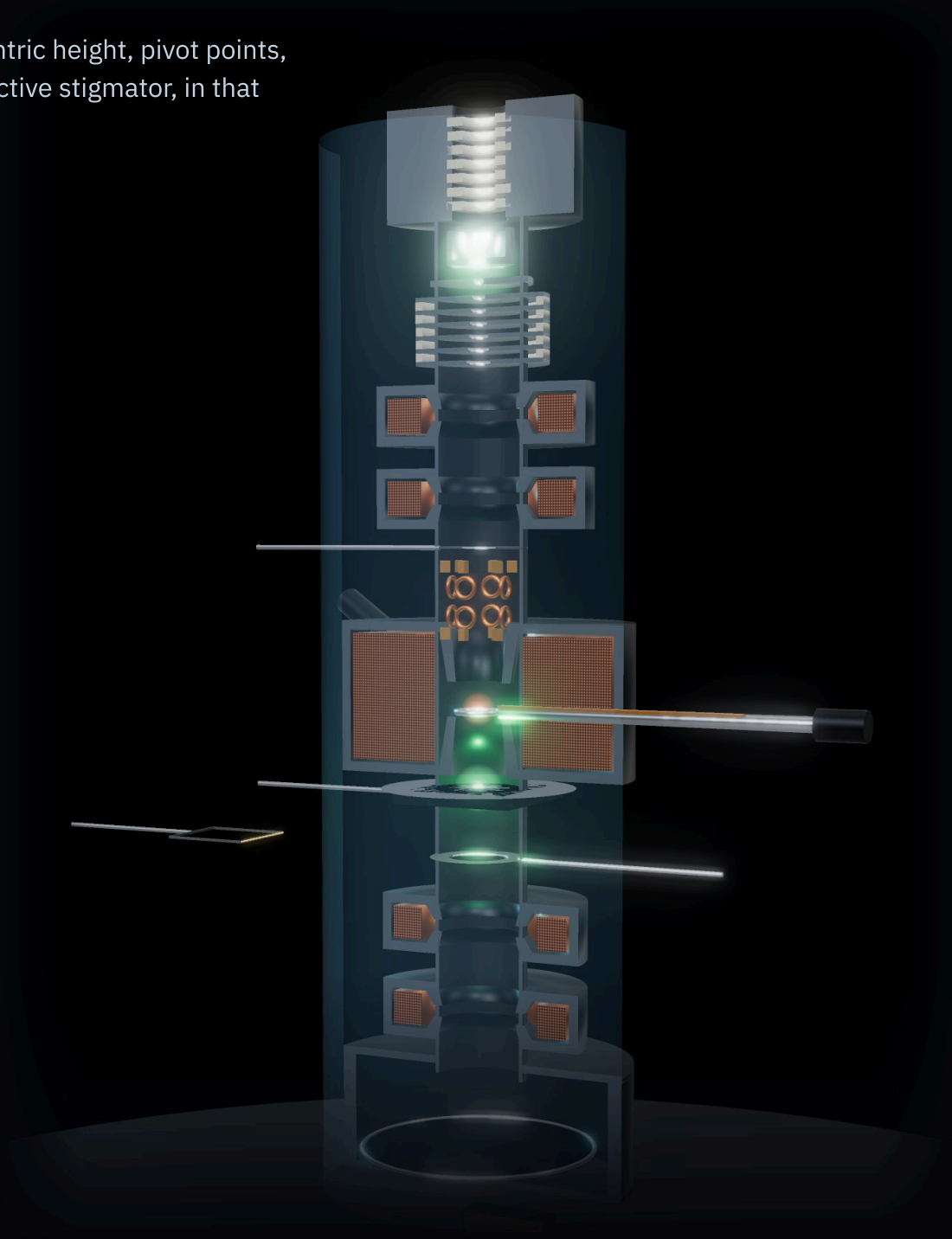
TEM direct *alignment*

Gun, illumination, eucentric height, pivot points, voltage center and objective stigmator, in that order.



SOP-01, version 1.1, October 2026
For new users and for refresher training
Figures computed with TEM-view

Seeing with Electrons
TEM-view · Advanced-EM

Scope and preparation

This procedure aligns a TEM column for imaging in parallel illumination. Do the steps in order. Each step assumes the previous ones are correct, so if a later step behaves unexpectedly, go back one step and check it.

