PURDUE UNIVERSITY
Discovery Park

Thermo Scientific Apreo SEM
pre-training

Purdue Electron Microscopy Facility
Birck Nanotechnology Center

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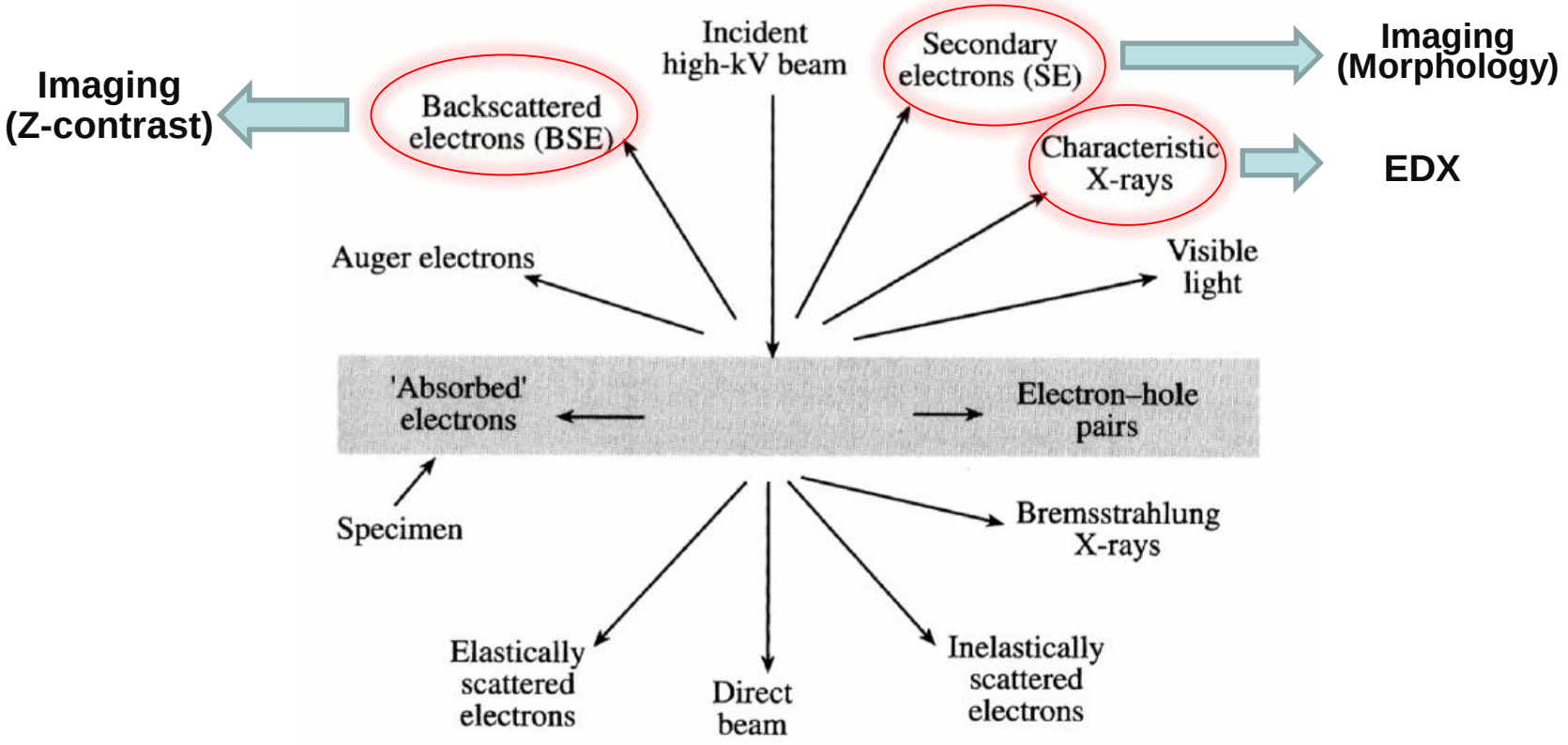
Basic Electron-material interaction

