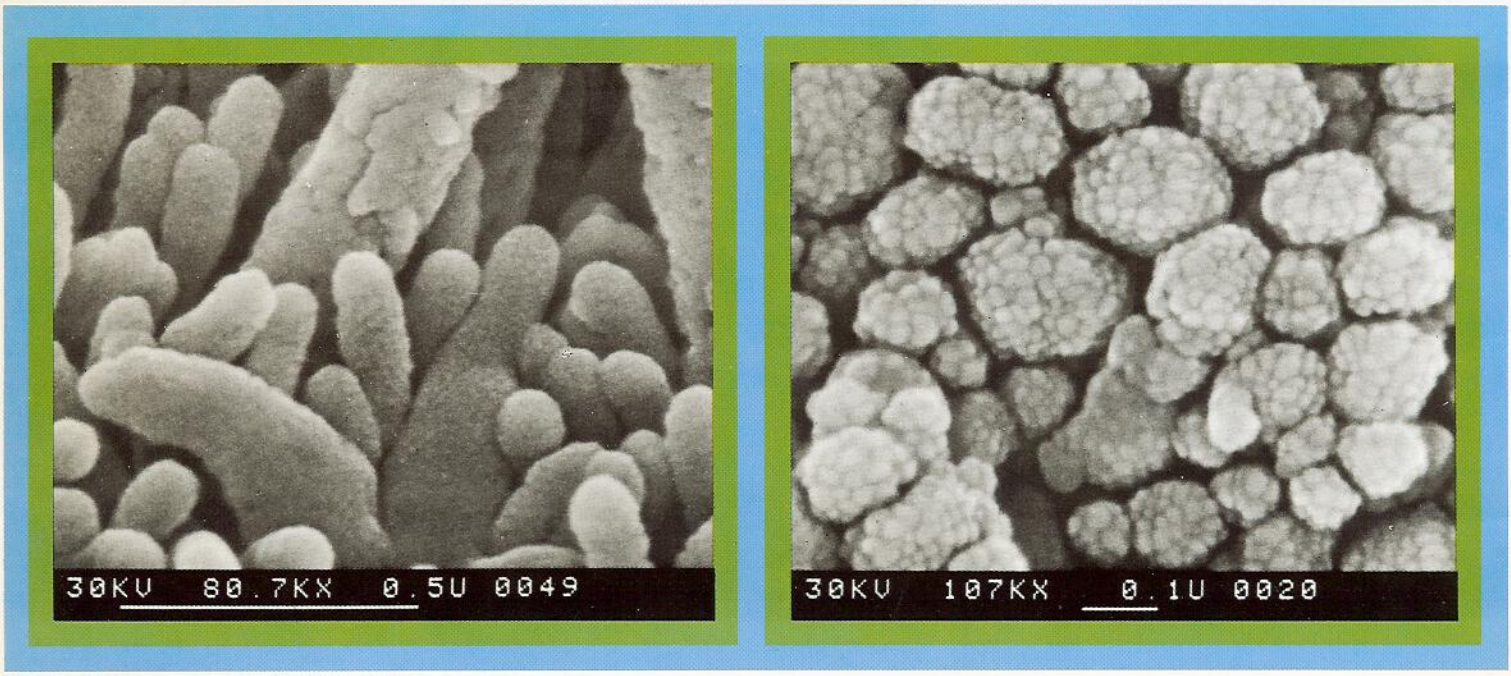


ISI International Scientific Instruments, Inc.

Beyond the state-of-the-art

When the world looks back at the progress of scanning electron microscopy since its introduction in the early sixties, it will surely say that of all the advances in technique and instrumentation since then, by far the most notable was the introduction in 1979 of the DS-130 by International Scientific Instruments. That is because the DS-130 goes way beyond the present state-of-the-art. It is a great leap forward. There are many reasons why. Foremost among them are four world firsts combined in one SEM.

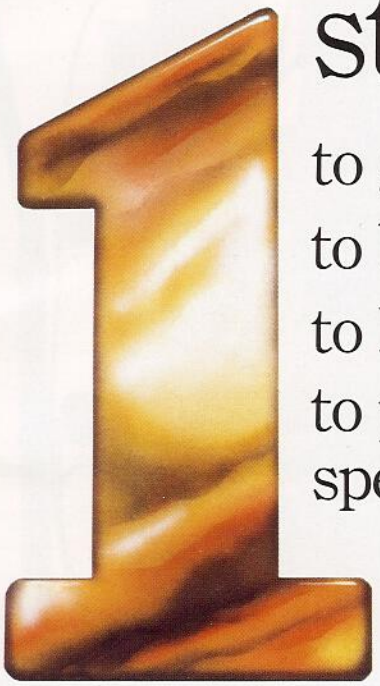




1. Sample of lung tissue 80,700×.

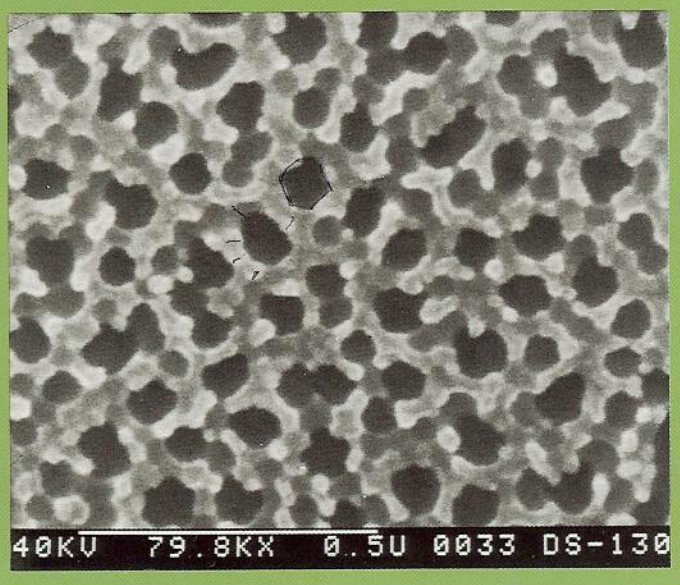
2. Gold coat on carbon 107,000×.

The DS-130 is the

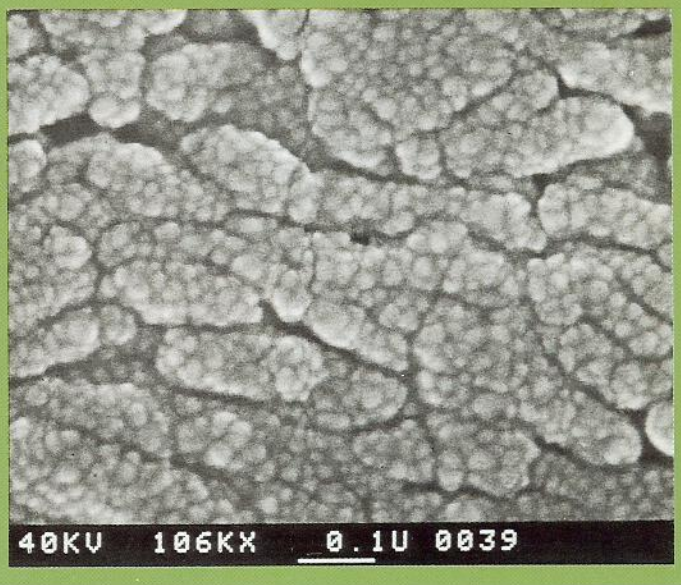


st

to guarantee 30 Å resolution
to be computer controlled
to have a revolutionary 5 lens system
to provide an upper and lower specimen stage



