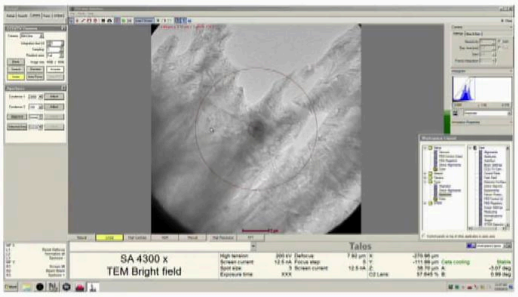
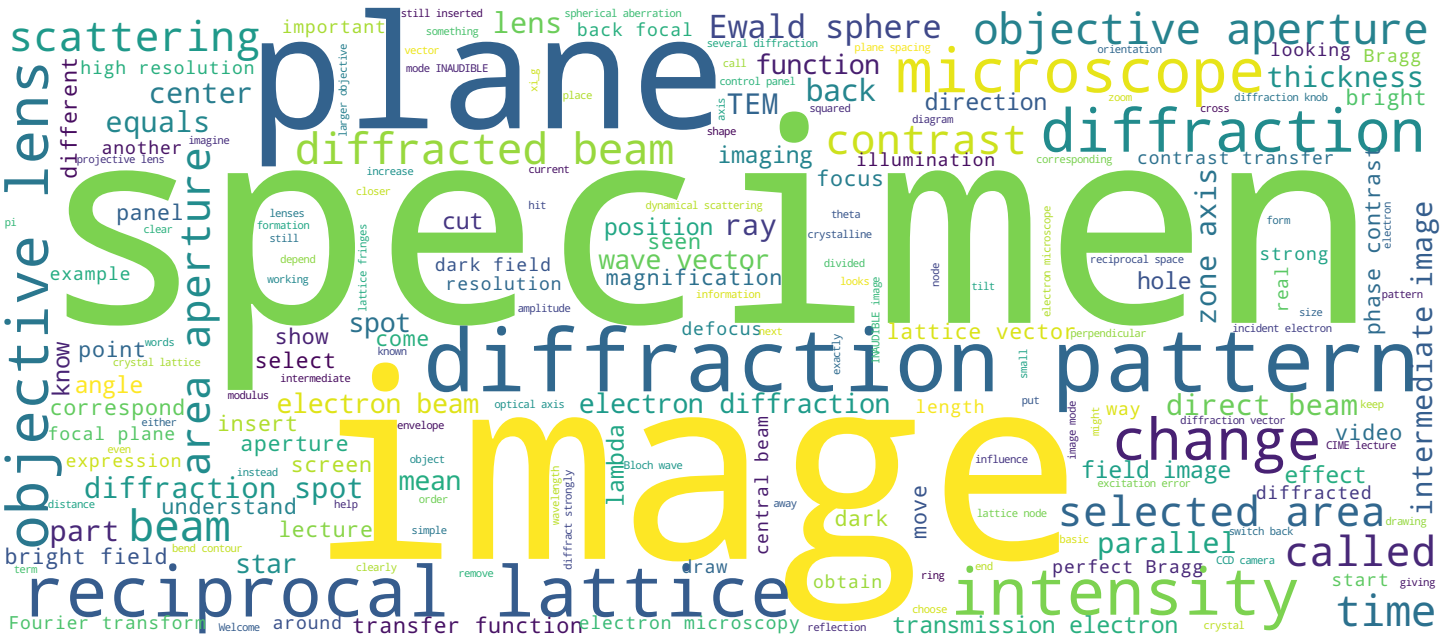
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE



Demonstration at the microscope

Transmission Electron Microscopy

Prof. C. Hébert & Dr. D. Alexander



Welcome to CIME's lecture on transmission electron microscopy for material science. In this video, I will take you to the microscope and show you how it can record images and diffraction patterns.

Notes

Summary

0m 05s

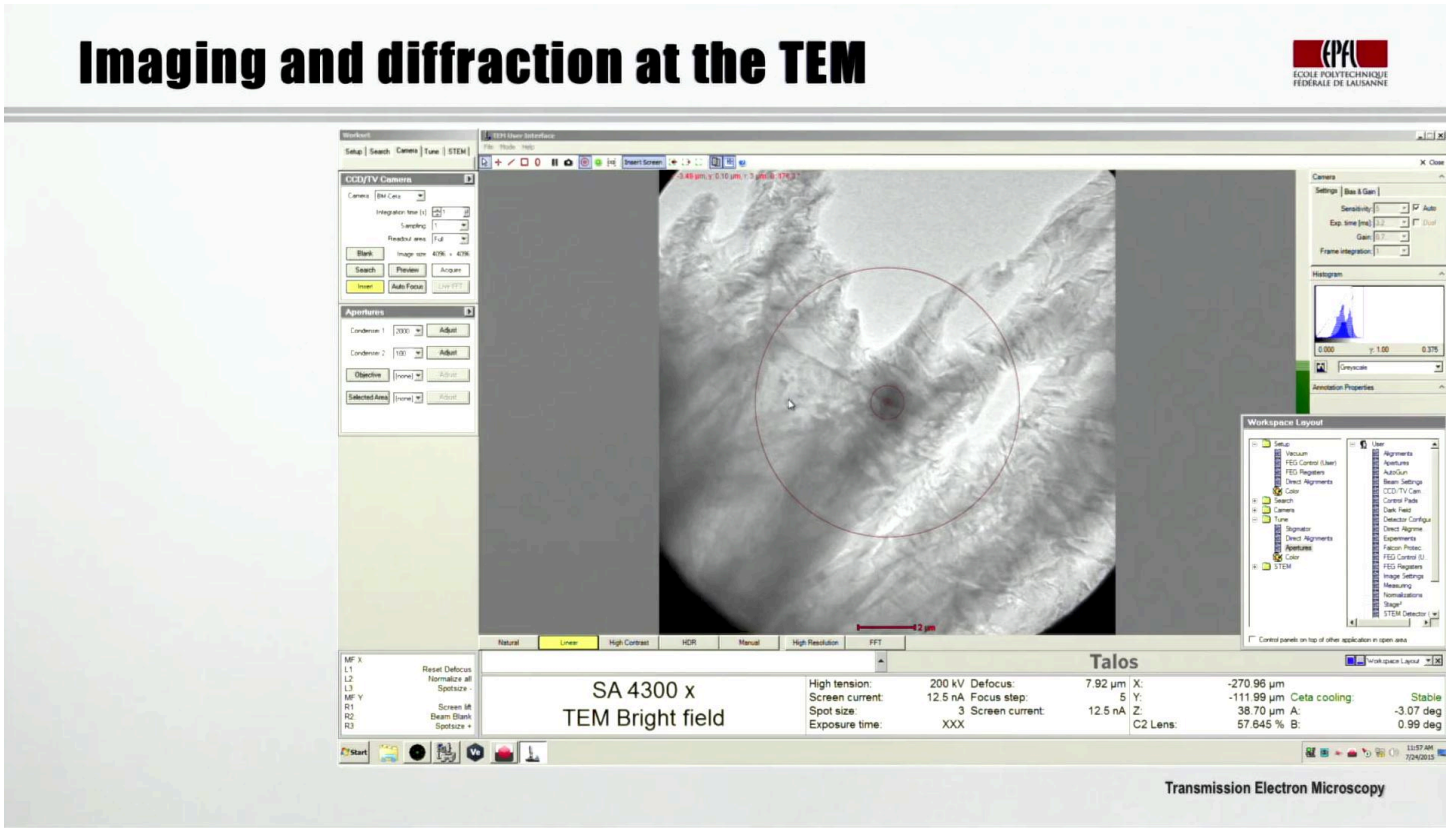
Imaging and diffraction at the TEM

First of all, I need to introduce you the control panel of the microscope. This panel, which I have at my disposal, and where I can change, for example, the magnification of the image or the diffraction pattern, I can change the intensity, as we saw on a previous video, I can also move the specimen to select different areas, or I can change the position of the illumination on the specimen. I have also a very important knob, which is called “diffraction", and this one will help me to switch between “image mode", (INAUDIBLE) image the first intermediate image, and “diffraction mode" (INAUDIBLE) image the back focal plane of the objective lens.