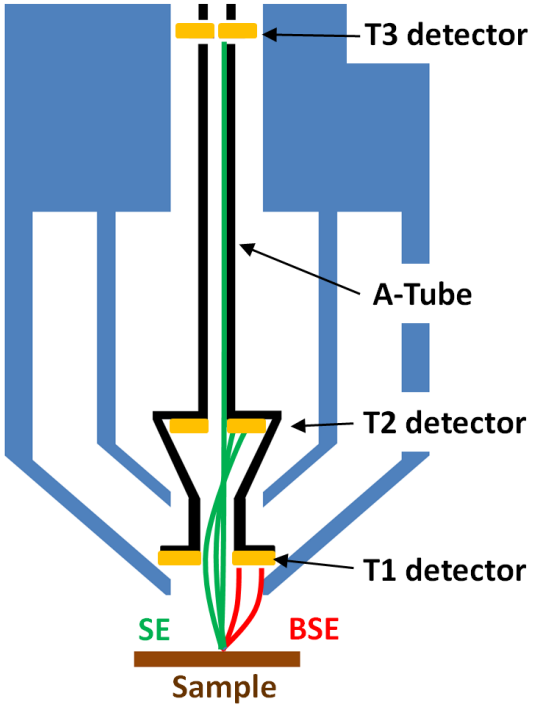


Signals generated by electron-material interaction

David, B., WILLIAMS, C., & Barry, C. (2016). *Transmission electron microscopy: a textbook for materials science*. SPRINGER-VERLAG NEW YORK.

Standard Mode

This is the survey mode ideal for navigating and reviewing sites at lower magnifications. The A-Tube is on the ground potential, and the default detector is the ETD in the Secondary Electron mode. Maximum probe current is limited to 13 nA.

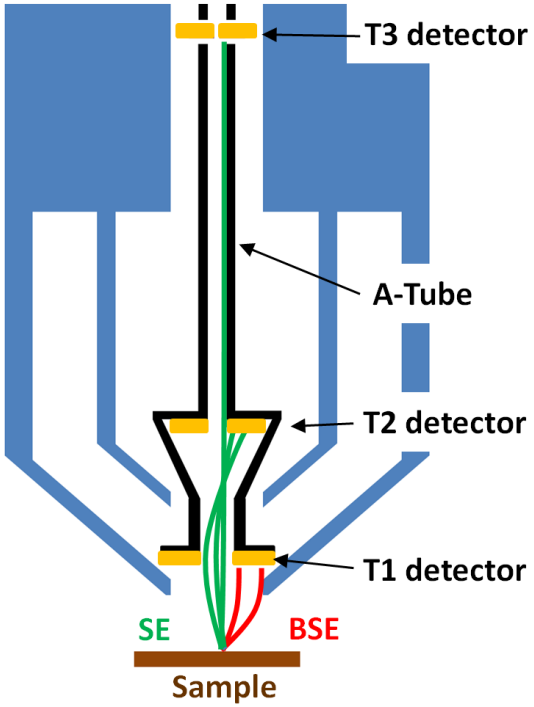


Schematic of Trinity Detector

Images are cited from the Thermo Scientific Operation Manual

OptiPlan Mode

1. Here primary electrons are accelerated by the potential of the Acceleration tube (A-Tube) and pass through the column at high energy. They are decelerated back in between the T1 detector and the sample. Secondary as well as backscattered electrons are also collimated into the final lens by the A-Tube electrostatic field and detected by the Trinity detectors (T1, T2, T3).
2. This mode is used for ultrahigh resolution electron imaging of the sample at short working distances (1 – 2 mm). The A-tube is at the highest potential and the T1 and T2 detectors should be used. The full range of the Beam Deceleration mode (if installed) is available for this Use case.
3. In this mode, the maximal working distance depends on the landing energy (Beam Deceleration mode). It ranges linearly from 5 mm (at 200 eV) to 70 mm (> 10 keV). It is possible to use overview imaging at the maximal field of view, so there is no need to switch the Use Case for navigation purposes.