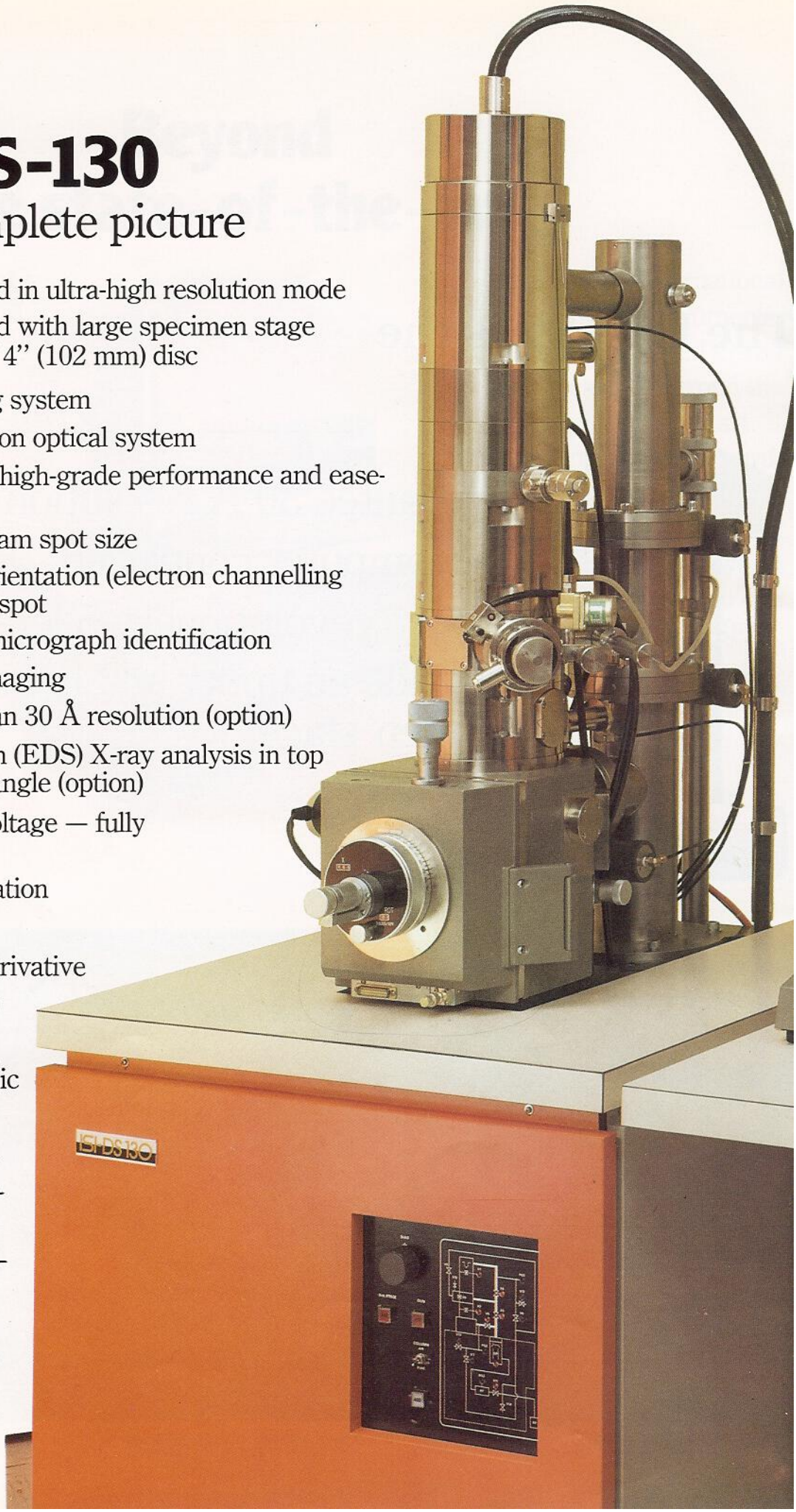
3. Anodized aluminium 79,800×.



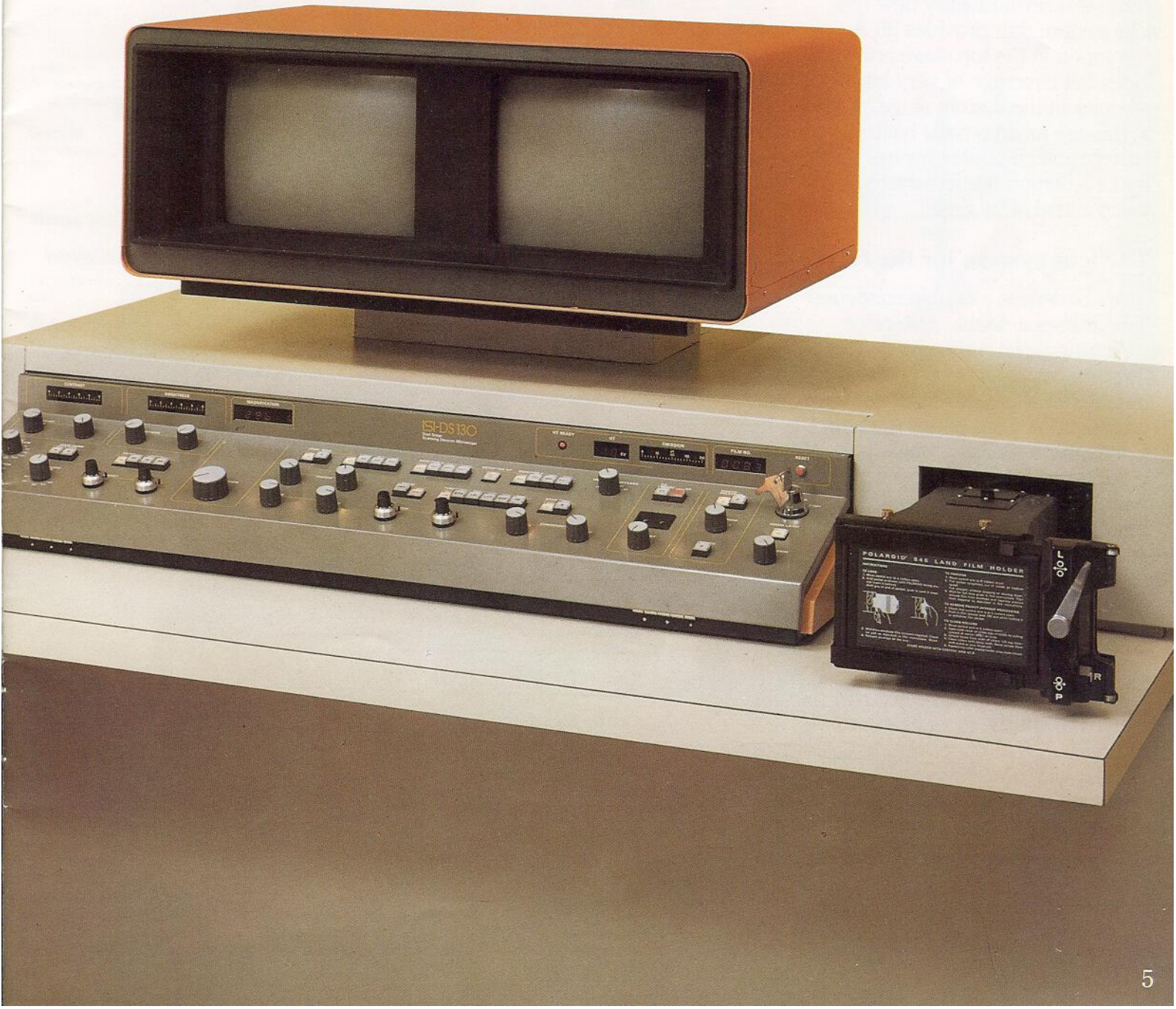
4. Magnetic tape 106,000×.

DS-130
the complete picture

- 30 Å resolution guaranteed in ultra-high resolution mode
- 60 Å resolution guaranteed with large specimen stage providing full coverage of 4" (102 mm) disc
- 2 stage specimen handling system
- revolutionary 5 lens electron optical system
- computer control ensures high-grade performance and ease-of-use
- less than 20 Å electron beam spot size
- built-in crystallographic orientation (electron channelling patterns) from a 3 micron spot
- automatic data entry for micrograph identification
- back-scattered electron imaging
- STEM mode with less than 30 Å resolution (option)
- Energy Dispersive System (EDS) X-ray analysis in top stage with a 25° take-off angle (option)
- 1 to 40 kV accelerating voltage — fully compensated
- 10x to 300,000x magnification
- automatic beam system
- built-in gamma control, derivative processing, Y-modulation, signal inversion, foreshortening correction, 360° scan rotation, dynamic focusing
- advanced vacuum system
- split-screen dual-magnification/dual-signal imaging
- dual-screen dual-magnification/dual-signal imaging
- liquid nitrogen cooled anti-contamination device for top stage
- lanthanum hexaboride (LaB_6) source (option)



● 30 Å resolution ● computer control
● dual stage ● 5 lens system



Electron optics
the heart of the matter

Convention

Conventional three-lens electron optical systems can produce 60 Å resolution. To achieve 30 Å as a matter of routine is something else again. And that's why, in the DS-130 optical system, convention has been thrown to the winds. The result is a revolutionary new five-lens system that provides 30 Å resolution in the top stage and yet gives full coverage of very large samples in the bottom stage. Added to this are an automatic beam system and computer control that make a comprehensive system years ahead of its time.

The lens system for the future

The first lens is a double condenser lens. It uses a double pole piece with a single energising coil. That brings twin benefits — increased demagnification through a double crossover, and simplicity of control. Condenser lens 2 is a single pole piece type with an independent energising coil. Below condenser lens 2 there is a variable aperture system.

A touch of genius

Now comes the touch of genius. An 'S zone' lens (high strength single field condenser/objective) is used to cut the focal length to almost half that of conventional SEMs, with a corresponding decrease in spherical and chromatic aberration. Consider this. The c_S factor (spherical aberration) for the DS-130 is 4mm.

In conventional SEMs it is 60-70mm. Likewise the c_C factor (chromatic aberration). Conventionally with a normal objective lens it is 18-20mm. With the DS-130 it is cut dramatically to 3mm.

These two factors are the most important elements which give the DS-130 a top stage resolution of 30 Å with extraordinary image brightness. (The c_S and c_C factors are examined further at the end of this brochure).