Notes

Summary

0m 18s

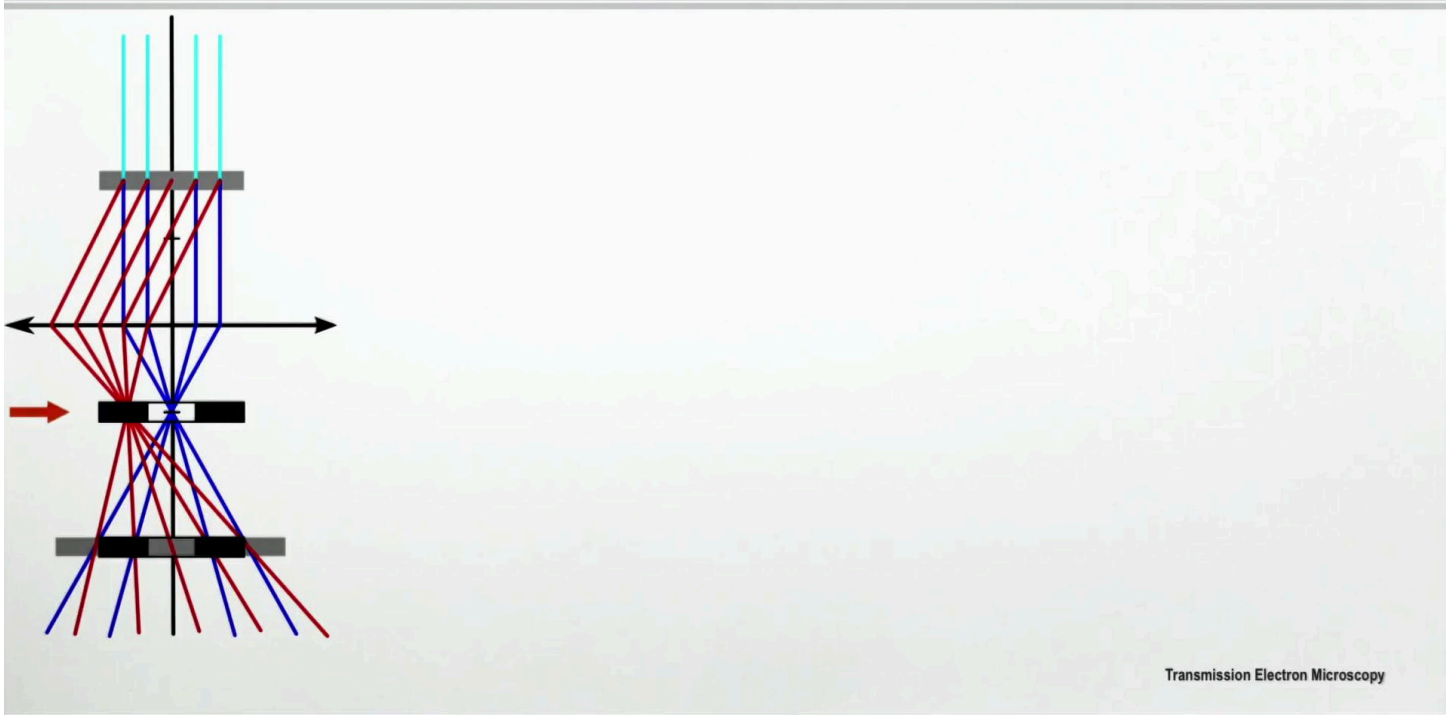


Then, we have the screen capture of the software that controls the microscope and gives us an image filmed of either the specimen or the diffraction pattern. This is this big panel. In the center you have the image where we will see the image displayed by the intermediate and projective lens, in that case, this is an image of a specimen. The ring that you see corresponds to the illumination on the specimen. At that position, you see the magnification that is chosen, and on the left panel, I have the possibility to choose aperture, either the selected area aperture or the objective aperture. To help you understand how it is working on the microscope, you will also have a sketch of the transmission microscope.

Notes

Summary

1m 12s



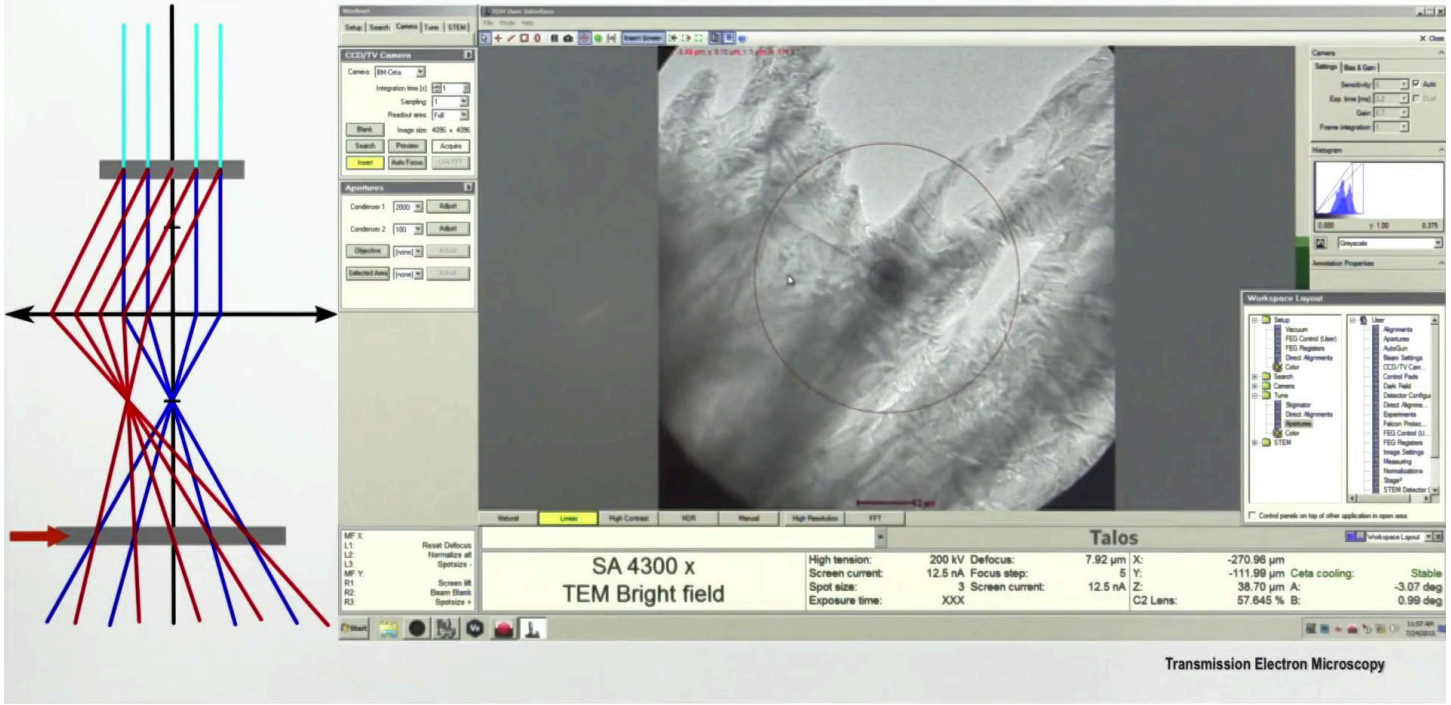
This is this small drawing, which we had before with the specimen, illuminated by a parallel beam of electrons, and we imagine that the specimen is crystalline, so we have undiffracted electrons and some electrons which are diffracted by the specimen. That is the objective lens, in the back focal plane of the objective lens we have the diffraction pattern, and, later on, we have the first intermediate image. Those black drawings are the aperture, this is the objective aperture and this is the selected area aperture. And with the orange arrow, I will symbolize which plane I am currently imaging.