	Step	Adjustments	Checked with
1	Gun	Flash & Go (cold FEG only), gun shift, gun tilt	Crossover position at two spot sizes; screen current
2	Illumination	Beam shift, C2 aperture, condenser stigmator	Beam spread through crossover
3	Eucentric height	Stage Z	α wobbler
4	Pivot points and voltage center	Pivot points X and Y, beam tilt	Pivot-point wobblers; HT wobbler
5	Objective stigmator	Objective stigmator X and Y	Live FFT of an amorphous area

Before you start

- Gun and column vacuum are within the normal operating range.
- The high tension has been at the operating voltage long enough to be stable.
- The specimen holder is inserted and the stage is at α = β = 0°.
- The objective and selected-area apertures are retracted.
- The microscope is in TEM mode at medium magnification, with the beam on the viewing screen or screen camera.
- You know the type of electron source (table at right).

Terms used

Brightness (also called intensity or C2) spreads or condenses the beam. **Crossover** is the brightness setting at which the beam is smallest. The **multifunction knobs** are the X and Y knobs that drive the alignment currently selected.

Electron source and Flash & Go

Source	Emission	Flash & Go
Cold FEG	Decreases slowly as gas adsorbs on the tip	Yes, when emission has dropped and at the start of a session
Schottky FEG	Stable	No
LaB_6 or W thermionic	Set by filament heating	No. Saturate the filament instead.

Caution. Flash & Go applies only to cold field-emission sources. Do not attempt it on a Schottky or thermionic gun.

Note. Knob names, menu names and wobbler names differ between manufacturers and software versions. Where this guide and your facility's procedure or the manufacturer's manual disagree, follow the facility and the manufacturer.

Step 1

Gun alignment

Gun shift and gun tilt place the source on the axis of the condenser system. If they are off, the beam moves when the spot size is changed, and the available current is lower.

1. **Cold FEG only.** If the emission current has dropped, or at the start of the session, run Flash & Go and wait for the emission to stabilize. Skip this on other sources.
2. Condense the beam to crossover with the brightness knob.
3. Select a high spot number (small spot) and center the beam with **beam shift**.
4. Select a low spot number (large spot). If the beam has moved, center it with **gun shift**.
5. Repeat steps 3 and 4 until the beam stays in place at both spot sizes.
6. Select **gun tilt** and adjust for maximum screen current.

Result. The crossover stays centered at all spot sizes and the screen current is at its maximum.

Note. Beam shift acts below the condenser lenses and gun shift acts at the source. How far a source offset moves the spot depends on the spot size, so correcting at each end of the spot range and repeating converges on both. If your alignment software asks for a different spot size or knob at each stage, follow the software.

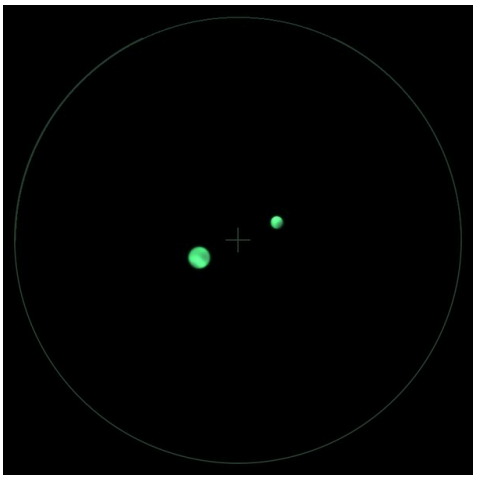


Fig. 1a. Gun shift misaligned. Crossovers at two spot sizes, superimposed, land in different places.

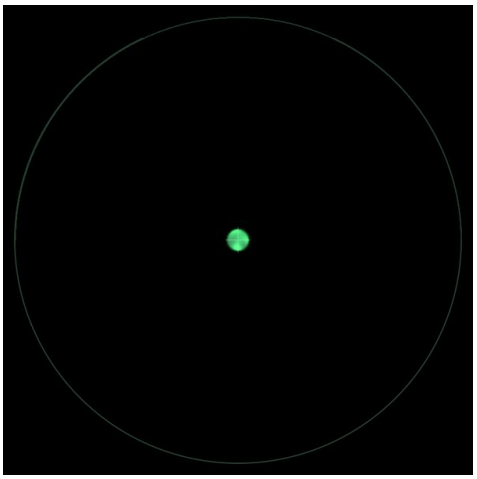


Fig. 1b. Gun shift aligned. Both spot sizes land at the same place.

