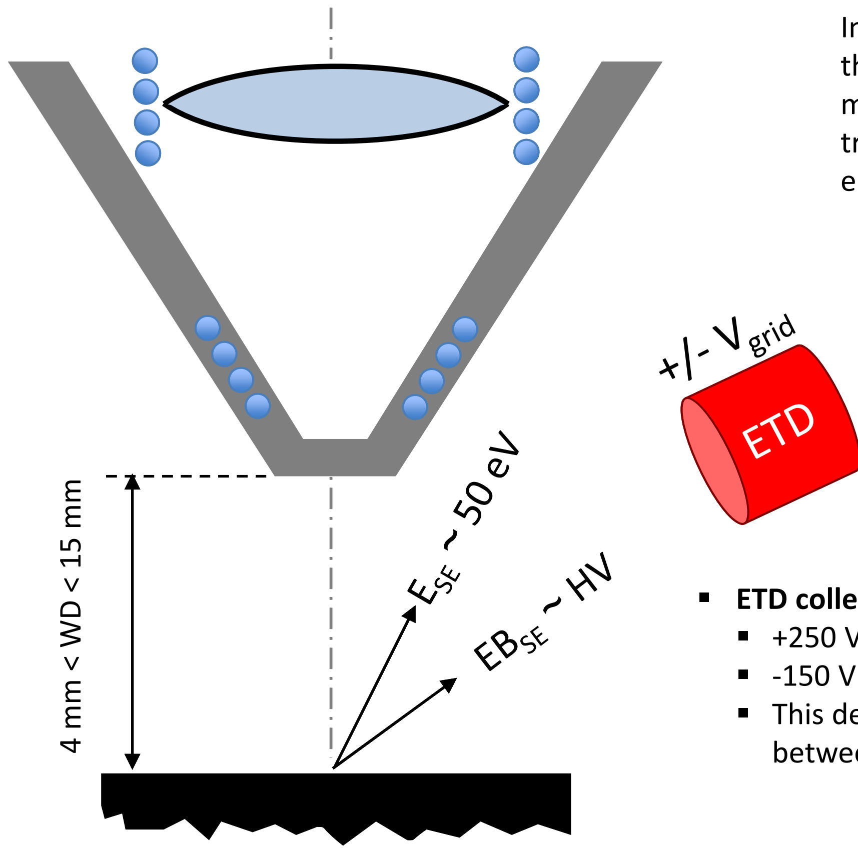
MODE 1 OPERATION

- **In mode 1 imaging, the objective lens is configured as a traditional pin hole lens**
- **Use mode 1 for low magnification and sample navigation**
- **Also use for initial focusing and linking**
- **The ETD (Everhart-Thornley detector) is the default detector**
- **All detectors can be used in this mode**
  - The TLD will give very little signal at low voltage and/or current!
  - The ICD will give very little signal without sample bias!
  - The CBS and MD require electron energy and/or current and/or sample bias!



In mode 1, the upper coils inside the pole piece are active, which makes the lens behave as a traditional pin hole electromagnetic lens