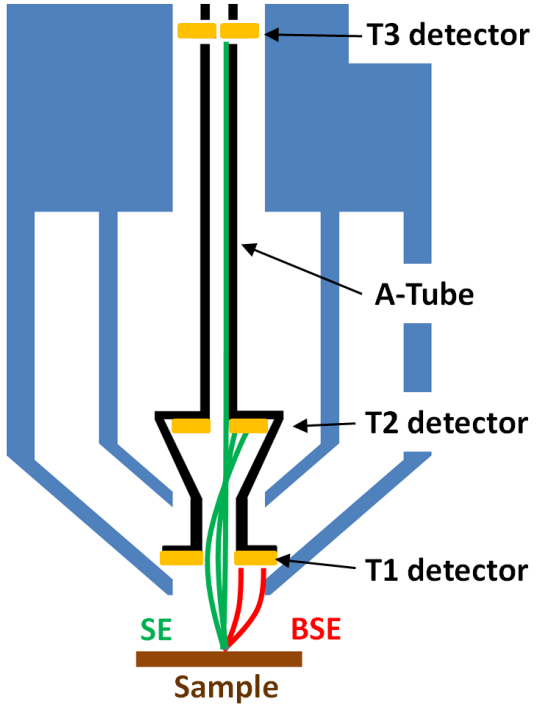


Schematic of Trinity Detector

Images are cited from the Thermo Scientific Operation Manual

Immersion Mode

1. This Use case is available only with the Immersion lens (option). The primary electrons are accelerated by the potential of the A-Tube (Acceleration tube) and pass through the column at high energy. They are decelerated back in between the T1 detector and the sample. Moreover, immersion magnetic field is applied in between the pole piece and the sample to form the smallest possible beam diameter. The secondary as well as backscattered electrons are collimated into the final lens and detected by the Trinity detectors (T1, T2,T3). Described combination of the electro-static and magnetic lenses is called Compound lens.
2. The Immersion Use case should be used to reach the ultimate performance – the best resolution. The optimal working distance for ultra-high resolution imaging is suggested to the user by the Working distance indicator, typically the lower the landing energy the shorter the optimal working distance. The maximal working distance depends on the landing energy. It ranges linearly from 5 mm (at 200 eV) to 70 mm (> 10 keV). The maximal field of view is working distance dependent and it ranges from one hundred micrometers to three millimeters.



Schematic of Trinity Detector

Images are cited from the Thermo Scientific Operation Manual

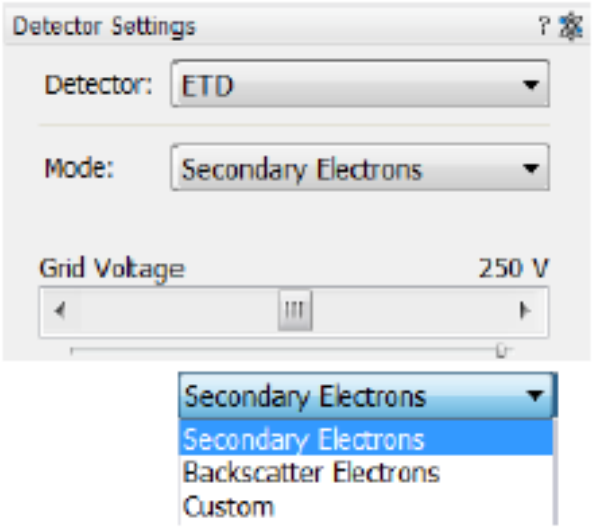
Spot Size and imaging modes

Spot size recommendation for their use

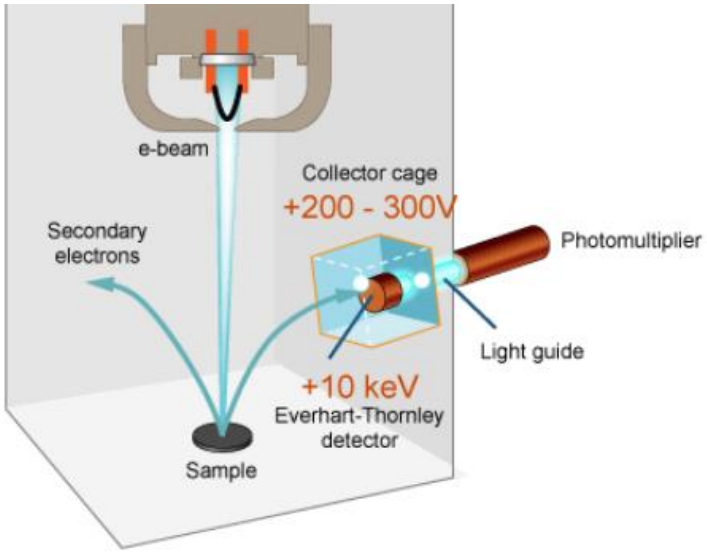
SEM column Use case	Spot size	Best use
Standard / OptiPlan / Immersion	*1 - 4*	Very low currents, charging and sensitive samples
Immersion	*3 - 7*	Ultra high resolution
Standard / OptiPlan	*4 - 6*	High resolution
Standard / OptiPlan / Immersion	*6 - 12*	Standard imaging
Standard / OptiPlan / Immersion	*12 and more*	High current imaging, X-ray analysis with SDD detectors
Standard / OptiPlan	*10 - 17*	High current imaging, X-ray analysis, EBSD detector, cathodo-luminiscence
Standard / OptiPlan	*18 - 20*	Very high currents, fast analysis