The fifth lens

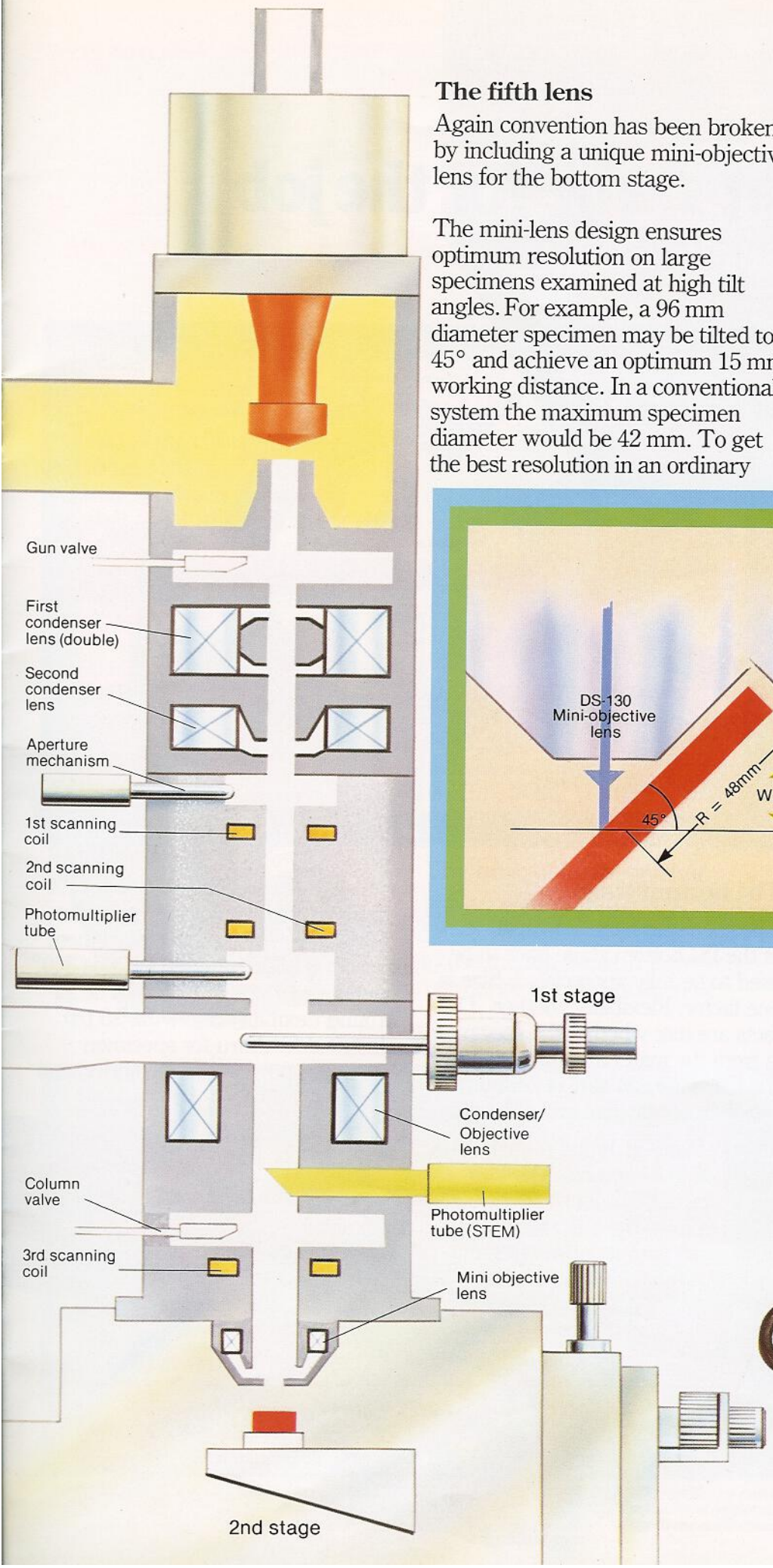
Again convention has been broken by including a unique mini-objective lens for the bottom stage.

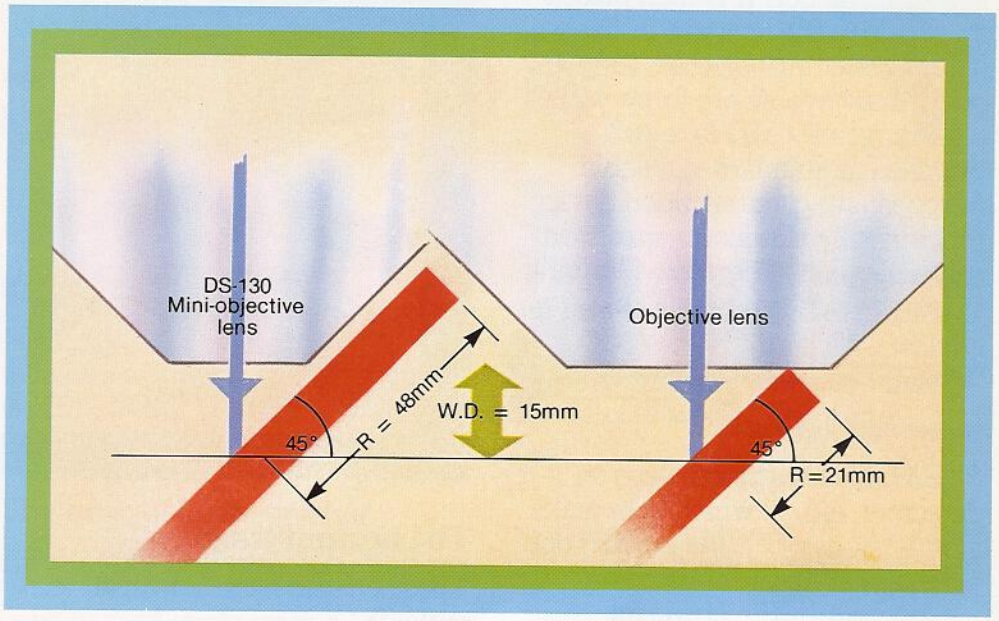
The mini-lens design ensures optimum resolution on large specimens examined at high tilt angles. For example, a 96 mm diameter specimen may be tilted to 45° and achieve an optimum 15 mm working distance. In a conventional system the maximum specimen diameter would be 42 mm. To get the best resolution in an ordinary SEM lens system the working distance would be more than double — giving degraded resolution. (See below).

There is also more room and scope for special experiments/dynamic studies with hot/cold or tensile stages, micro- analysis etc.

The geometry of this lens allows the use of X-ray systems with higher X-ray take-off angles at normal specimen incidence.

Resolution in the lower stage is guaranteed at 60 Å, with 50 Å attainable.





The source

A triode electron gun with tungsten hairpin filaments is the standard electron source. For extra brightness there are lanthanum hexaboride (LaB_6) filaments or semi-pointed hairpin filaments that can increase brightness by up to ten times. Filament cartridges are pre-aligned and change of filament is fast and easy.

Electron gun is instantly accessible for exchange of filaments. Changing column liners is equally quick.

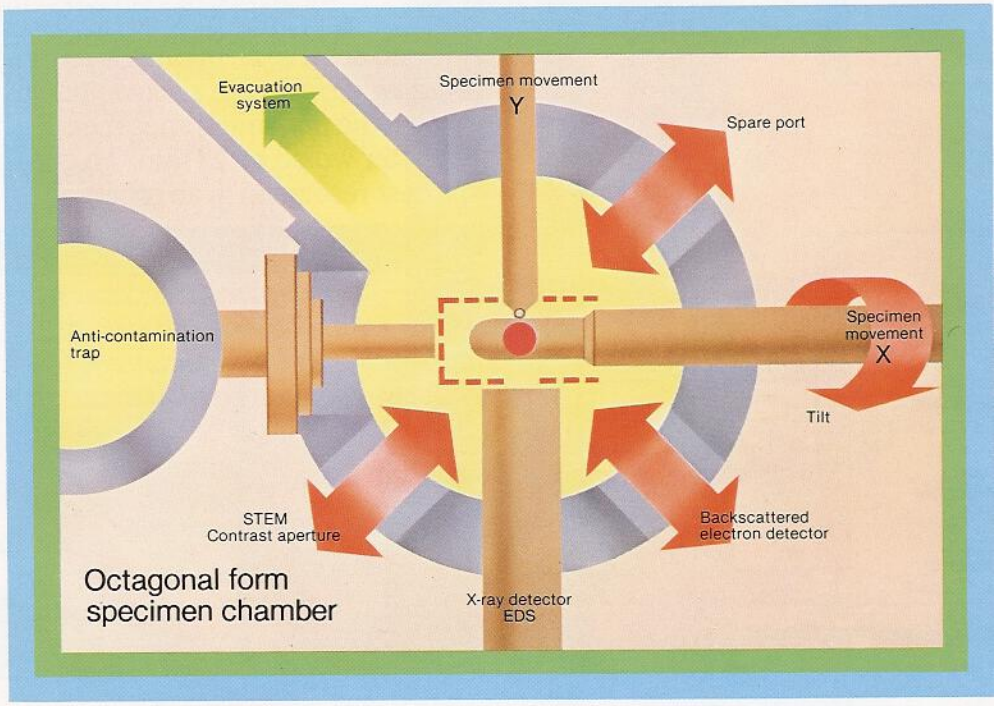
The right stage for the job

The top stage

Guaranteed resolution for the top stage is 30 Å. Any specimen up to 8mm in diameter x 5mm thick can be mounted easily into the top stage specimen holder. It is then placed directly into the lens gap of the top stage condenser/objective lens. X and Y movements are 6mm with a tilt range of −10° to +90°. Supplied as standard is a liquid nitrogen anti-contamination device that virtually eliminates specimen contamination. There are four built-in ports which can take EDS,

Specimen holder—upper stage.