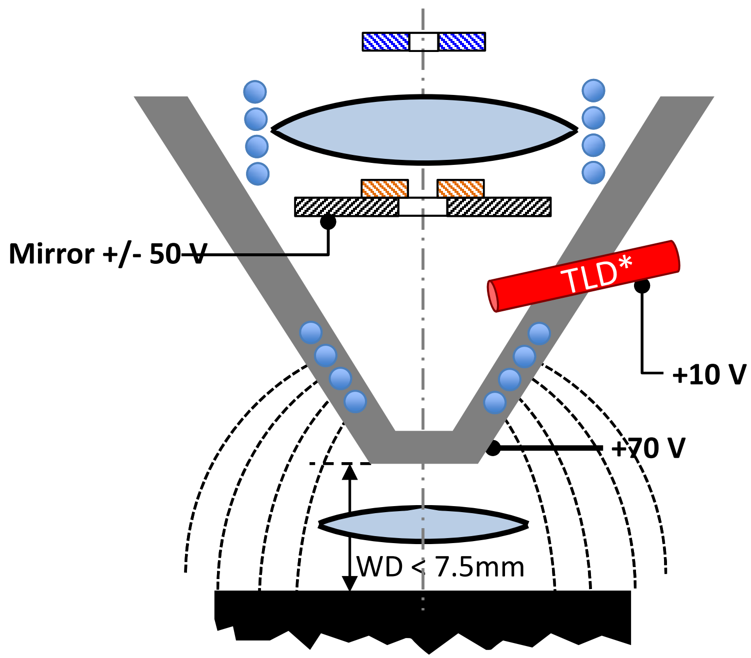
- **ETD collector grid has an adjustable bias**
  - +250 V is standard in SE mode (SE and BSE signal)
  - -150 V is standard in BSE mode (BSE only signal)
  - This detector can be adjusted to any custom value between -240 V and +250 V

MODE 2 OPERATION

- **Use mode 2 for high magnification,**
- **The default detector in mode 2 is the TLD (through-the-lens detector)**
- **The TLD is similar in design to an ETD but is located inside the column, i.e., it is a low energy electron detector suitable for collecting SEs with no stage bias**
- **All detectors but the ETD can be used in Mode 2**
  - Electrons from the sample can't penetrate the immersion lens field and thus can't get to the ETD
- **Both the upper and lower lens coils are active, resulting in an immersion lens**
  - In this mode, the sample is immersed in the B-field of the lens
- **Note, you CANNOT use magnetic samples in Mode 2**
- **Can adjust bias on TLD for different functions**
  - Reduce suction tube voltage can minimize positive charging, *i.e.*, pulling too many electrons from sample surface
  - Reduce suction tube voltage to -50 V to only detect SE3s (SEs produced by BSE from sample hitting pole piece

The electron mirror deflects SEs into the TLD at standard value of -15 V

Varying the electron mirror will change the number of SEs detected. Positive values mean no SE contribution.



The standard detector for Mode 2 is the TLD

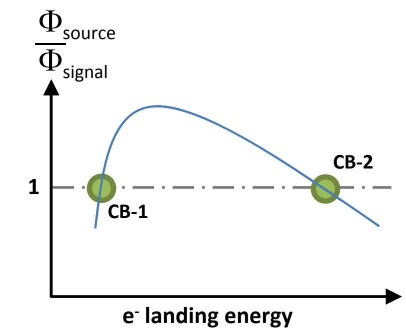
With the TLD in SE mode, the TLD carries a bias of +10 V and the pole piece carries a bias of +70 V

the +70 V is referred to as the suction tube voltage. It can be set from -245 V to +245 V to regulate the relative fractions of SE and BSE that reach the detector

- **Suction tube and mirror both have an adjustable bias, analogous to the grid bias on the ETD**
  - -15 V is standard for the mirror in SE mode, 0V in BSE mode
  - +70 V is standard for the suction tube in SE mode, -245V in BSE mode