Images are cited from the Thermo Scientific Operation Manual

Everhart Thornley Detector(ETD)-SE/BSE/Custom

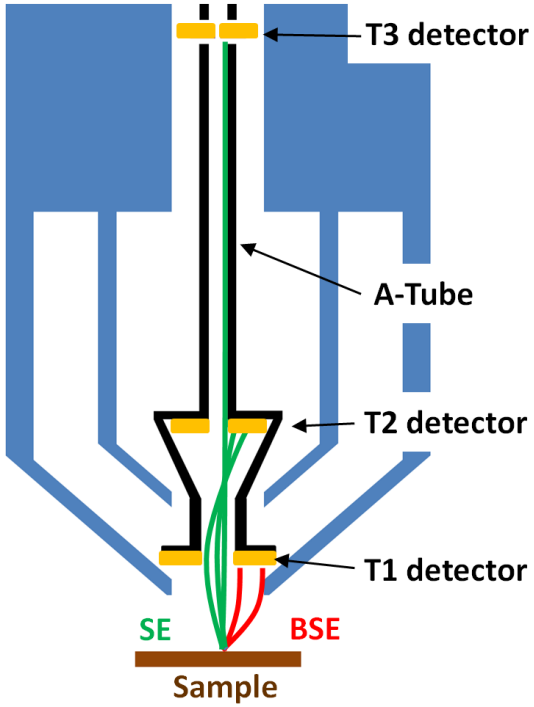


Detector setting of ETD
(SE:250V BSE:-150V)
(from Thermo Scientific Manual)

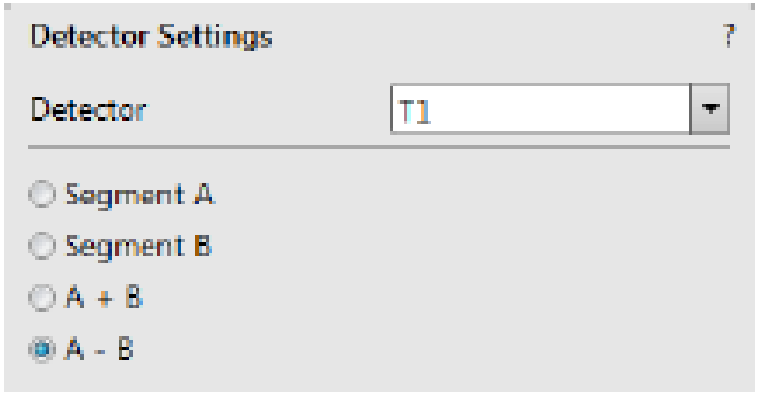


Schematic of ETD
(from google image)

Trinity Detectors T1/T2



Schematic of Trinity Detector



Schematic of T1 setting

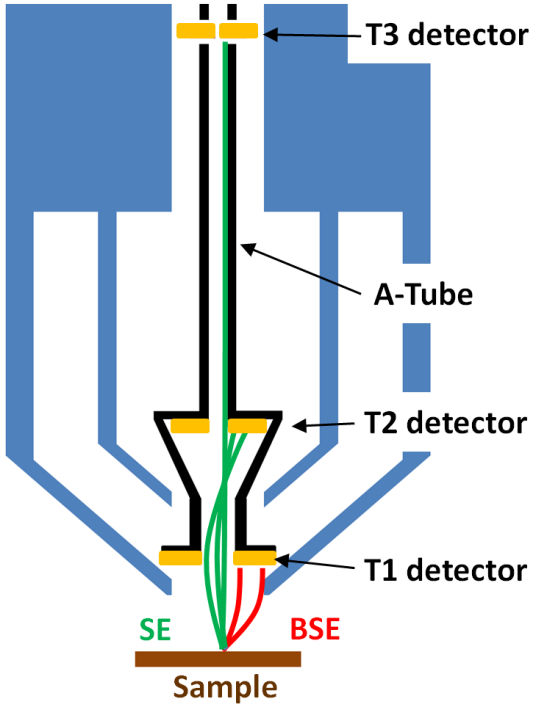
T1-BSE detector(OptiPlan and Immersion mode)