STEM, backscattered electron detectors, etc. — which help make the DS-130 one of the most powerful analytical tools in the world.

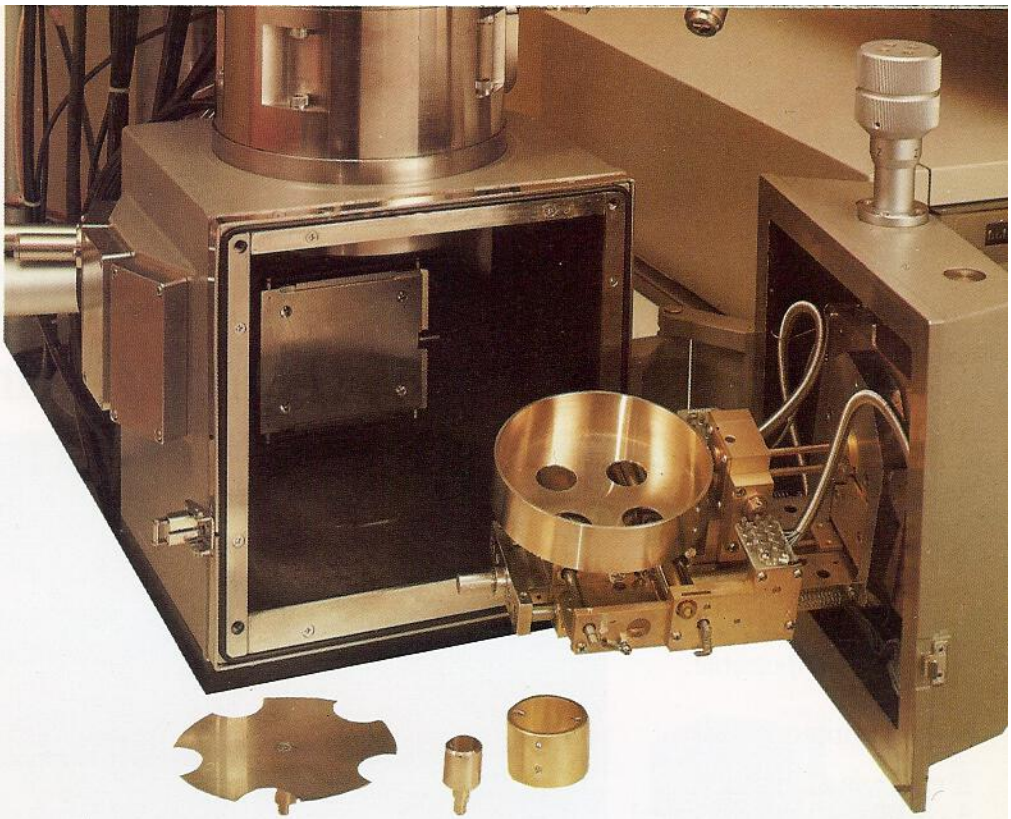


Octagonal form specimen chamber

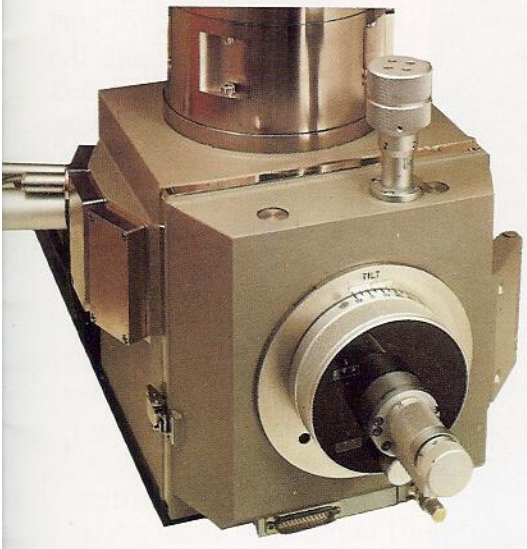
The bottom stage

The specimen handling capabilities of the ISI bottom stage have to be used to be fully appreciated. Size is one factor. Flexibility another. The facts are that whether the specimen is from the material or life sciences, the ISI stage can almost certainly handle it better than any other stage.

There is digital readout of X, Y and rotation. The positioning of the controls allows the operator to move the sample position easily while concentrating on the CRT. X and Y movements are each 56mm. Tilt is −10° to +80°. Z movement is from 8 to 53 mm and there is 360 continuous rotation. That's true all-around flexibility. Note the 25 pin electrical feedthru for specimen biasing or powering accessories, and the BNC connector for specimen current analysis.



A wide range of specimen holders to suit practically every application is available. All are easy to fit to the stage.
The size of the chamber is huge — able to take a 6" x 4" x 3" (152 x 102 x 76mm) specimen with full coverage of a 4" dia by 3" thick (102 x 76mm) sample. The door with the specimen holder attached swings smoothly out for easy access.

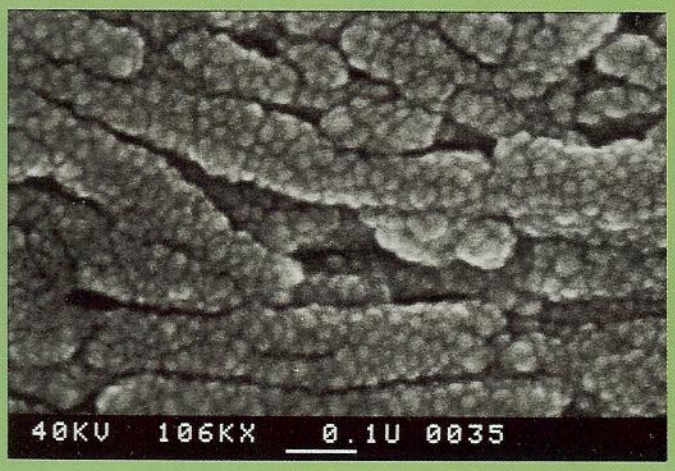


In addition to the secondary detector, the chamber has five extra ports built-in. That's enough to allow the mounting of such systems as EDS, WDS, SIMS, hot and cold stages etc.

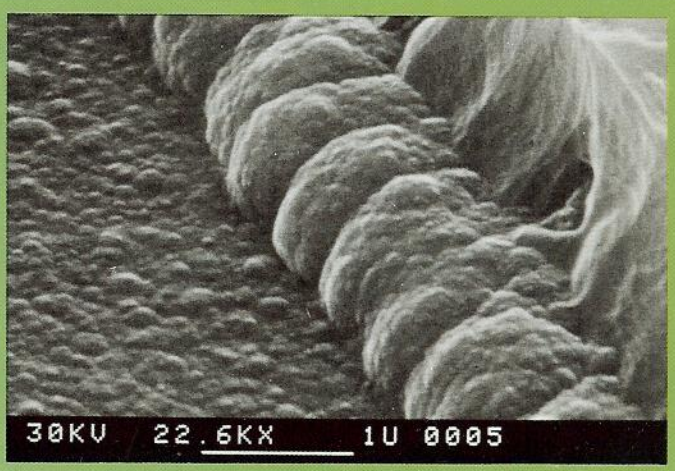
The best of both worlds

For the very best resolution that the DS-130 can provide, it is necessary to use the top stage. If however, very large samples need to be surveyed, then the ISI bottom stage can provide guaranteed resolution of 60 Å (50 Å easily attainable) which is probably better than any other SEM in the world. The sample chamber is a massive 7" x 7" x 7" (178 x 178 x 178 mm).

Switching from one stage to another is at the press of a button. And the DS-130 can be bought with the top stage only, the bottom stage only, or both. Designed to suit your needs.



1. Specimen of mag. tape shows guaranteed high resolution of top stage.



2. Micrograph of 4 inch silicon wafer tilted at 45° illustrates high resolution capability of bottom stage. Despite large sample size and high tilt angle good results are easily attained. See diagram page 7.