STAGE BIAS

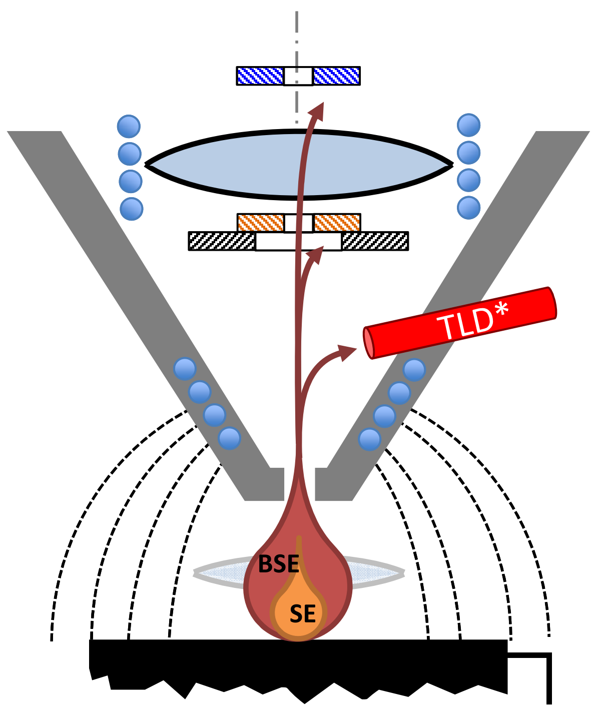
- **Stage bias can be used in mode1 or mode2**
- **Stage bias can be adjusted between (negative) 50 V and 4000 V**
  - Stage bias is always negative to decelerate beam electrons
  - Electron landing energies can be as low as 20 eV when using stage bias
  - Must use stage bias below 350V
  - Improve resolution at low e- landing energy
  - Improved control of surface charging
- **Stage bias effects**
  - Can fine tune operation near charge balance points
  - SEs and BSEs have additional energy thus less affected by surface charging
  - High electron energy in column to allow for good focusing and to minimize chromatic abberations and low energy at the sample to reduce charging and interaction volume



Plot of total electron emission vs landing voltage. Two charge balance point exist. The charge balance points are typically <2kV. Using stage bias allows the charge balance point to be reached with a relatively high accelerating voltage.

With stage bias, we have an accelerating voltage equal to the landing voltage plus the stage bias, which allows favorable conditions in the column and low landing energy

We can utilize high energy electron detectors under conditions that would otherwise provide insufficient signal



Stage bias: up to -4000 V

Stage bias accelerates electrons emitted from the sample.

Stage bias forces low energy electrons closer to the optic axis and up the column.

Increasing stage bias will add topography to the MD and CBS.

Stage bias is required for the ICD resulting in all ICD images showing topographical features.

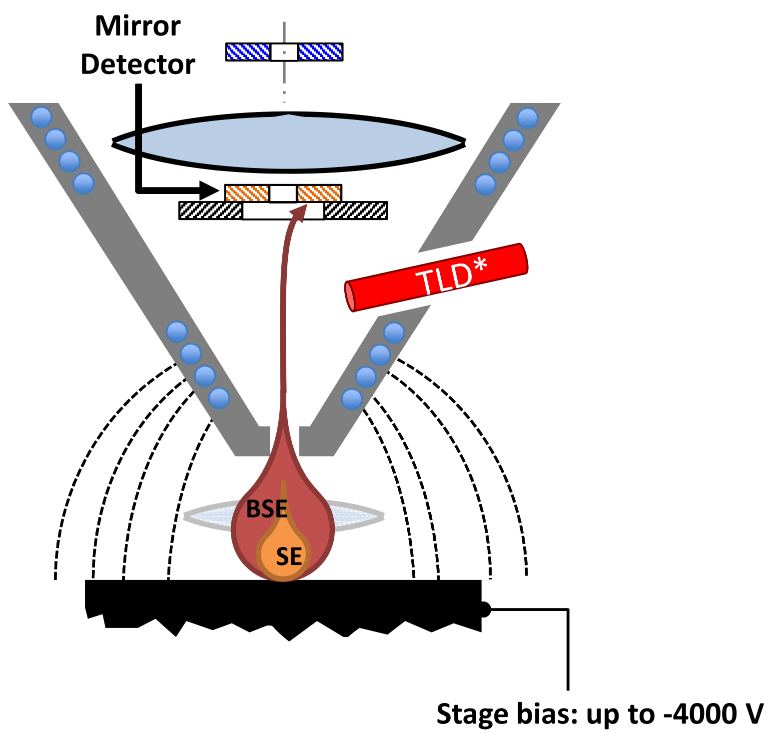
- **Notes on stage bias**
  - Tilted samples do not work well, nor does tilting the stage
  - Symmetric samples mounted in the center of the sample holder work best