Notes

Summary

2m 15s

Imaging and diffraction at the TEM



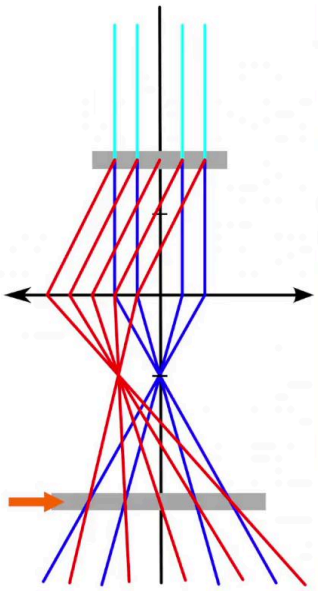
When I move to the microscope I see it in that state, I have the image, I am imaging the first intermediate image and I have no aperture.

Notes

Summary

3m 06s

Imaging and diffraction at the TEM



Transmission Electron Microscopy

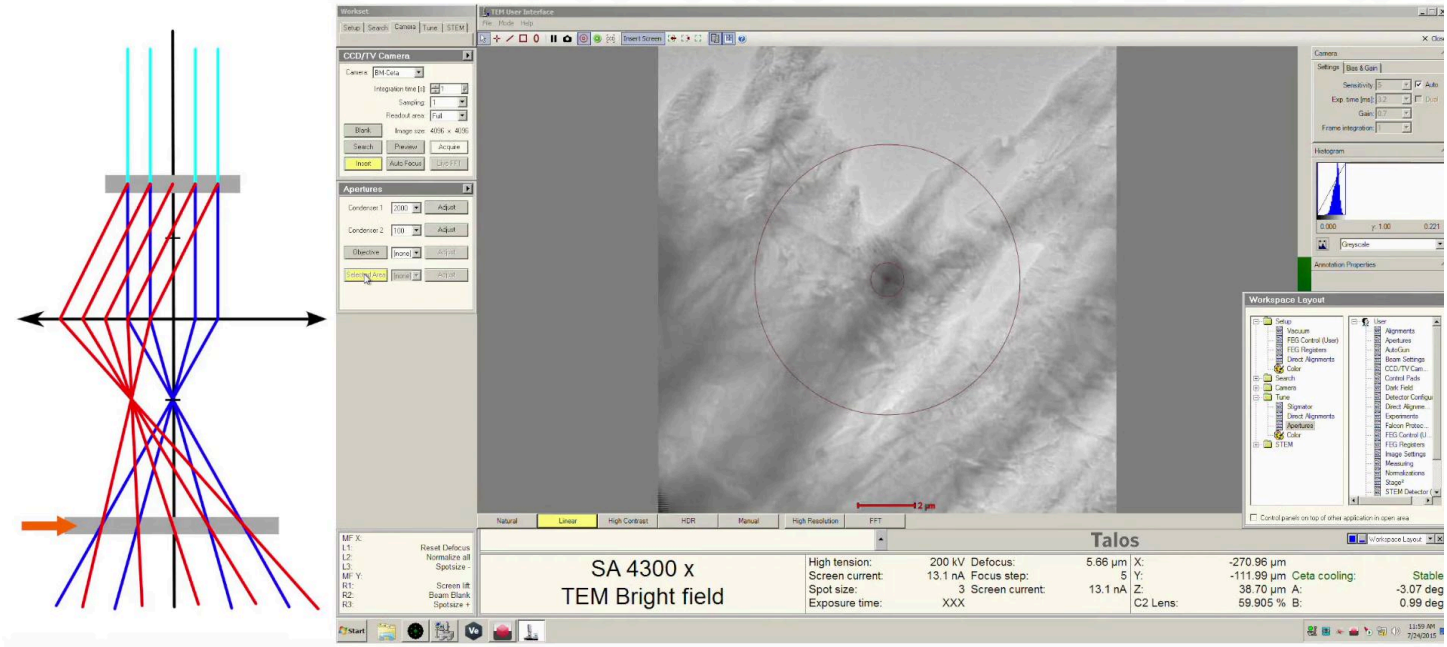
First I adjust the focus, with the focus knob, we change the current in the objective lens to obtain the minimum contrast.

Notes

Summary

3m 19s

Imaging and diffraction at the TEM

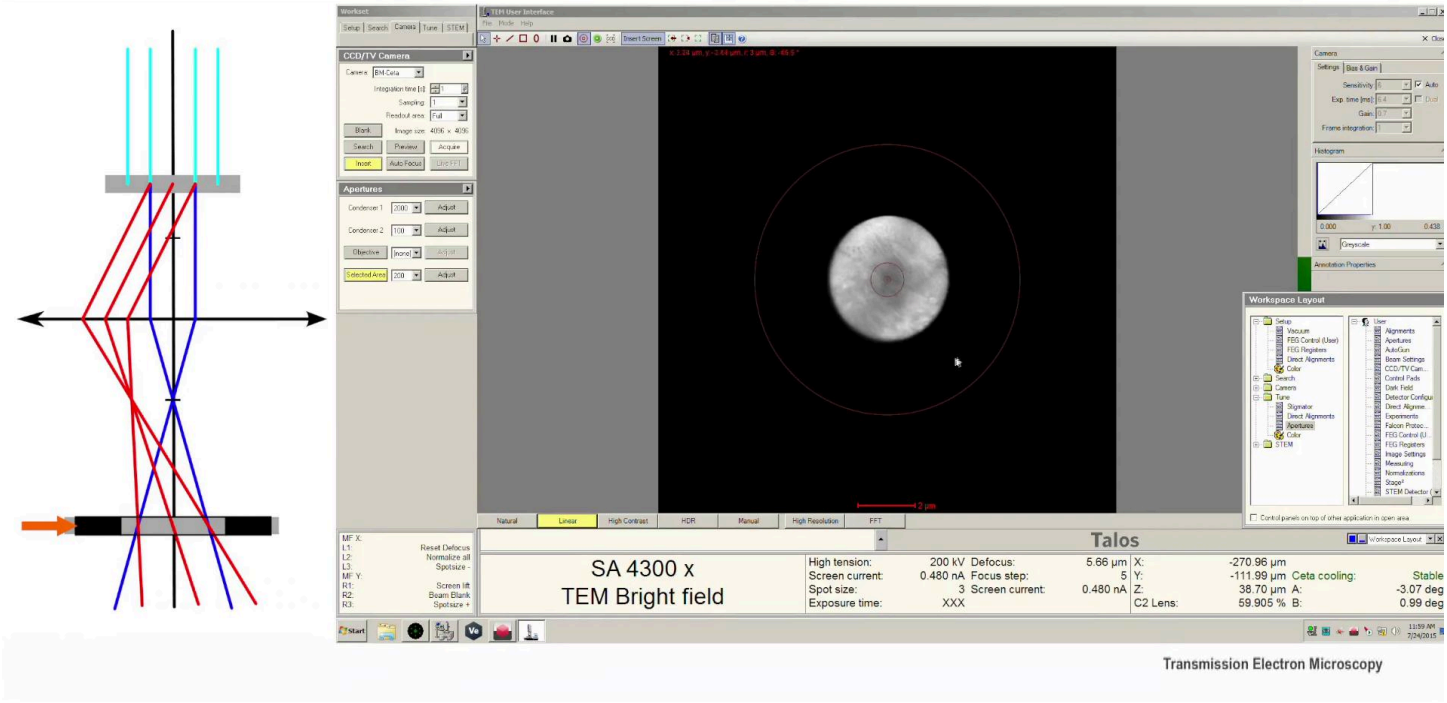


Then, I will insert the selected area aperture, which comes in the first intermediate image given by the objective lens.

Notes

Summary

3m 28s



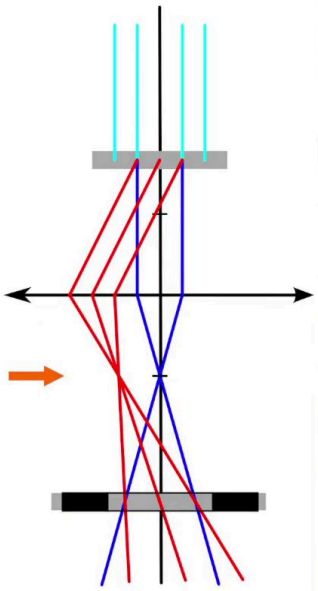
This aperture cuts the image and is now visible.