Step 2

Illumination: C2 aperture and condenser stigmator

With the C2 aperture centered, the beam spreads and condenses about a fixed point, so a change in brightness does not move the illuminated area. With the condenser stigmator corrected, the beam stays round on both sides of crossover.

C2 aperture

1. At crossover, center the beam with beam shift.
2. Spread the beam with the brightness knob until it fills about half the screen.
3. If the beam does not spread evenly about the center, move the C2 aperture toward the center.
4. Return to crossover, re-center with beam shift, and spread again. Repeat until the beam spreads concentrically.

Condenser stigmator

1. Spread the beam slightly to one side of crossover. With condenser astigmatism, the beam is elliptical.
2. Go to the other side of crossover. The long axis of the ellipse turns by 90°.
3. Select the condenser stigmator and adjust X and Y until the beam is round on both sides of crossover.

Result. The beam spreads concentrically about the screen center and is round on both sides of crossover.

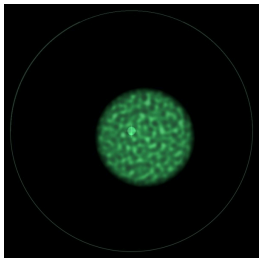


Fig. 2a. C2 aperture off-axis. The spread beam is not centered on the crossover.

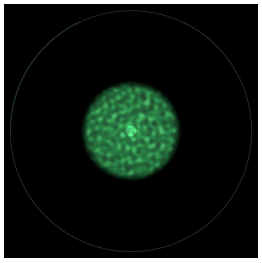


Fig. 2b. C2 aperture centered.

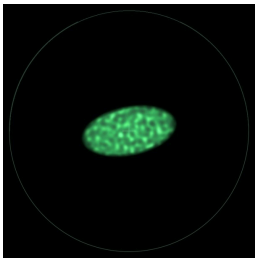


Fig. 2c. Condenser astigmatism, one side of crossover.

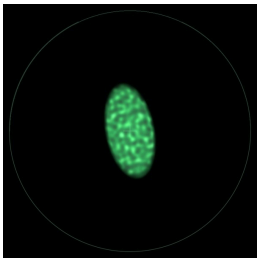


Fig. 2d. The other side. The ellipse has turned by 90°.

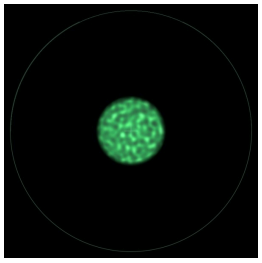


Fig. 2e. Condenser stigmator corrected.

Note. Center the crossover with beam shift before judging the C2 aperture. If both are adjusted with the beam spread, the two corrections interfere and do not converge.

Note. Judge condenser astigmatism on both sides of crossover. A slightly elliptical beam on one side only can come from the aperture edge; the 90° change in orientation is the reliable sign of astigmatism.

Step 3

Eucentric height

At the eucentric height, the area being viewed does not move sideways when the stage is tilted. It is also the specimen height for which the objective lens is set up, and the later alignments are made at this height.

1. Center a recognizable feature, such as an edge or a particle, at medium magnification.
2. Turn on the α wobbler. The stage tilts back and forth, typically by ±5° to ±15°.
3. If the image moves sideways, adjust stage Z until the movement stops. Use coarse steps for large movements and fine steps near the end.
4. When the feature only changes slightly in focus without moving, turn the wobbler off.
5. If your facility works at a standard objective focus, set it now and focus the image with Z.

Result. With the α wobbler on, the image does not move sideways.

Note. Check the eucentric height again after moving to a different area of a specimen that is not flat, and after reinserting the holder.

If the image keeps moving. Confirm that the wobbler tilts α and not β, and that the movement is not drift: turn the wobbler off and watch for a few seconds. If stage Z reaches its limit, the specimen may be mounted too high or too low in the holder.