MIRROR DETECTOR

- **The MD is designed to be an in-column BSED and is a high energy electron detector**
  - Can be used in mode1, but there is much more signal for a given beam voltage and current in mode2
  - Requires electron energy and current to produce sufficient signal
  - Higher landing energies or currents or stage bias or some combination thereof can be used to provide sufficient electron energy to make an image
  - In general, energy can either be a relatively high landing energy (>5kV) or adding sufficient stage bias (usually 2kV or more) or high current or some combination thereof
  - The cutoff energy is ~500V (at this energy significant current is required)
- **In the column detector just above the TLD electron mirror**
  - Annular geometry
  - Less topography sensitivity than the ETD/TLD or CBS but more than the ICD
  - Excellent on samples that surface charge
  - Signal contains a mixture of BSE and SE, depending on stage bias
  - Can operate simultaneously with CBS, ETD/TLD, and ICD
  - Can operate at very short working distance

MD with no stage bias will collect BSE

Adding stage bias will add SE signal to the image.

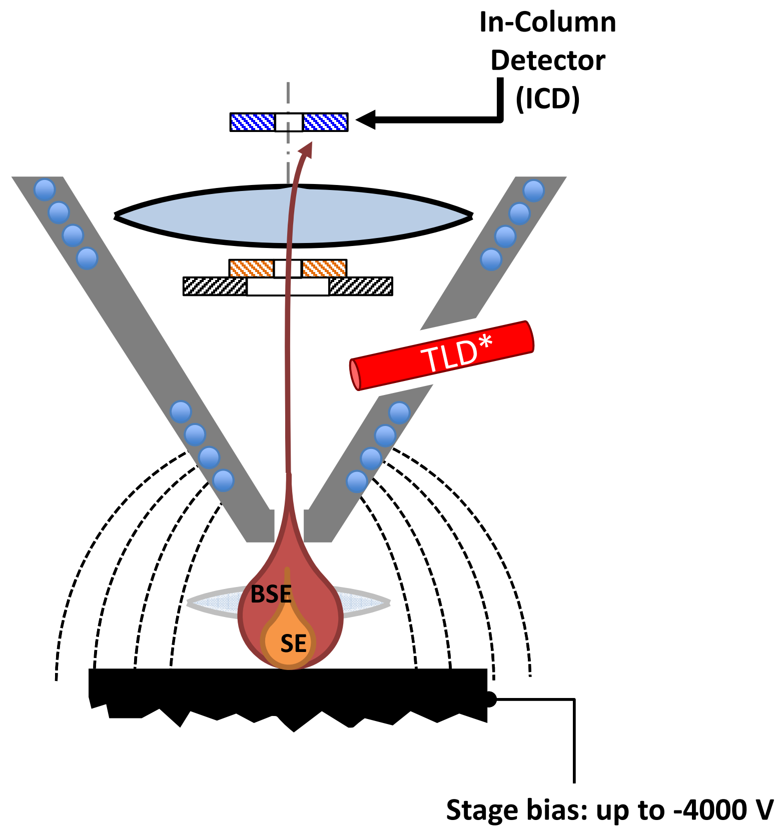


IN-COLUMN DETECTOR

- **The ICD is designed to be an in-column SED despite the fact that it is a high energy electron detector**
  - This means that the ICD requires a low landing energy and high sample bias to both generate large numbers of SEs and accelerate them toward the detector
  - The ICD will work best in mode2 where the immersion field will encourage electrons to spiral back up the column. In mode1, very few electrons from the sample get to the ICD, so signal in mode1 is very low.
  - The cutoff energy is ~500V, but significant current is required
  - The ICD works best with low landing energies (5keV or less) and high sample bias (2kV or more)
  - Under these conditions, SEs are accelerated to enough energy to be detected and they are also forced up the column to the ICD
  - The ICD will show mostly topography from (accelerated) SEs but the images will appear flat from the geometry
- **In the column detector approximately 20 cm above pole-piece**
  - Annular geometry
  - Can operate simultaneously with CBS, ETD/TLD, and MD
  - Can operate at very short working distance