Notes

Summary

3m 37s

Imaging and diffraction at the TEM



Transmission Electron Microscopy

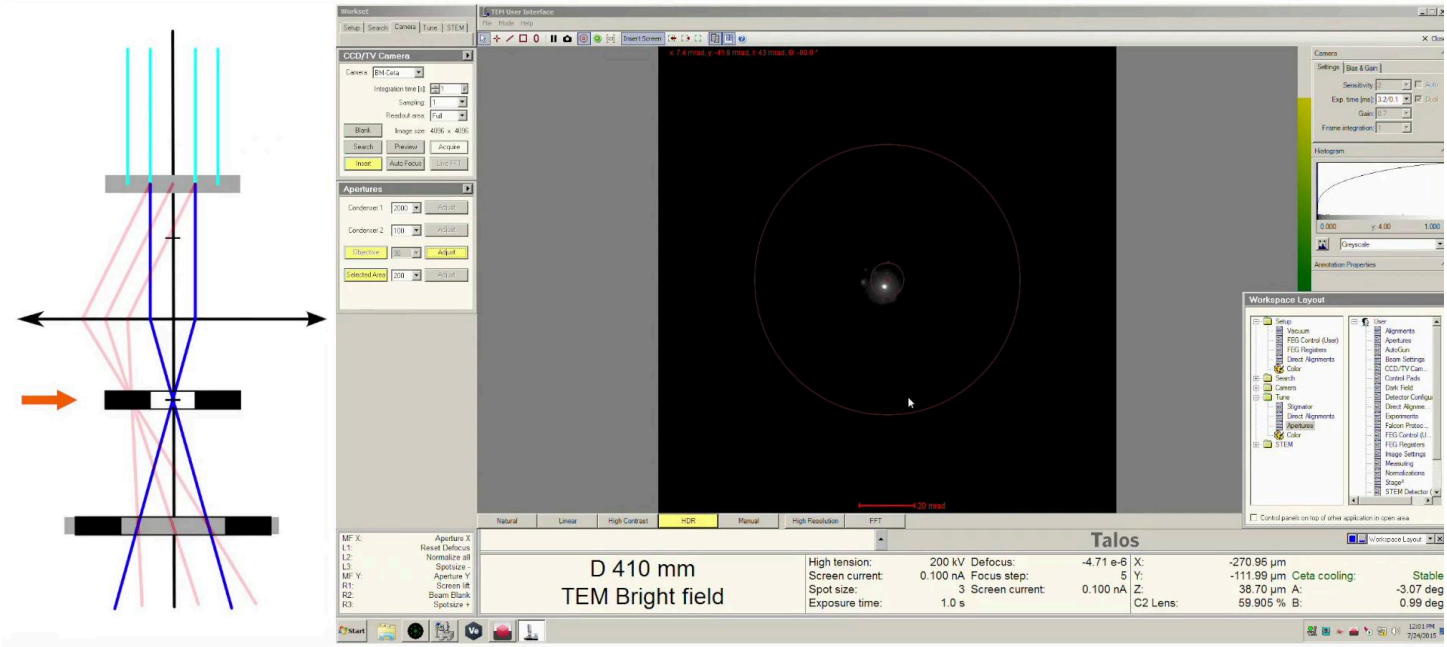
Now, on the panel, I will hit the diffraction knob.

Notes

Summary

3m 41s

Imaging and diffraction at the TEM



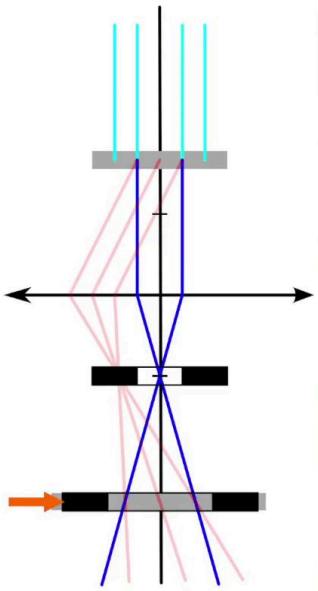
With this I change the current in the intermediate and projective lens and I have a diffraction pattern. On this diffraction pattern you see several diffraction spots and the pattern is not very regular, it looks like we are selecting several grains with different orientations. In the next step, I will insert the objective aperture, which will come in the diffraction pattern, and select only the central beam. I can choose the size of the aperture and, eventually, center it around the beam. Now you see that we have only direct beam and none of the diffracted one.

Notes

Summary

3m 46s

Imaging and diffraction at the TEM



Transmission Electron Microscopy

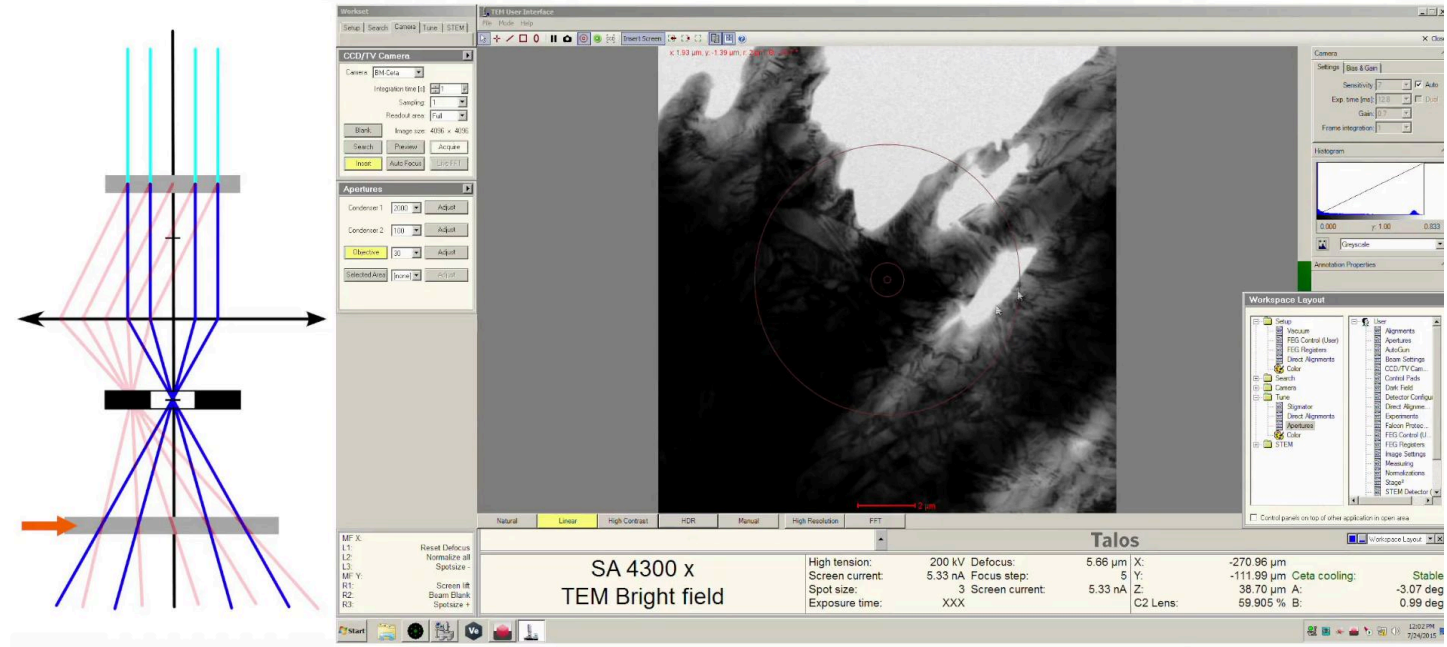
Then, back to the panel, I hit again the diffraction knob. I am back to “image mode”.