A+B: Composite mode

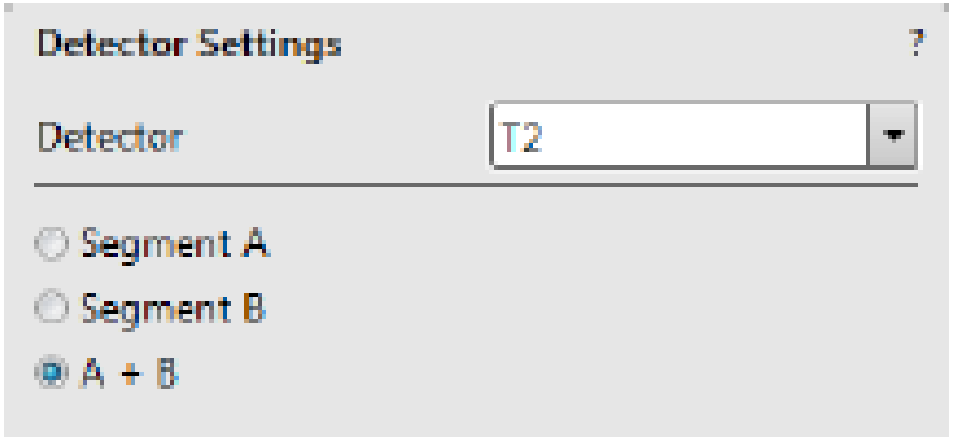
A-B: Pseudo-topographical imaging with suppressed Z-contrast and maximized topographical contrast

Images are cited from the Thermo Scientific Operation Manual

Trinity Detectors T1/T2



Schematic of Trinity Detector



Schematic of T1 setting

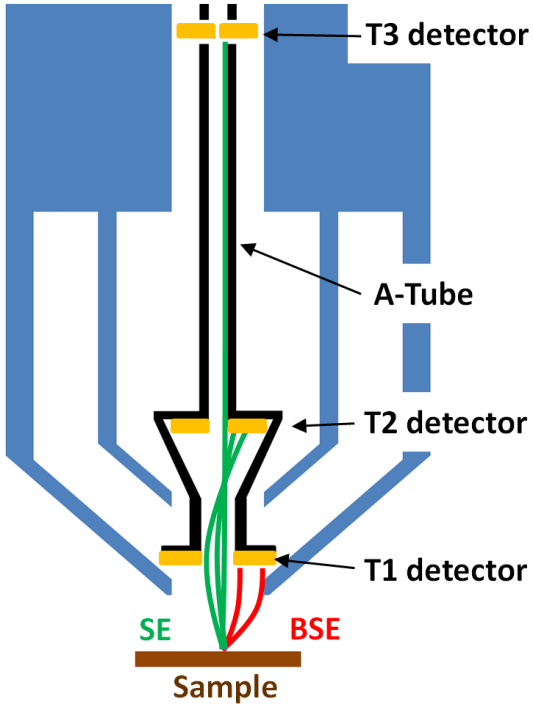
T2-SE detector(OptiPlan and Immersion mode)