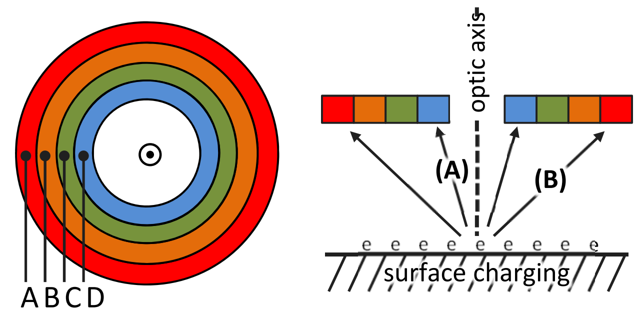
The geometry of the system means that ICD images will appear to be flat, i.e., it is difficult to tell what is in a pore and what is at the surface.

Images formed with the ICD will be mostly SE and will show much topography while simultaneously flattening out large topographical changes, e.g., structures inside a hole can appear to be almost at the surface.



CONCENTRIC BACKSCATTER DETECTOR

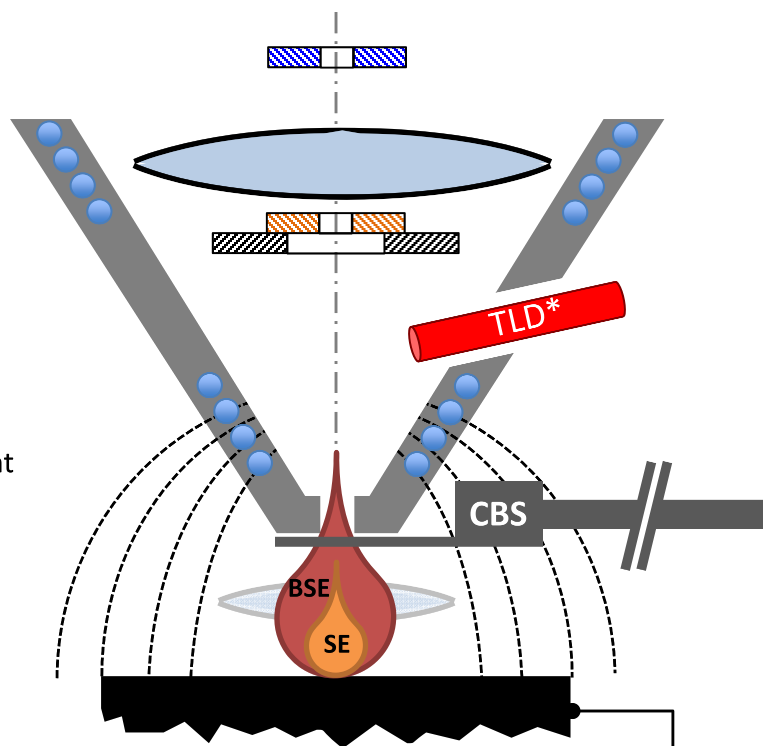
- **The CBS is designed to be an insertable BSED (high energy electron detector)**
  - Requires electron energy or current to produce sufficient signal
  - The cutoff energy is ~350V, but at this voltage significant current is required
  - Higher landing energies or currents or stage bias or some combination thereof can be used to provide sufficient electron energy
- **Retractable annular multi-ring backscatter detector**
  - Annular geometry
  - Excellent surface topography sensitivity
  - Signal is combination of SE and BSE
  - Operate simultaneously with ETD/TLD, ICD, and MD
  - Minimum working distance of 3 mm, no sample tilt!
  - Can customize combinations of rings



CBS geometry

Geometrically, the CBS has the potential to be the most topography-sensitive detector

CBS appears to be the most tolerant of surface charging



CBS with no stage bias will be a pure BSE signal.

With stage bias, the CBS will collect both SE and BSE signal.

Stage bias: up to -4000 V