Notes

Summary

4m 31s

Imaging and diffraction at the TEM



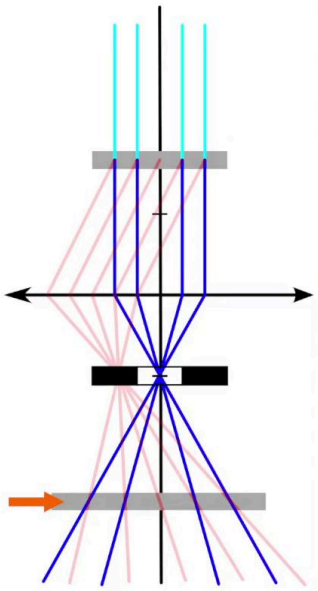
I see again the first intermediate image but this time with a stronger contrast and still with the selected area aperture inserted. I will take it out, so we have the whole image of the specimen. What we see now is an image of the specimen but with much higher contrast than we had before. The place where we have a hole is bright, that is why the image is called “bright field". You recognize several dark parts on the specimen. The contrast has two origins: first of all, parts of the specimen, which are thicker, especially on the bottom left part of the image, will appear much darker because they are scattering more electrons, so more electrons are cut by the objective aperture, which is still inserted. But also on the rim of the specimen, close to the hole, you see a lot of bright and dark contrasts. These are diffraction contrasts. If you look carefully, some grains appear dark while others appear much brighter, it depends on the orientation of this particular grain, some will diffract strongly and be dark, and some will not be in good diffraction conditions and they will appear brighter.

Notes

Summary

4m 38s

Imaging and diffraction at the TEM



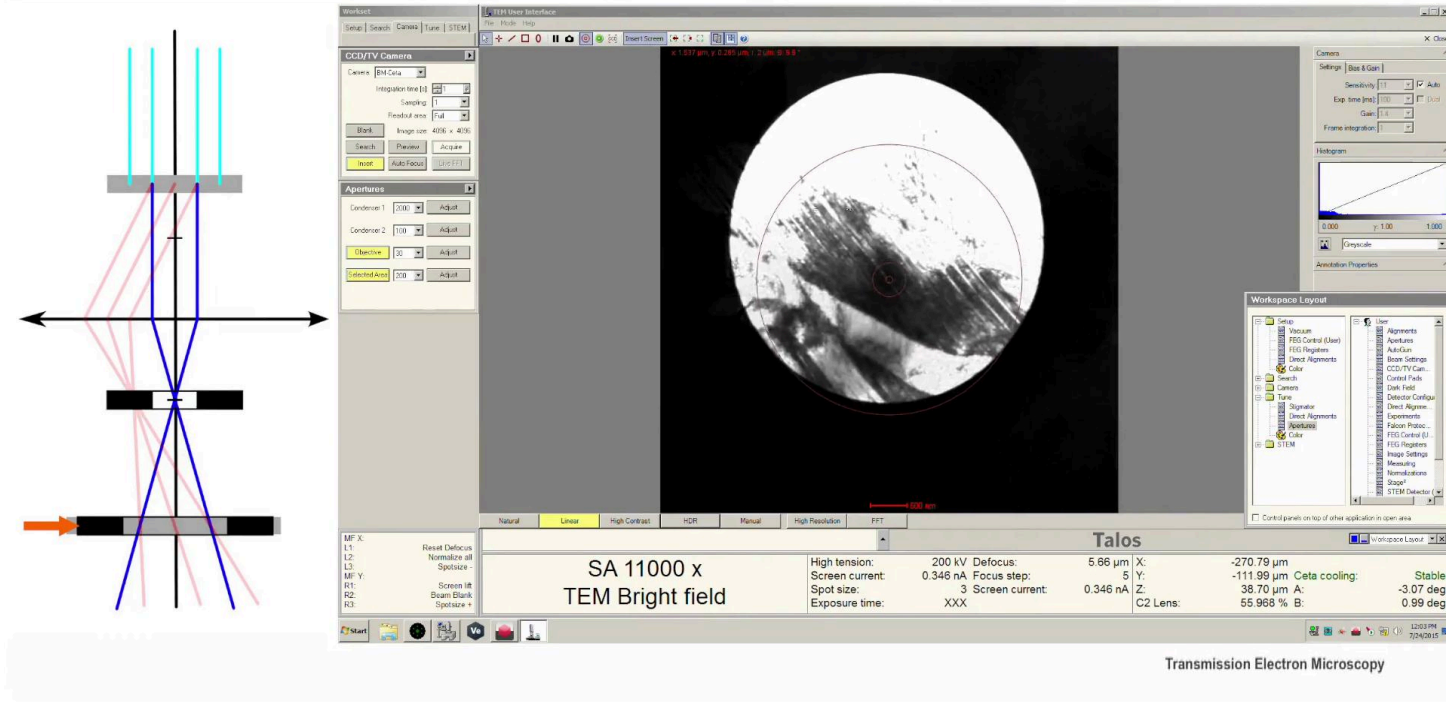
Transmission Electron Microscopy

Back to the control panel, I can change the magnification and also adjust the brightness, so that I keep the illumination on the area which I see on the screen.

Notes

Summary

6m 10s



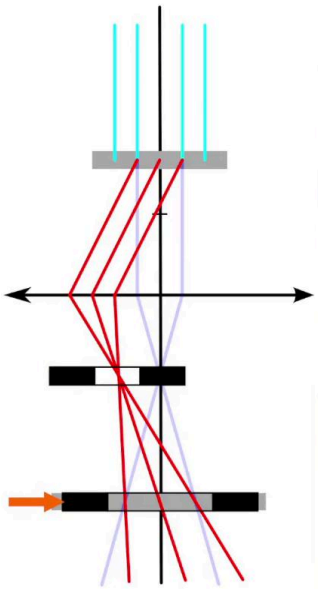
So I zoom in on my specimen and I can also move it. I am still keeping this interesting contrast due to the objective aperture. Now you see in the center of the screen, there is a grain which appears very dark. It might be interesting to have a diffraction pattern originating only from this grain. What I will do is, I will insert a smaller selected area aperture, which will cut the image and select only the part of the image that I am interested in.

