

MSE 460 TEM Lab 4: **Bright/Dark Field Imaging Operation**

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Aims: The aim of this lab is to familiarize you with bright/dark field imaging operation. You will know the principle and methods to form and record a bright/dark field image.

TEM: JEOL-2100F TEM

Time: 3 hours

You may need the notes from earlier labs. Please bring them with you.

You may spend the first hour to repeat what you learned in Lab 2. It includes:

- I. Getting familiar with TEM structure, functions and knobs
- II. TEM startup
- III. Obtain good illumination
- IV. Set the sample at eucentric height
- V. Condenser lens alignment
- VI. Beam tilt purity
- VII. Objective lens alignment (Voltage center)
- VIII. Image focus and astigmatism correction (Fresnel-fringe method)

*Note: It is **critical** that you check the **sample tilts are <<5-10 degrees** before beginning the BF/DF portions of this lab, as otherwise they may interfere with the objective aperture.*

IX. **Bright field imaging**

A bright field image is formed using the direct beam. An objective aperture is needed to select the direct beam and exclude the diffracted beams when an image is formed. It is situated in the back focal plane of the objective lens as shown in the figure below.

1. Find and center an interesting specimen area.
2. Make sure that the sample is at eucentric height and **BRIGHT** field mode is selected (Std Operation Window).
3. Focus (**BRIGHTNESS**) the beam to crossover and press **SA DIFF**.
4. Center the direct beam of the diffraction pattern if necessary (w/ **PLA**).
5. Insert **OBJECTIVE APERTURE** (which is situated at the back focal plane) into the beam by selecting **OL** and then choosing the aperture size. Note: **One of the 2 apertures should be centered**. If you can not see the aperture you want to use, do

not touch the aperture X and Y controls right away. You should load the second aperture and see if it is near the center. Then you may center this aperture and turn to first one and center it again. You repeat the procedure until you find the one you want to use.

6. Press **MAG1** to see a bright field image (Now the viewing screen is conjugated to the initial image plane indicated in the figure below).

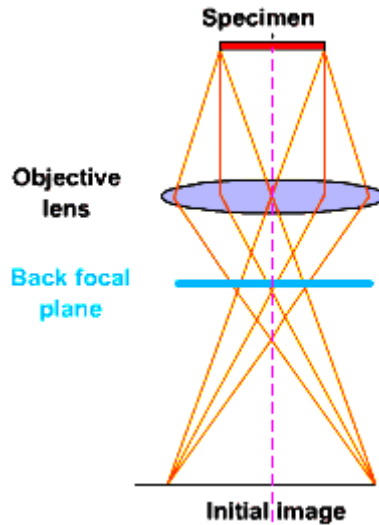


Figure: objective lens imaging, back focal plane and image plane

1. Adjust fine focus and OBJ STIG if necessary.
2. Lift the screen (**F1**) and take a digital image by using CMOS (**RIO CAMERA**). You may have to try different exposure times.

X. Dark field imaging

A dark field (DF) image is formed using a diffracted beam or a group of adjacent diffracted beams. The objective aperture is used to select the diffracted beam by either shifting the aperture or tilting the beam. The transmitted beam is excluded in dark field imaging.

Tip: It is difficult to focus a DF image. Image focus should be done in BF mode.

Method 1: Shifting the OBJ aperture

1. Follow the procedure to form a BF image (IX. 1-7).
2. Focus the beam and press **DIFF**.
3. Take out the **OL APERTURE** and have a look at diffraction pattern.
4. Re-insert the **OL APERTURE** and position it around a diffraction beam.
Question: The selected diffraction beam should not be far away from the transmitted beam, otherwise, the image quality may be poor. Why?
5. Press **MAG1** to see a dark field image
Question: The vacuum area is dark and sample area is bright in a DF image. Why?
6. Adjust **BRIGHTNESS** to open the beam so that the interesting area is homogeneously illuminated.