A+B: Composite mode

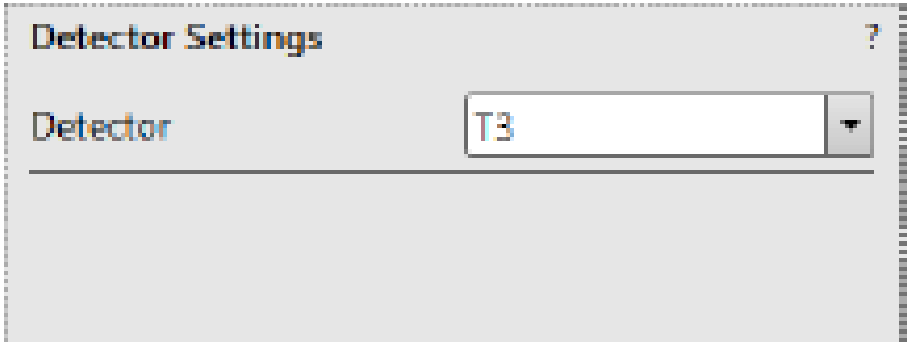
Note: The intensity of the signal– the higher the beam current and the shorter the WD, the higher the T2 signal

Images are cited from the Thermo Scientific Operation Manual

Trinity Detectors T1/T2



Schematic of Trinity Detector



Schematic of T3 setting

T3-SE/BSE detector(OptiPlan and Immersion mode)

Note:

High KV + no stage bias: BSE image

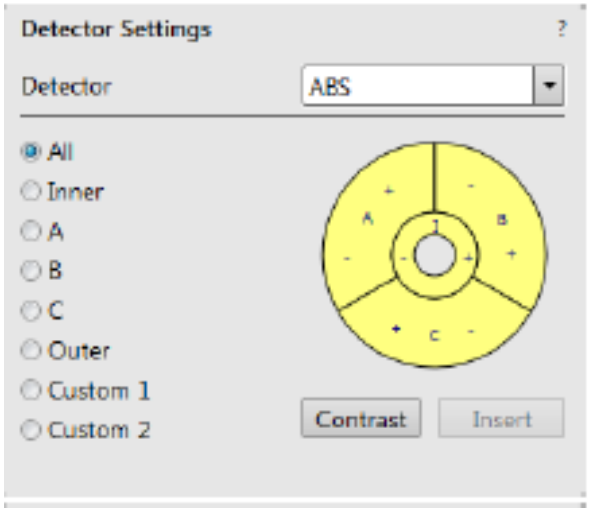
High kV+ stage bias: SE+BSE image (clear surface sensitivity)

Images are cited from the Thermo Scientific Operation Manual

Directional Backscattered Detector(DBS)-ABS/CBS

Angular Backscattered Detector(ABS)

DBS detector



Schematic of ABS settings

ABS helps distinguish topographic contrast from different signal directions

Note:

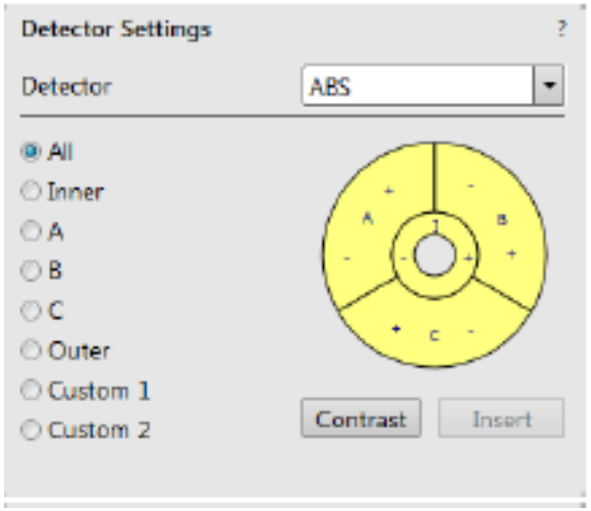
1. ***All*** **is the normal BSE image, with suppressed topographical contrast and maximum Z contrast**
2. ***Inner / Outer*** **uses shadows to create strong topographical and atomic number contrast**
3. ***A / B / C*** **is the pseudo-topographical image with suppressed atomic number contrast and maximum topographical contrast**

Images are cited from the Thermo Scientific Operation Manual

Directional Backscattered Detector(DBS)-ABS/CBS

Concentric Backscattered Detector(CBS)

DBS detector



Schematic of ABS settings

ABS helps distinguish BSE scattered close to or far from the beam axis

Note:

1. **The *Contrast* button equalizes signals (contrast) from different segments so they do not to override one another and have the same contrast in different displays in which the ABS / CBS detector is used.**
2. **The distribution of electrons collected by the detector segments changes with the setting of the working distance, the lens mode and the Beam Deceleration mode**

Images are cited from the Thermo Scientific Operation Manual