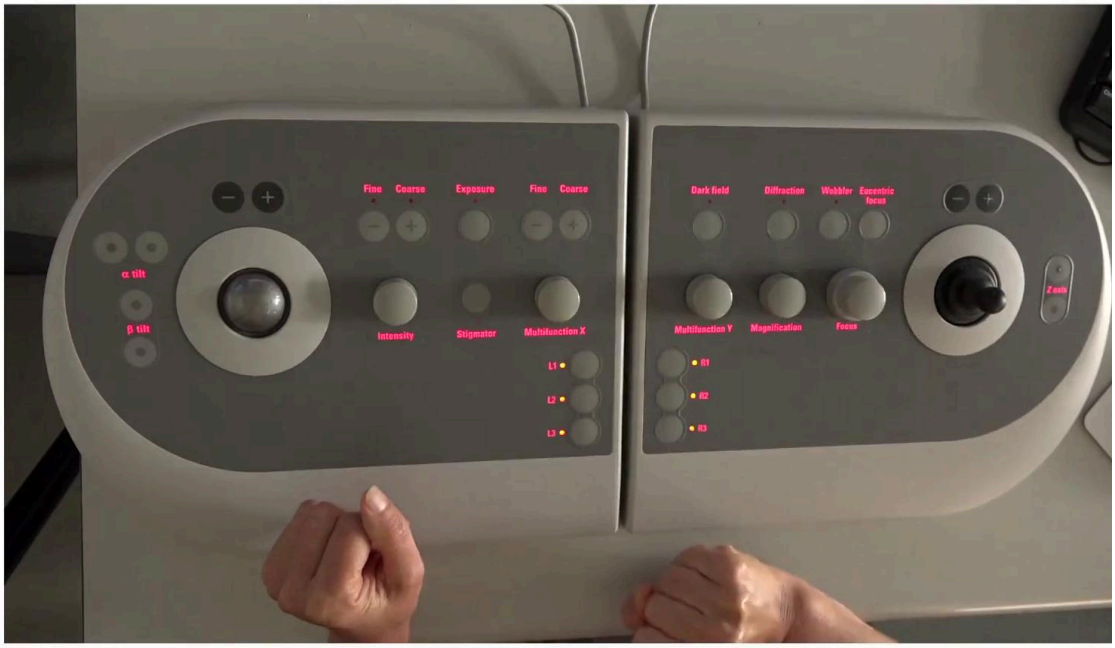
Notes

Summary

6m 26s

Imaging and diffraction at the TEM





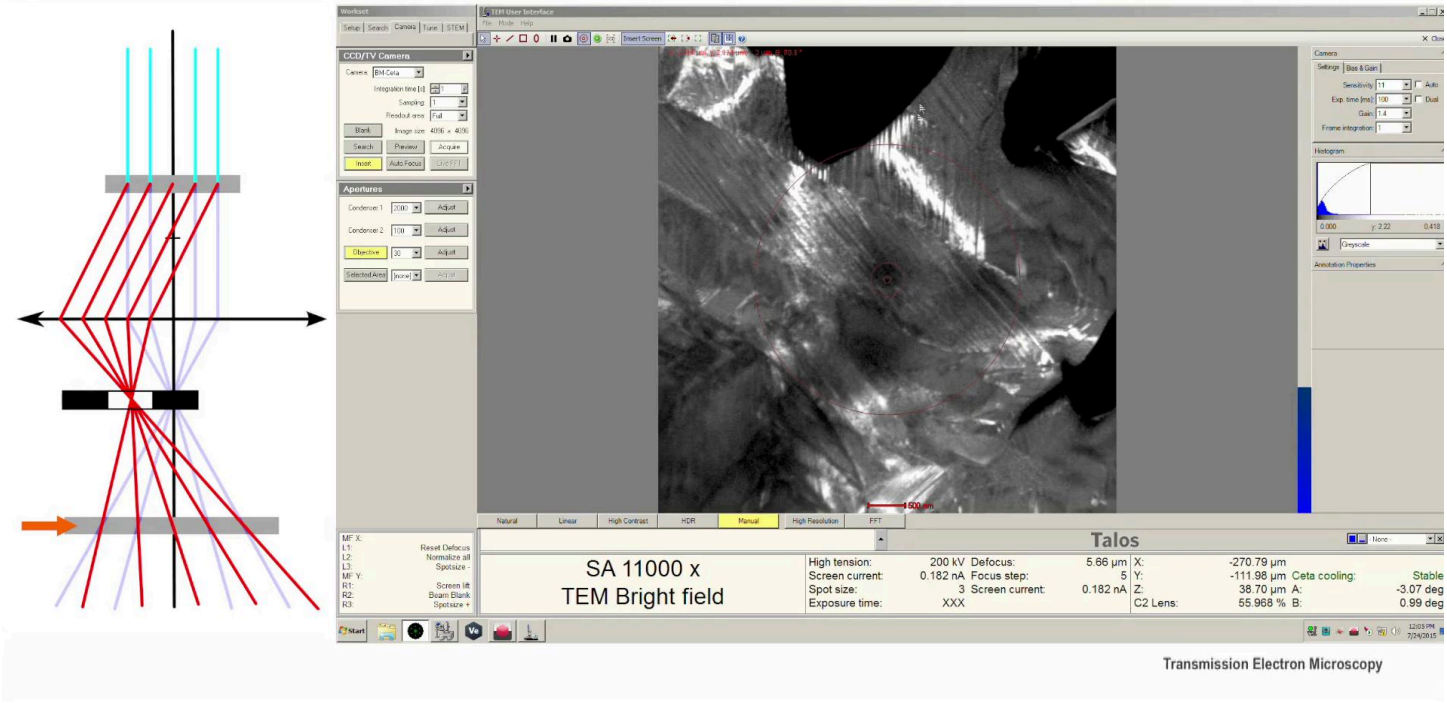
Transmission Electron Microscopy

Now I will go back to “diffraction”. I see not much, because the contrast aperture, or objective aperture, is still inserted, so I have to remove it to see the diffraction pattern, and know you see the clear diffraction pattern of, nearly a single crystalline grain close to the zone-axis orientation. And now inserting again an objective aperture, but this time I will not center it around the central beam, but I will choose one of these bright diffraction spots that I had in my diffraction pattern.

Notes

Summary

7m 17s



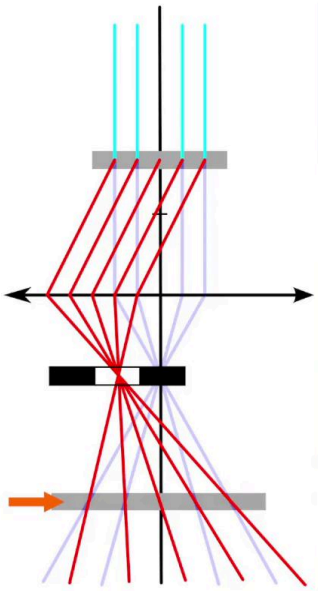
If I hit back “diffraction", I am back to “image mode”, imaging the first intermediate image. I need to remove the selected area aperture and what you see now is the same specimen with a different contrast, the hole is dark because in the hole I have no diffraction or diffusion of electrons so they are all cut by the aperture. The specimen itself has brighter parts And the very bright parts are the ones which diffract strongly in the direction which I have selected with the objective aperture.

Notes

Summary

8m 09s

Imaging and diffraction at the TEM



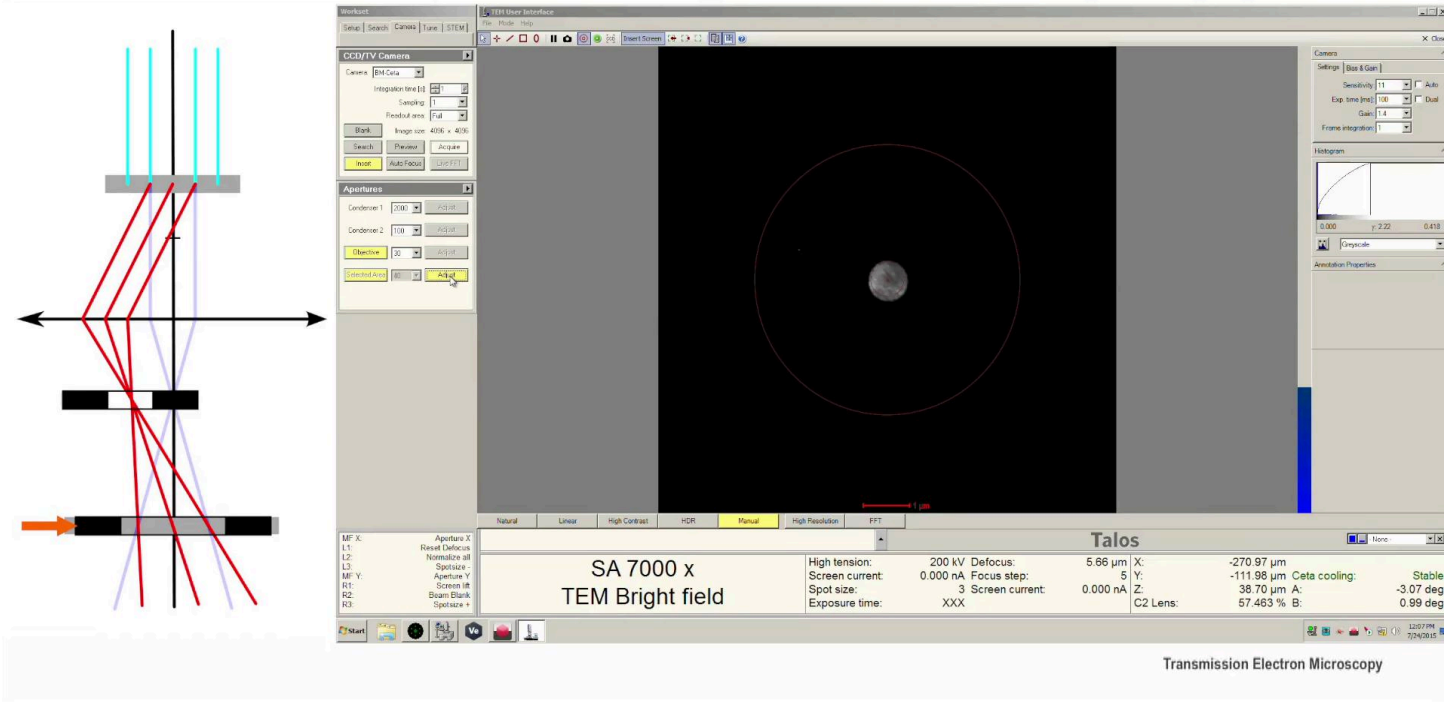
Transmission Electron Microscopy

This is called a "dark field" image.