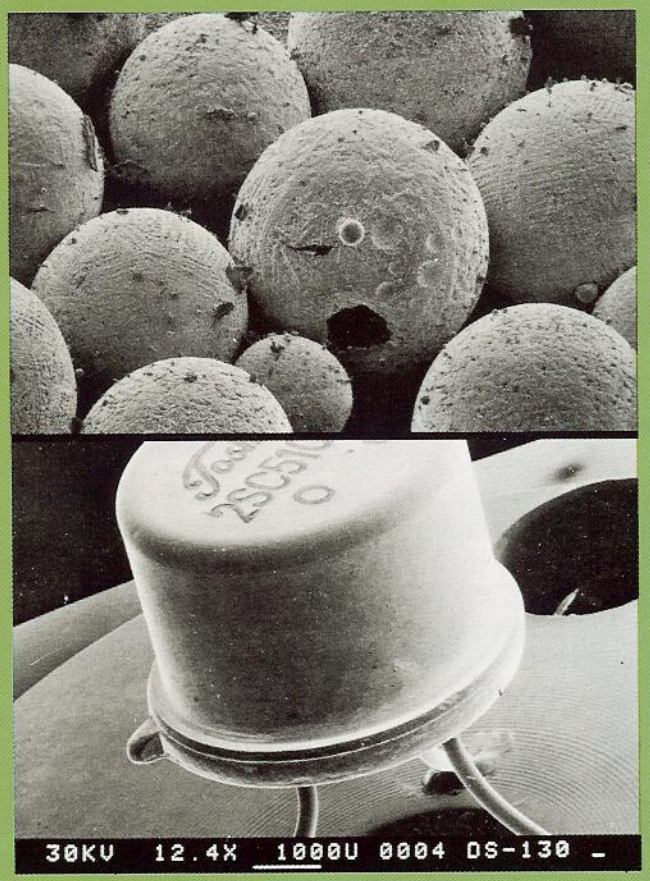
Computer control
the complex made simple

If it was necessary to set manually all the working conditions of the highly complex lens system, efficient operation of the DS-130 would be practically impossible. Hence the microcomputer.

It controls all the key functions. Electron optical lenses, stigmator currents, deflection amplitudes, amplifier gains are all computer controlled.

Not only is the operation of such an advanced research system simple and straightforward, but it also achieves optimum results at all times.

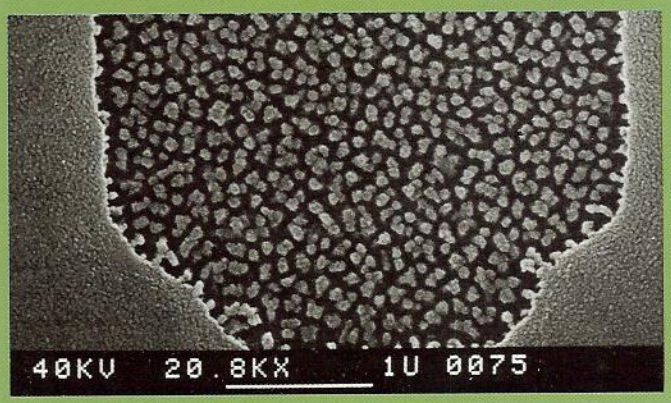
Manual override of the microcomputer is possible where extraordinary working conditions are required.



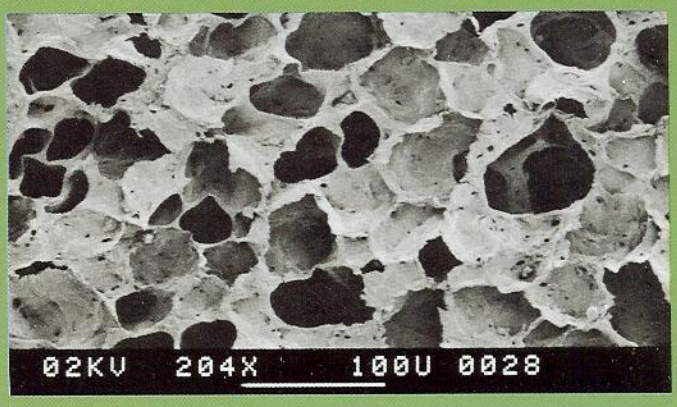
Low and high kV micrographs at low magnification showing computer control flexibility. Top. Bronze spheres at 1 kV × 80. Bottom. Upper stage micrograph showing high kV (30) and low magnification (× 12) without image distortion.

Audible advice

Built into the microscope is a device which gives an audible signal to the microscopist if the working conditions are not correct. If, for example, beam settings are not right for a selected magnification, the computer will emit a short buzzing tone. This is just one more example of how the DS-130 helps the operator take perfect pictures every time.



Silicon crystal growth on integrated circuit.



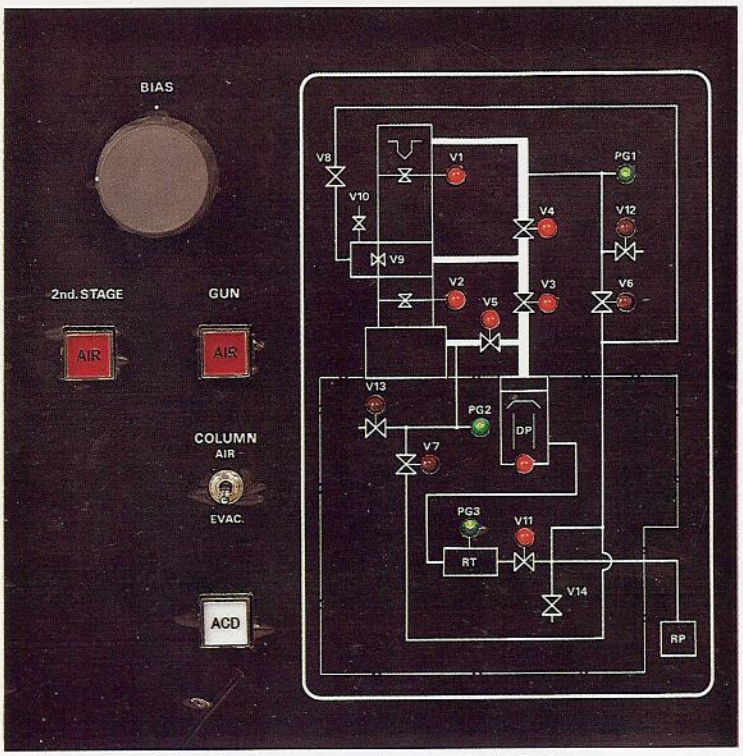
Low kV, low magnification micrograph of uncoated lung tissue. Difficult for most scanning electron microscopes. Easy for the DS-130.

The vacuum system
safe and sure

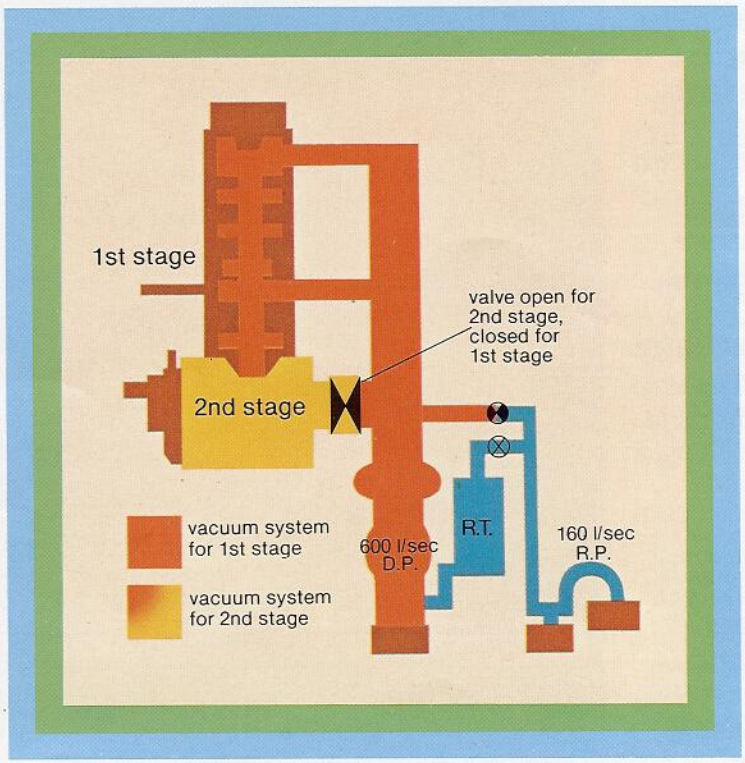
Quickly obtained and efficiently maintained. That's what a microscopist wants of the vacuum system. In the DS-130 a 600 litre per second diffusion pump, a liquid nitrogen trap that prevents backstreaming and a 160 litre per minute mechanical pump all combine to achieve this at the push of a button. The vacuum system is completely automatic.

Airlocks allow filament change while maintaining high vacuum in the rest of the system. Another airlock allows specimen exchange in the bottom stage while maintaining high vacuum throughout the entire column and gun chamber. The pneumatic valving system is microprocessor controlled. Additional valves allow isolation of the vacuum manifolds for special experiments.

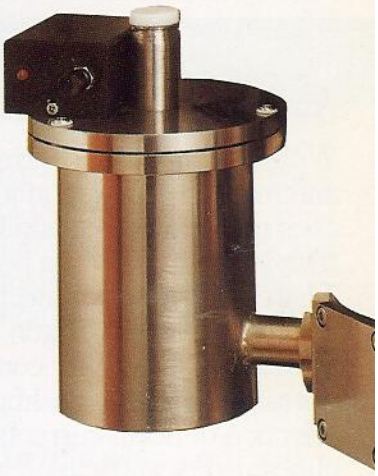
The top stage has its own pre-pump airlock system. Changing specimens takes about 20 seconds.



Diagrammatic display of vacuum.status on front panel of DS-130.



Additionally a cold finger type liquid-nitrogen anti-contamination system helps eliminate specimen contamination.



If power, vacuum or water fails, there is full protection. All appropriate valves close automatically and remain shut until the operator decides otherwise.