7. Cover the viewing window.
8. Use CMOS to record a DF image (you may need a long exposure time).

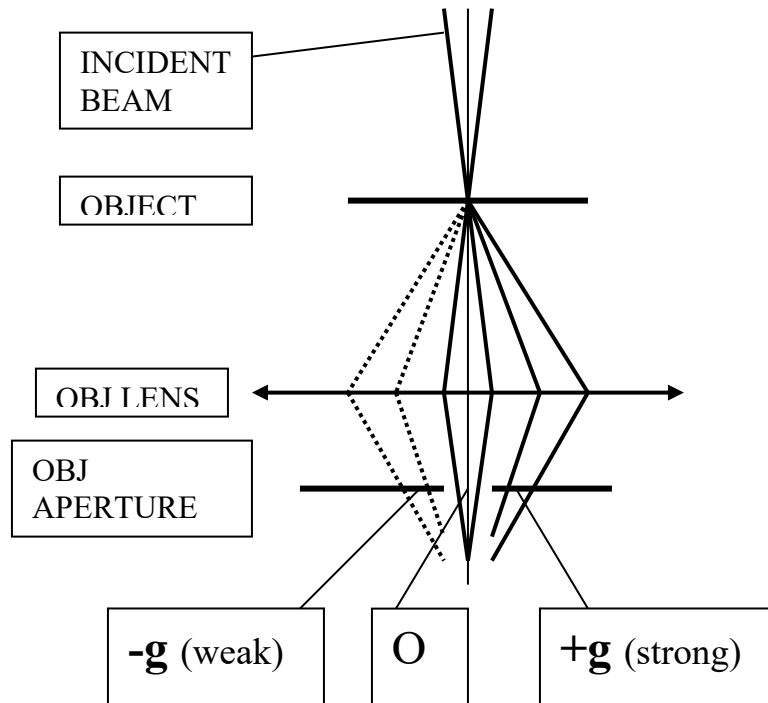
Method 2: Central dark-field imaging

1. Follow the procedure to form a BF Image (IX. 1-7).
2. Focus the beam and press **DIFF**.
3. Take out the **OL APERTURE** to see the diffraction pattern.
4. Select **DARK** field mode.
5. Use **DARK TILT** (left control panel) to center a diffracted beam inside the aperture hole.
6. Insert and center the **OL APERTURE**.
7. Press **MAG1** and center (CLA and SHIFT X&Y) the beam to see a dark field image.
8. Illumination (**BRIGHTNESS**) may be adjusted before a DF image is recorded.
Tip: Bright field image can be easily obtained by pressing **BRIGHT** button in the Standard Operation Window on the JEOL PC. Image focus and OBJ astigmatism can be checked in bright field mode. Press **DARK** button to return to DF image.
9. Use CMOS to record a DF image (you may need a long exposure time).

XI. Bright field imaging under 2-beam condition

The specimen is tilted to 2-beam condition and a bright field image is formed using the transmitted beam selected by a centered objective aperture.

1. Tilt the specimen so that the pattern only shows two strong beams, that is, one transmission disc and one strong diffraction disc **g**, as shown in the diagram.
Tip: If the diffraction pattern changes a lot, the interesting area may move out of the beam, which frequently occurs when the specimen is tilted along the second tilt axis no matter whether the specimen is at eucentric height.
2. **Make sure that tilts are not higher than 5-10 degrees before you insert OL APERTURE.** You should not need to tilt far off zone to reach the two-beam condition (usually <5 degrees).
3. Insert **OBJECTIVE APERTURE** (which is situated at the back focal plane) into the beam by selecting **OL** on the left panel and then choosing the aperture size (1 or 2).
Check the tilting angle or contact EPIC staff if the aperture does not go in smoothly.
4. Press **MAG1** and open the beam to see a bright field image (Now the viewing screen is conjugated to the initial image plane indicated in the figure below).
Tip: Because specimen is normally bent, two-beam condition can be achieved in a limited area instead of whole area. Try to correlate image contrast of different areas and imaging condition of these areas.
5. Adjust fine focus and **OBJ STIG** if necessary
6. Use RIO camera to record images.



XII. Central Dark field imaging under 2-beam condition

A central dark field (DF) image is formed using a diffraction beam selected by a centered objective aperture. The electron beam has to be tilted so that the diffraction beam passes through the optical axis of objective lens.

Tip: It is difficult to focus a DF image. Image focus may be done in BF mode.

1. Follow the BF imaging procedure (1-10) to form an image.
 2. Focus the beam and press **DIFF**
 3. Take out the **OL APERTURE** to see the diffraction pattern
 4. Select **DARK** field mode
 5. Use **BEAM TILT** to move the **-g** weak diffraction disc to the screen center as shown in the diagram.
- Tip: The **-g** weak disc will become strong when it is centered. Keep the beam centered while the beam is tilted.
6. Insert and center the **OL APERTURE**.
 7. Press **MAG1** and center the beam to see a dark field image.
 8. Illumination (**BRIGHTNESS**) may be adjusted before a DF image is recorded.
 - Tip: Bright field image can be easily obtained by pressing **BRIGHT** button.
 - Image focus and **OBJ** astigmatism can again be checked in bright field mode.
 - Press **DARK** button to return to DF image.
 - Tip: If time is allowed, try to record BF/DF images using different **g** and compare their contrast. Some defects may disappear under certain conditions, which is useful to determine the nature of the defects.
 9. Use RIO camera to record images

XIII. Shut down the TEM (see Lab 2 notes)