Notes

Summary

8m 56s



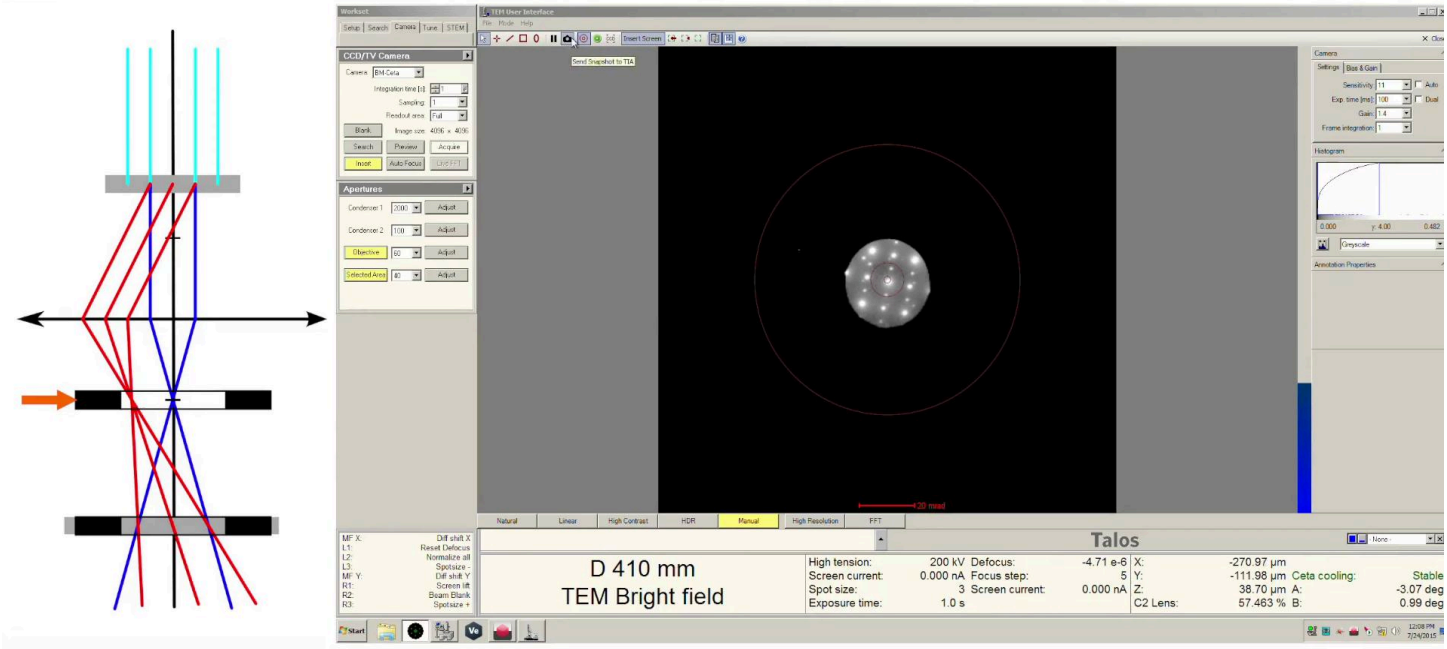
Again, I can play around, change magnification, adjust intensity, to zoom in and out of my specimen, but still keep the same dark field contrast. I might want to have a closer look at my specimen and go to high resolution. For this, I insert again the selected area aperture, adjust it properly to select the same small area of my specimen as before.

Notes

Summary

9m 02s

Imaging and diffraction at the TEM



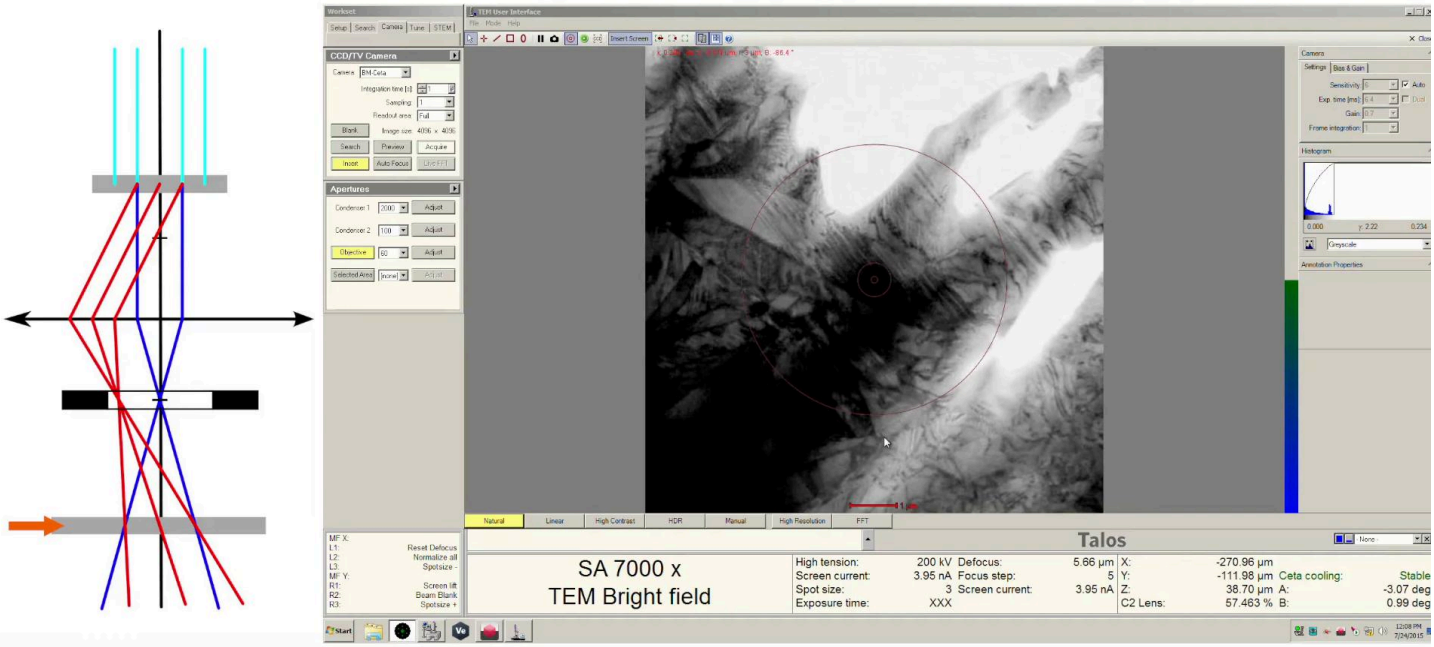
I switch back to “diffraction" and I will select a much larger objective aperture, which will take several diffraction spots, and I center it around the central beam.