DS-130
the SEM that has everything

Most modern SEMs offer a broad range of image processing and display facilities as options. The DS-130, because it's for front-line research scientists, has them all built-in, AND a range of specialist options for particular uses. The standard DS-130 gives you all of the following.

Automatic beam system

With the computer controlled automatic beam system a scientist does not have to be a skilled microscopist to get the best results. There is no need for mechanical column alignment or gun translation. Computer controlled operation provides pushbutton selection of beam currents for almost every application with no final aperture changes, no column realignment, no focus change, no image shift, no change in astigmatism.

Accelerating voltages are from 1 to 40 kV in 1 kV steps, with immediate lens and high-voltage stabilisation, and with kV change causing no alteration in brightness, no image shift, no image defocusing, no magnification change and no image rotation. Of course, magnification and gun bias are automatically compensated when accelerating voltage is changed.

Fingertip control

Apart from manipulation of the specimen stage the entire control system is grouped on a desk console. The operator can quickly see what is happening by just glancing down.

Adjusting the electron-optic functions is a simple matter of pressing back-lit pushbuttons. All this, plus foolproof, one-button photography, makes operation really smooth and fast — especially when the computer does all the parameter adjustments. And all essential data, with micrograph identification, is there on the finished micrograph and recorded automatically.

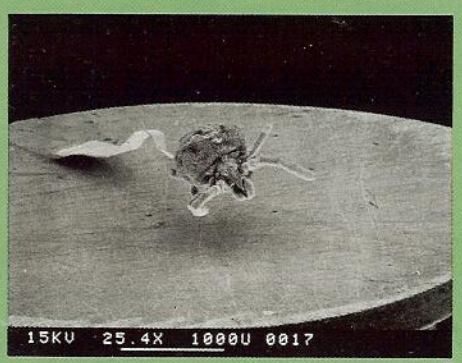
Viewing displays

The CRTs are made to look at. Is there another SEM with twin 12-inch (305 mm) diagonal display tubes? Their high-brightness, long-persistence, blue-phosphor screens are ideal for high-resolution detail and for long-period viewing. The separate high-resolution recording display, plus camera, is close by the operator's right hand, at desk level.

Wide magnification range

Magnification is from 10x to 300,000x continuously variable

1



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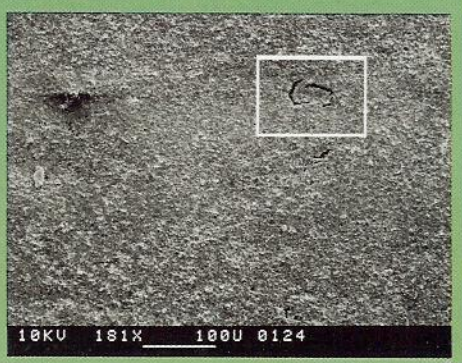

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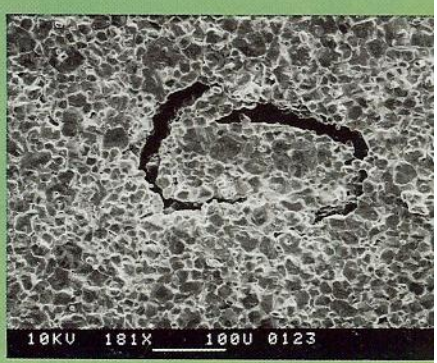
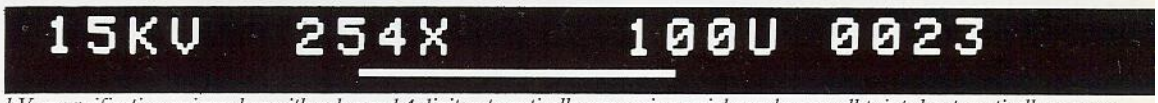


Note the console design for ease of use. Non-routine operation controls (top) are usually left covered.

throughout the range. The unique five lens system ensures that the DS-130 gives good quality micrographs at low and high magnification — and all the way through.

side of the screen while viewing a backscattered electron, X-ray or cathodoluminescence picture on the other.

'viewfinder' over the region of interest. The area selected appears automatically at the higher magnification on the other display



kV, magnification, micron bar with value and 4 digit automatically sequencing serial number are all printed automatically on every micrograph.

Split-screen dual imaging

Simultaneous display and recording of different images are an important feature which extends the research capability of the instrument. It is, for example, possible to display a secondary electron image on one

Dual magnification

Simultaneous imaging of two magnifications is particularly convenient for selecting areas of the sample for detailed examination at high magnification. On the lower magnification image, the operator positions an electronically produced

(or, on split-screen imaging, on the other side of the display). Magnification ratios of 2x, 5x or 10x can be compared, and there is no loss of orientation between the two views.

Automatic contrast/brightness control

Contrast/brightness conditions are automatically adjusted at the push of a button. There is no need for manual adjustment to obtain the correct setting. Perfectly exposed micrographs are assured every time.

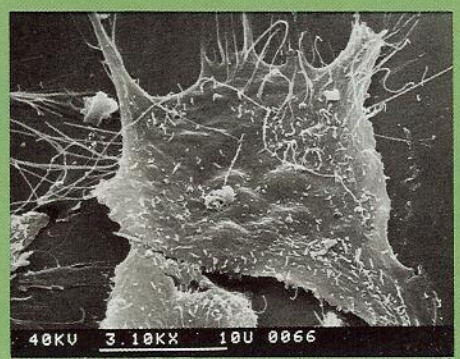
Dynamic focus

A touch of the dynamic focus control ensures micrograph sharpness from edge to edge. It is especially useful at very high tilt angles and at low magnifications.

4

5

8



9

1. Split screen dual magnification, dual imaging micrograph of a specimen containing zinc and iron particles. Left side shows ordinary secondary electron imaging. On the right, backscattered electron detection highlights one type of particle by atomic number contrast.

2, 3, 4, 5. Micrographs of mite show how easy it is to zoom in on detail using automatic beam system.

6, 7. Dual screen, dual magnification pair. Sample—ceramic fracture.

8, 9. Use of dynamic focus on 9 shows edge-to-edge micrograph sharpness even with high tilt. Cultured cell specimen.

The theory of the optics

Spherical and chromatic aberration

The contribution to the electron beam spot size caused by spherical aberration may be defined as:

$d_S = \frac{1}{2} c_S \alpha^3$

where d_S = spot size contribution from spherical aberration
c_S = spherical aberration co-efficient
α = electron beam illumination angle

Consequently, the larger the c_S factor, the larger the electron beam spot size.

One method of reducing the c_S factor is to use a high-strength, single-field condenser objective lens and to place the specimen directly in the lens gap. This is the fundamental reason why the ISI DS-130 achieves its superior resolution. The ISI DS-130 uses an 'S zone' condenser/objective lens. With this, the focal lengths are cut to nearly half that of conventional SEMs with a correspondingly rapid decrease in spherical aberration. Conventional SEMs must contend with c_S factors in the 60-70mm range; the ISI DS-130 with its S zone lens enjoys a c_S factor of 4mm. Spherical aberration may be defined in simple terms as the inability of the electrons on the periphery of the electron bundle to focus at the same point on the specimen as the electron in the centre of the bundle. This is illustrated in the upper diagram.

Using the same analogy, the second factor which contributes deleterious effects to the electron beam is chromatic aberration. Chromatic aberration may be simply defined as the inability of the lens to focus, at the same point, electrons with different energies. This is shown in the lower diagram.

The contribution to the electron beam spot size from chromatic aberration may be defined as:

$$d_C = c_C \alpha \frac{\Delta V}{V}$$

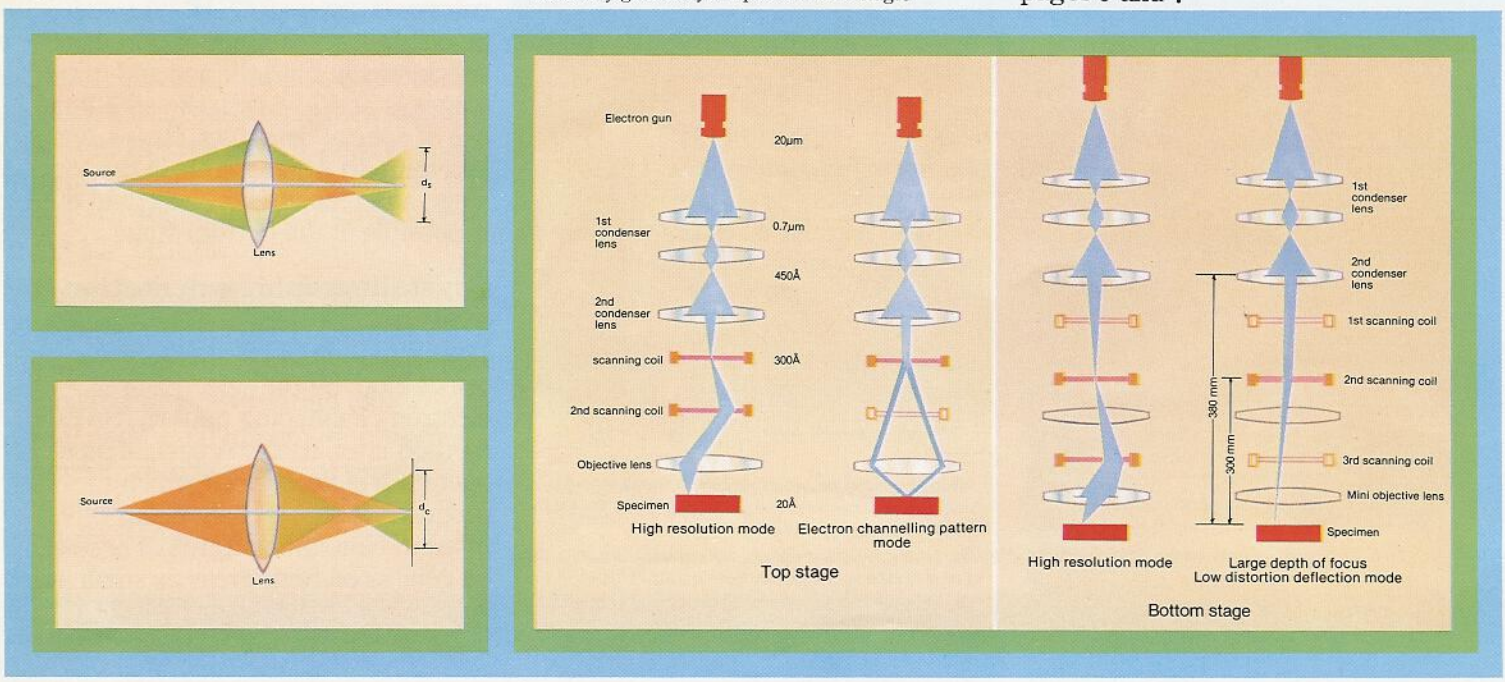
d_C = contribution to spot size from chromatic aberration
c_C = chromatic aberration factor
α = illumination angle
V = electron beam energy

Conventional type SEMs using a normal objective lens have chromatic aberration factors of 18mm to 20mm. The ISI DS-130 by use of its revolutionary high-field condenser/objective lens enjoys a low chromatic aberration factor of 3mm.

By minimising both of these factors ($c_S + c_C$), the ISI DS-130 can guarantee a resolution of 30 Å in the top stage condenser objective lens with extraordinary image brightness.

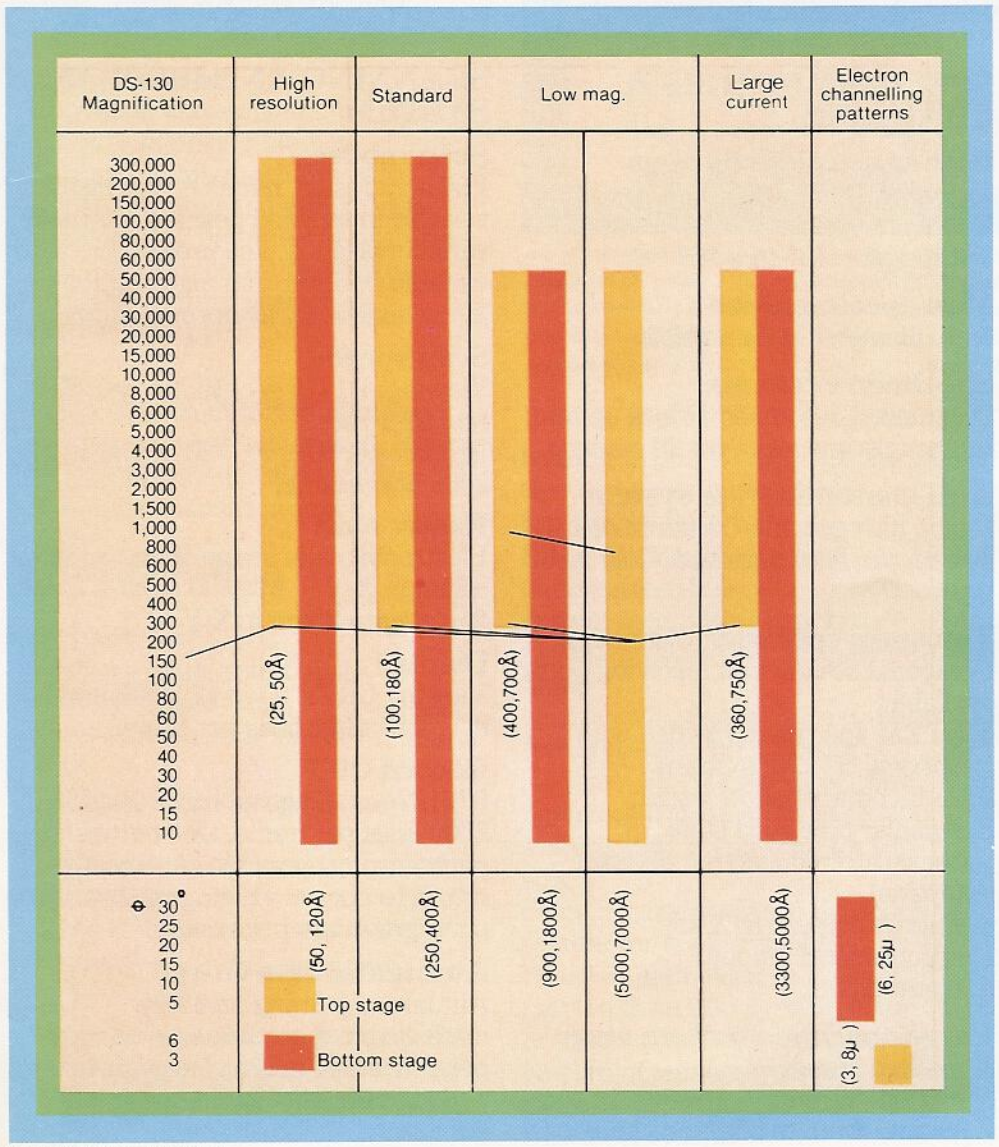
Additional information on the electron optics system is given on pages 6 and 7

Lens configuration for top and bottom stages



	Function	Gun/ Gun Align	1st condenser lens	2nd condenser lens	1st scanning coil	2nd scanning coil	Objective lens	3rd scanning coil	Mini objective lens	
Top stage	High res.	O	O	O	O	O	O	X	X	
	Standard	O	O	O	O	O	O	X	X	
	Low mag.	O	O	O	O	O	O	X	X	
	*	O	O	O	X	O	X	X	X	
	LCT	O	O	O	O	O	O	X	X	
	ECP	O	O	O	O	X	O	X	X	
	Free	O	variable	variable	O	O	O	X	X	
	*below 300X									
	Gun									
O = operative X = not operative										
Bottom stage	High res.	O	O	O	X	O	X	O	O	
	Standard	O	O	O	X	O	X	O	O	
	Low mag.	O	O	O	X	O	X	X	X	
	LCT	O	O	O	X	O	X	O	O	
	ECP	O	O	O	X	O	X	X	O	
	Free	O	variable	variable	X	O	X	O	O	

Lens system operating modes



Operating mode functions

ISI service

ISI scanning electron microscopes are renowned for their reliability across the world. The DS-130 is no exception. A bank of fuses, a fault-finding module and plug-in interchangeable printed circuit boards are accessible to make service a straightforward job.

Fully trained service engineers are strategically located in practically every part of the world to give back-up service that is second to none.

Performance Specification

RESOLUTION

30 Å guaranteed with top stage (condenser/objective lens). 60 Å guaranteed with bottom stage (mini objective lens), 50 Å attainable.

STEM resolution

Better than 30 Å guaranteed (option).

ECP resolution

Electron channelling patterns from a 3μm spot at ±5° minimum rocking angle to ±30° maximum rocking angle. Rocking angle digitally displayed via LEDs (option).

ELECTRON OPTICS

Accelerating voltage

1 kV to 40 kV in 1 kV steps — digital display via LEDs.

Electron gun

Self biasing triode electron gun with manual bias override control. Cartridge type gun assembly with variable filament-to-wehnelt cap spacing.

HV wobbler

Automatic high voltage wobbler as alignment aid.

Alignment

Electromagnetic beam shift and tilt via balanced double deflection alignment coils. No external mechanical alignment is necessary.

Condenser lens aperture

Externally selectable and alignable during operation; 4 positions — 50μm, 80μm, 160μm and 320μm.

Top stage condenser lens

Strongly excited condenser/objective lens of 'S-zone' type design with spherical and chromatic aberration coefficients of 16 and 4 times respectively better than conventional objective lenses. Better than 5 ppm stability.

Bottom stage objective lens

Mini design objective lens with stability better than 10 ppm. Pre-aligned final aperture allowing beam current selection from 10^{-12} amperes to 10^{-5} amperes without changing final aperture.

Magnification range

Using either objective lens, 10x to 300,000x with magnification fully compensated for any change in accelerating voltage, working distance, or tilt angles. Digital display via LEDs.

Dynamic focusing

Allows edge-to-edge micrograph sharpness at any specimen tilt angle.