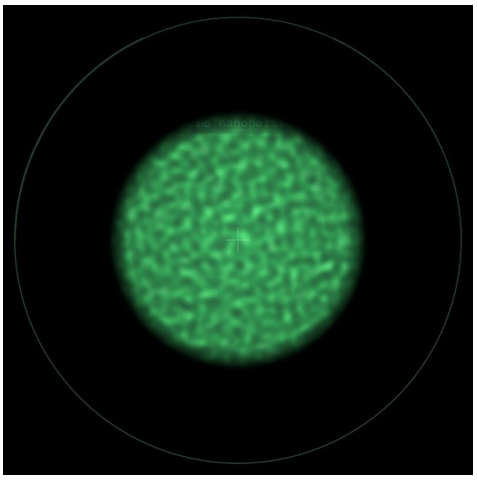


Fig. 3a. Specimen not at eucentric height. Two frames at opposite tilts, averaged; the image is blurred by the sideways movement.

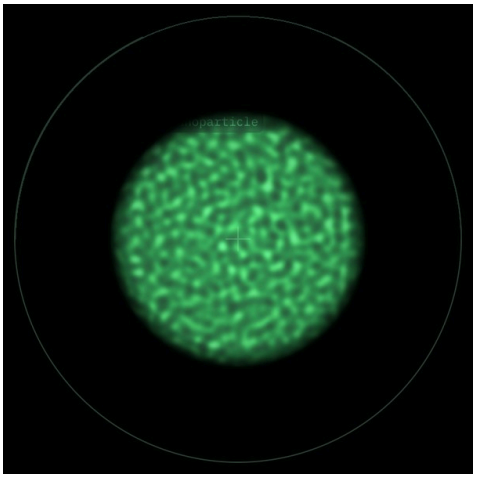


Fig. 3b. At eucentric height. The two frames overlap.

Step 4

Pivot points and voltage center

The pivot points separate beam tilt from beam shift, so that tilting the beam does not move it across the area of interest. The voltage center (or current center) then places the beam on the axis of the objective lens.

Pivot points

1. Condense the beam to a small spot near crossover and select beam tilt pivot point X. The wobbler tilts the beam back and forth in X.
2. If two spots are visible, bring them together with the multifunction knobs.
3. Repeat for pivot point Y.
4. If your instrument has beam shift pivot points, align them in the same way.

Voltage center

1. Spread the beam and center a feature on the screen.
2. Turn on the HT wobbler (voltage center) or the objective current wobbler (current center), depending on your instrument.
3. The image expands and contracts. If it also moves to one side, adjust beam tilt with the multifunction knobs until it expands and contracts about the screen center.

Result. Each pivot-point wobbler shows a single stationary spot, and with the HT wobbler on, the image expands and contracts about the center without moving sideways.

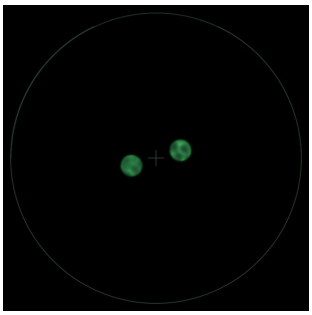


Fig. 4a. Pivot point misaligned: two spots.

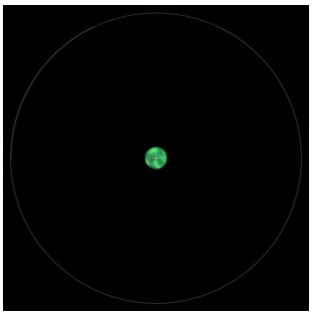


Fig. 4b. Pivot point aligned: one spot.

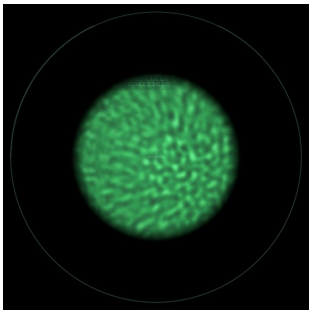


Fig. 4c. Voltage center off. Two frames of the HT wobble, averaged; the image is blurred by the sideways movement.