Notes

Summary

9m 42s

Imaging and diffraction at the TEM

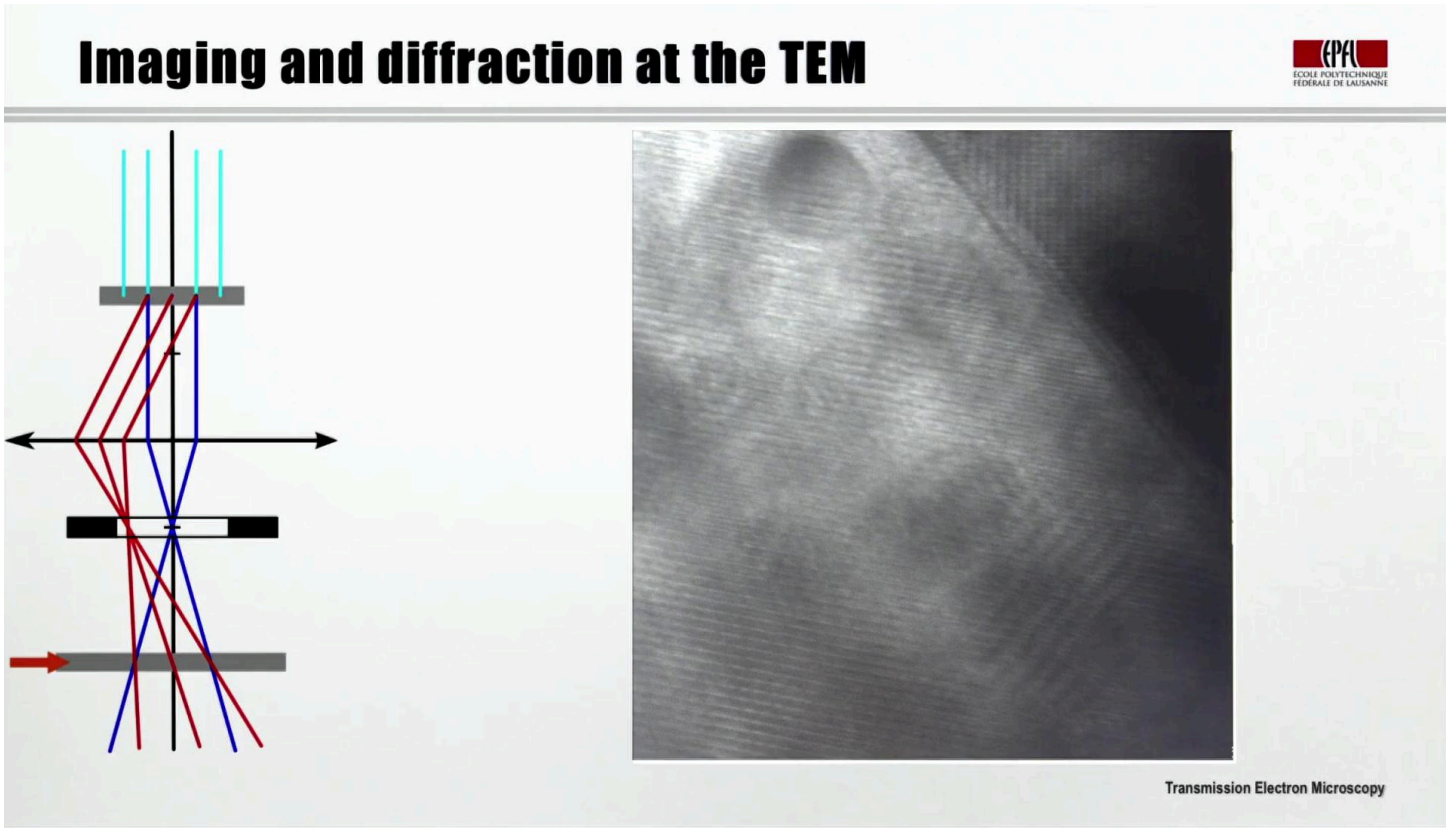


Back to “image" by hitting the diffraction knob and removing the selected area aperture. We have again a bright field image with less contrast than in the first one, it is clear, we have a larger objective aperture, so we have selected, also, some diffracted beams.

Notes

Summary

10m 12s

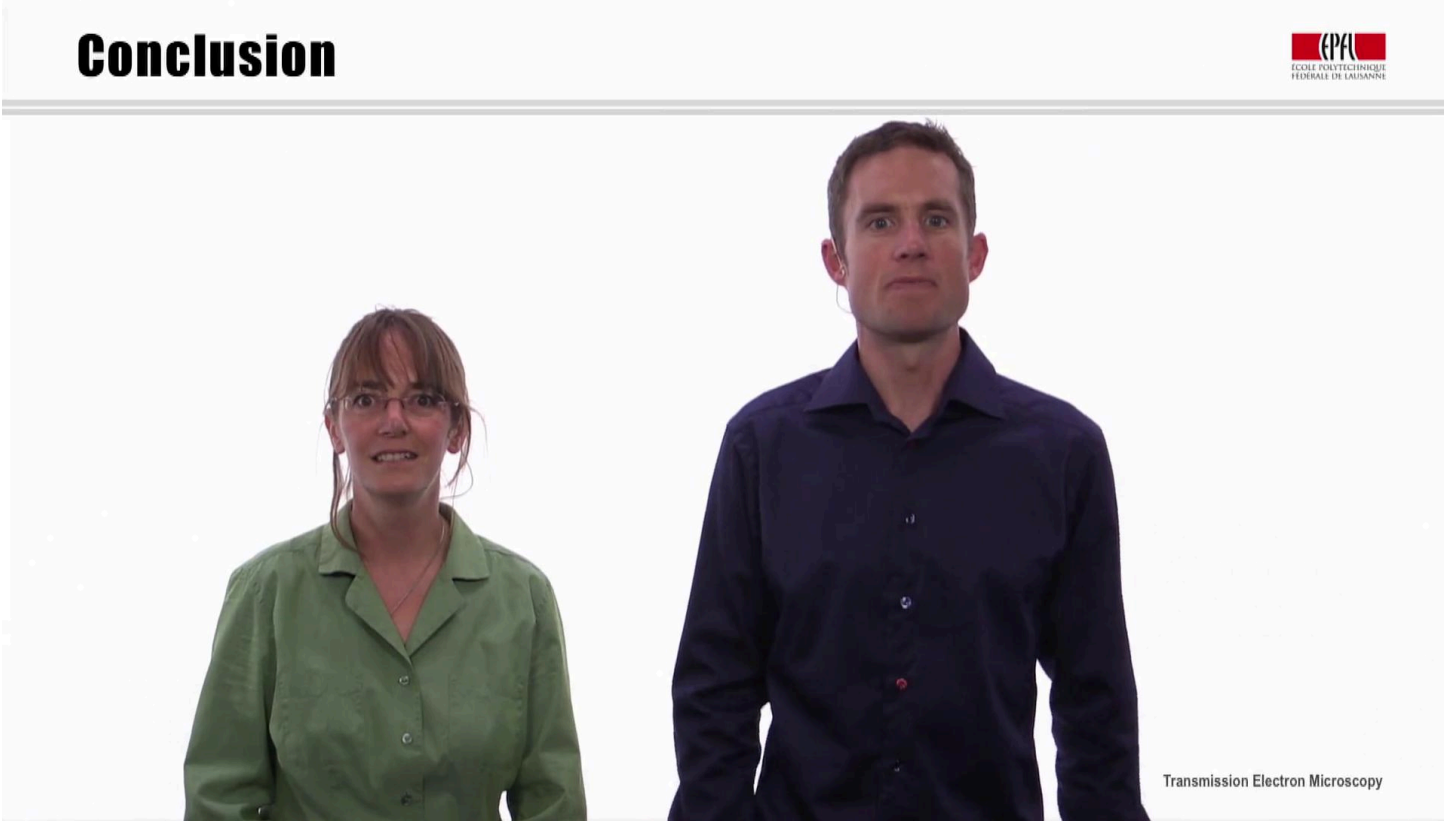


And now I am increasing magnification and adjusting the intensity to keep it on the specimen. You see the magnification on the bottom of the panel. Once I have reached a very high magnification in that case more than one million times, I start to see on my screen what is called "lattice fringes". Actually, with the resolution of the video capture of the screen you cannot really recognize them on this video. So, we will switch back to the presentation and I will show you the capture images that have been taken on the CCD camera. To have you better understand what I mean with "high resolution", I now have inserted this image, which was acquired on a good CCD camera on the microscope. You see clearly the lattice fringes and you will understand how they are formed in the module about high resolution and face contrast.

Notes

Summary

10m 38s



Now we are finished with the introduction. You have had the building parts of the TEM, as well as its main operating modes. In the following videos, we will start considering electron scattering by the sample in more depth, and for this I will pass over to Duncan. Thank you Cécile. When imaging any, crystalline sample in TEM elastic scattering from the crystal lattice, that is diffraction, will dominate the image contrast. Therefore, understanding electron diffraction is vital to TEM analysis. Here, starting from an assumed understanding of the basics of crystallography and diffraction, in the coming lectures we will consider both the theory of electron diffraction and its influence on TEM image contrast.

Notes

Summary

11m 58s