Microprocessor control

Precise setting of all electron optical parameters accomplished by microprocessor control to guarantee optimum performance at all times. Includes microprocessor controlled buzzing system to advise operator if improper beam conditions exist for a selected magnification.

SPECIMEN STAGES & CHAMBERS

High-resolution top stage

X motion: 6mm
Y motion: 6mm
Tilt range: —10° to +90°

Max. specimen size

8mm diameter by 5mm high.

Specimen exchange

Prepumped automatic airlock system. Exchange time less than 30 seconds.

Anti-contamination system

Liquid nitrogen anti-contamination system provided standard. Cold plate type.

Top stage specimen chamber

Octagonal design with following ports available:

1. STEM aperture (provided with optional STEM system)
2. Anti-contamination system
3. Annular type solid state backscattered electron detector (option).
4. Energy dispersive X-ray spectrometer (option)
5. Unused port.

Large-specimen bottom stage

X motion: 56mm
Y motion: 56mm
Z motion: 8mm to 53mm continuous
Tilt range: —10° to +80°
Rotation: 360° continuous
Electrical connections: 25 pin electrical feed-thru and BNC connector for specimen current analysis. Exchange time less than 2 minutes.

Max. specimen size

6" (152mm) x 4" (102mm) x 3" (76mm) thick. Full coverage of a 4" (102mm) diameter sample.

Specimen exchange time

Less than 2 minutes.

Bottom stage specimen chamber

Chamber size 7.5" x 7" x 7" (191 x 178 x 178mm).
Equipped with five spare ports for accessories or special applications.

SCANNING AND DISPLAY SYSTEM

Scan modes

Full area raster, reduced area raster variable in size and position, spot with variable position, line profile, line with variable position, and mapping for X-ray analysis, waveform monitor.

Scan speeds

Viewing: R1-0.5 sec: R2-0.1 sec: S1-5 sec: S2-10 sec:
Record: 40, 80, 160, 320 sec, all at 2000 lines/frame.

Raster shift

Electromagnetic image shift: top stage ±5μm in X-Y
2nd stage ±25μm in X-Y.

Display

Viewing CRTs: Two 12" (305mm) diagonal, 1000 lines per frame.

Record CRT

5" (127mm) diagonal high-resolution, 2000 lines per frame. One-button photography operation. Automatic return to normal viewing mode after photograph has been taken.

Automatic data entry

Automatic printing on every micrograph of accelerating voltage, magnification, micron bar with value, 4 digit automatically sequencing photo number.

Dual magnification display
Simultaneous display on two viewing CRTs or, in split screen mode at either x1, x2, x5 or x10 magnification ratio. View finder variable in X-Y position on low magnification side.

Second signal display
Independent second signal display for simultaneous image display on either separate viewing CRTs or split screen mode.

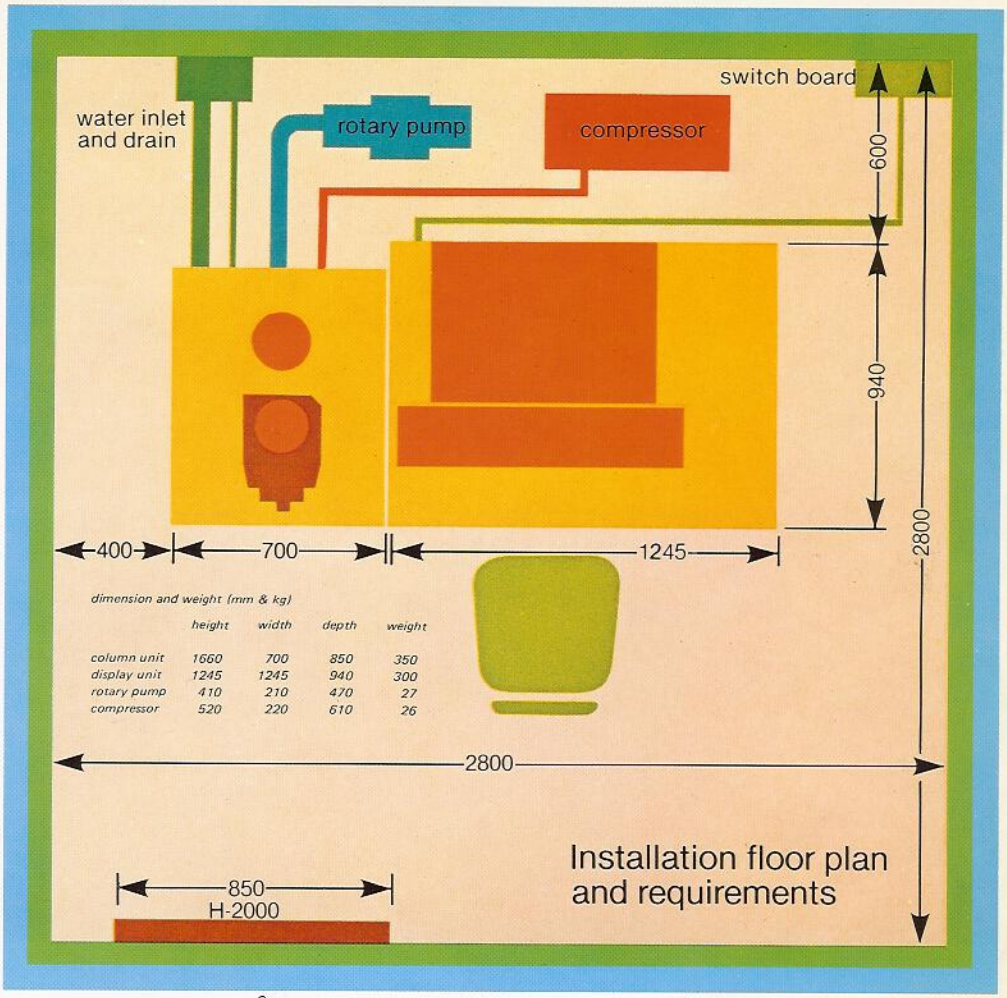
Signal processing
Four-level gamma control, derivative processing, Y-modulation, signal inversion, foreshortening (tilt) correction, 360° continuous scan rotation.

VACUUM SYSTEM

Operation
Fully automatic, push-button operated. Fail safe. Fully protected against power, water or vacuum failure.

Isolation valves
Gun/column valve maintains column high vacuum during filament change. Specimen chamber/column valve maintains column and gun at high vacuum during bottom-stage sample change. All valves are pneumatic — air driven. Column operating pressure, 10^{-6} torr.

Pumps
600 litre/sec. oil diffusion pump with liquid nitrogen baffle standard. Buffer tank for diffusion pump standard. 160 litre/min mechanical pump.



dimension and weight (mm & kg)

	height	width	depth	weight
column unit	1660	700	850	350
display unit	1245	1245	940	300
rotary pump	410	210	470	27
compressor	520	220	610	26

room: temperature: 5–40°C, humidity: less than 60%, floor load: 250kg/m²
power: single phase 200/210/220/240V 50/60Hz 5kVA
water: flow rate: 2 l/min. pressure: 1–5kg/cm², temperature: 5–20°C. faucet: 11mm
stray magnetic field: AC field: less than 3 mG, DC field: less than 10mG
pressure of compressor: 4–5kg/cm² floor vibration: 3 μm (5Hz)

Accessories

Accessory box
Accessory mode select unit
Beam blanking system
Carbon coating attachment for sputter coater
Charge-free anti-contamination system
50 litres/min mechanical pump for above system
Critical point drying apparatus
Electron beam induced current detection system
Externally selectable aperture system
Hot-cold stage
Independent cathodoluminescence detection system
Independent solid state backscattered electron detection system
Ion pump system
ISI-Robinson independent backscattered electron detection system (and power supply)
Liquid nitrogen cold trap for diffusion pump
Micrograph identification system with full alpha-numeric printout (16 lines, 32 characters per line)
Scanning transmission detection system (high resolution) for top stage
Scanning transmission detection system for bottom stage
Selected area electron channelling pattern detection system — top stage
Selected area electron chanelling pattern detection system — bottom stage
SEMcool system
SIMS capability
Spare parts kit
Specimen current amplifier system
Specimen current meter
Specimen measuring system
Sputter-coater for specimen preparation. Gold target, including vacuum pump
Sputter cryostage
Tensile stage capability
Water recirculator
X-ray spectrometer, energy dispersive
X-ray spectrometer, wavelength dispersive
X-ray microradiography stage
Y-modulation imaging
Z-prime (Z') eucentric tilting sub-stage
35mm camera with special hood
6 x 7mm camera with special hood

(NOTE. All specifications are subject to revision at any time.)

Performance Specification

RESOLUTION

30 Å guaranteed with top stage (condenser/objective lens). 60 Å guaranteed with bottom stage (mini objective lens), 50 Å attainable.

STEM resolution
Better than 30 Å guaranteed (option).

ECP resolution
Electron channelling patterns from a 3µm spot at ±5° minimum rocking angle to ±30° maximum rocking angle. Rocking angle digitally displayed via LEDs (option).

ELECTRON OPTICS

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- The world's first computer controlled SEM.
- The world's first light and transmission electron microscope.
- The world's lowest cost electron microscope.
- The world's widest choice of SEMs.

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