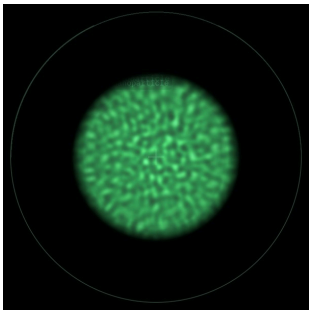


Fig. 4d. Voltage center aligned.

Note. The voltage center is a starting point. For high-resolution imaging, follow it with a coma-free alignment, using beam-tilt-induced image shift or a Zemlin tableau, according to your facility's procedure.

Step 5

Objective stigmator

Objective astigmatism focuses one direction more strongly than the perpendicular one. In the live FFT of an amorphous area it makes the Thon rings elliptical, or hyperbolic close to focus.

1. Move to a thin amorphous area, such as the support film or the edge of the specimen, at high magnification.
2. Turn on the live FFT and go to a moderate underfocus, so that several rings are visible.
3. Select the objective stigmator and adjust X and Y until the rings are circular.
4. Check through focus. The rings should change size evenly in all directions.
5. Return to the working area and focus.

Result. The Thon rings are circular at all defocus values.

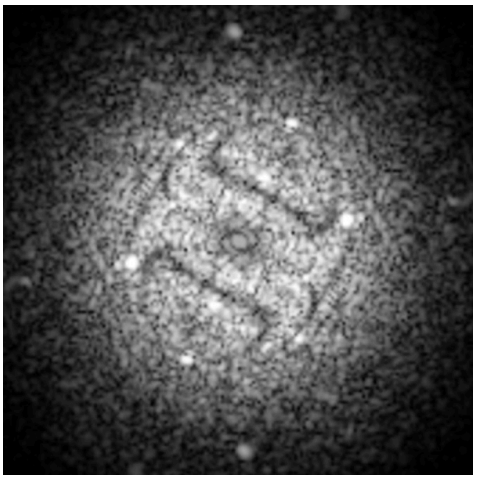


Fig. 5a. Live FFT with objective astigmatism, 80 nm underfocus.

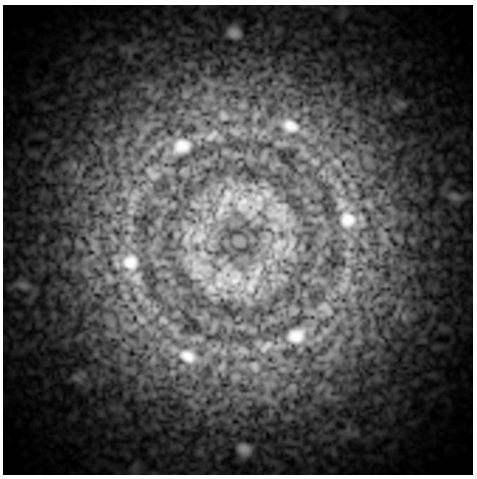


Fig. 5b. After correction with the objective stigmator.

Record

	Alignment	Criterion	Initials
☐	Flash & Go (cold FEG only)	Emission recovered and stable	
☐	Gun shift and gun tilt	Beam fixed at all spot sizes; maximum current	
☐	C2 aperture	Beam spreads concentrically	
☐	Condenser stigmator	Round on both sides of crossover	
☐	Eucentric height	No sideways movement with α wobbler	
☐	Pivot points X and Y	Single stationary spot	
☐	Voltage center	Image expands about the center	
☐	Objective stigmator	Circular Thon rings	

Practice on TEM-view

The figures in this procedure were computed with TEM-view, a physics-based TEM simulator that runs in a web browser. Its training task “TEM: direct alignments” sets a different random misalignment at each step and reports the result of every check at the end.

Open the training task

advanced-em.github.io/TEM-view/?train=tem-direct-align

Scan the code with a phone, or open TEM-view and select Training.

Simulated column

Select any part of the 3D column to see what it does and how it is measured.

Scored practice

Rate your own alignment, then compare it with the hidden misalignment.

Research data

With your consent, anonymous practice sessions are used to study how people align microscopes.

SOP-01 TEM direct alignment, version 1.1, October 2026
For training. Follow your facility's procedures and the manufacturer's documentation.
github.com/Advanced-EM/TEM-view

Seeing with Electrons

TEM-view · Advanced-EM