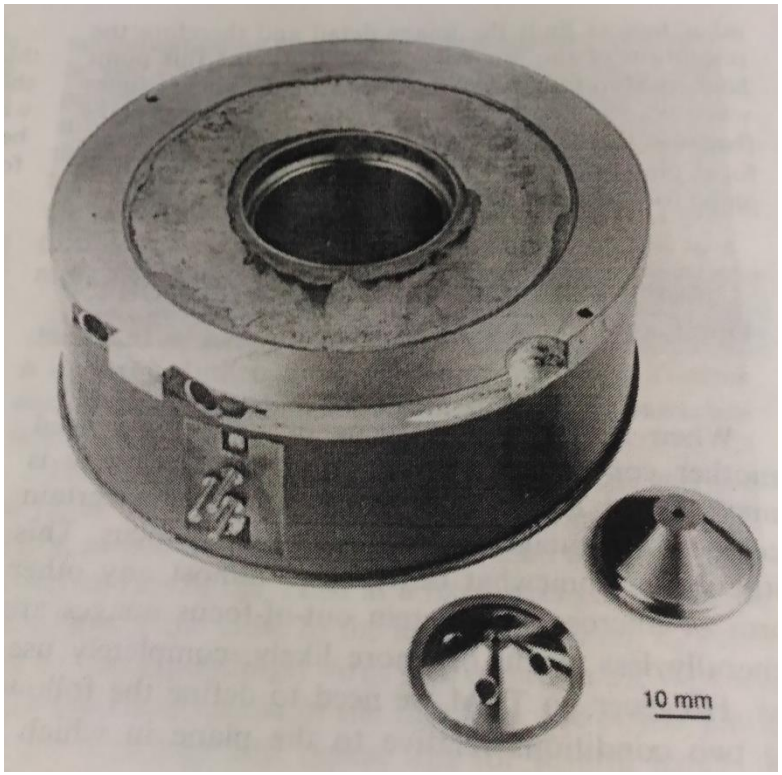
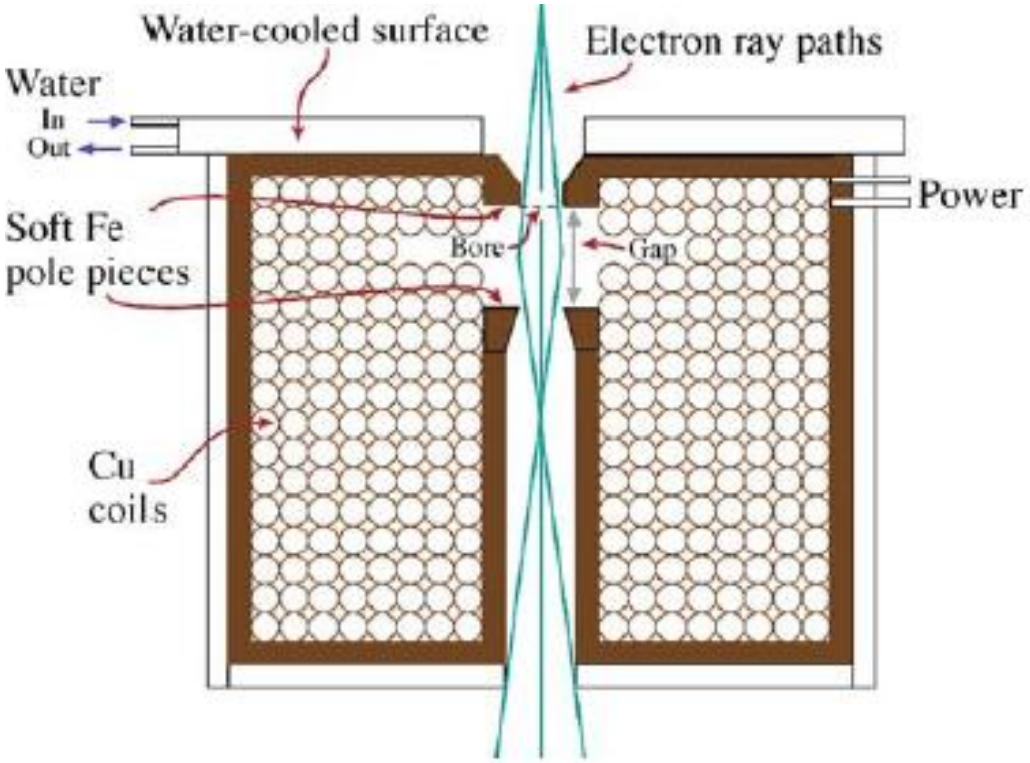
ELECTROMAGNETIC LENSES





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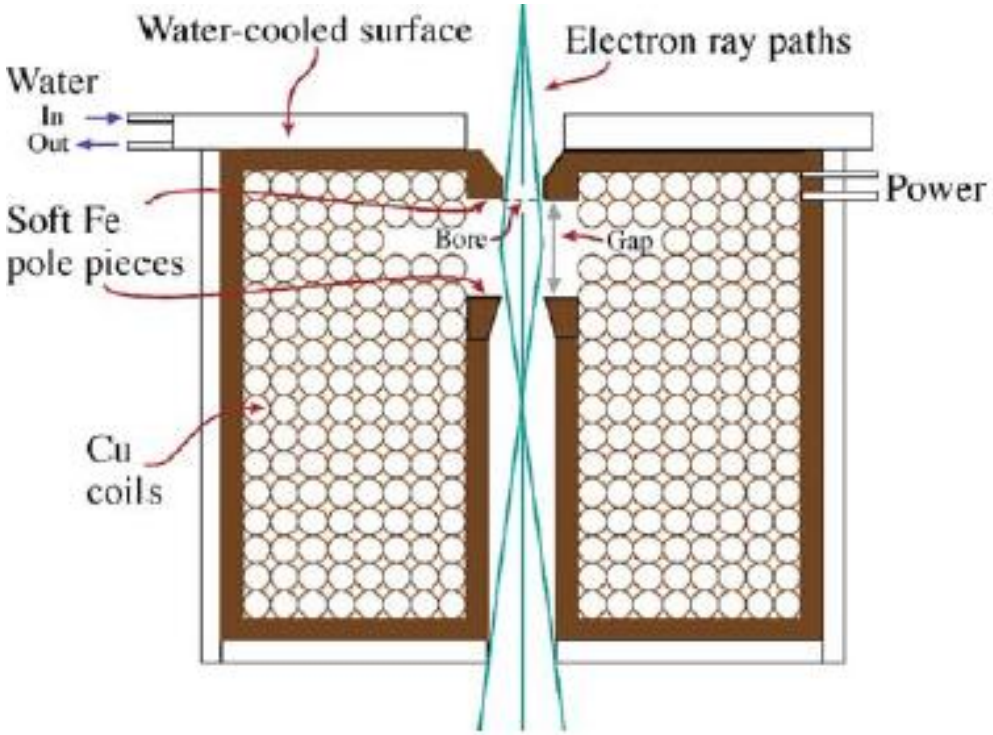
Electromagnetic lenses

Electromagnetic lenses are constructed from two parts:

- Frist there is a cylindrically symmetrical core of soft magnetic materials such as iron, with a hole drilled through it. Soft iron is called a polepiece. In most of the lenses there are two polepieces (upper and lower), which can part of same piece of soft iron. The distance between the polepiece faces is called gap.
- The second part of the lens is a coil of copper wire which surrounds each polepiece. When current pass through the coil, a magnetic field is created in the bore. This field is inhomogeneous along the length of the lens, but axially symmetric.



Lenses in TEM vs. optical microscope

- **TEM**

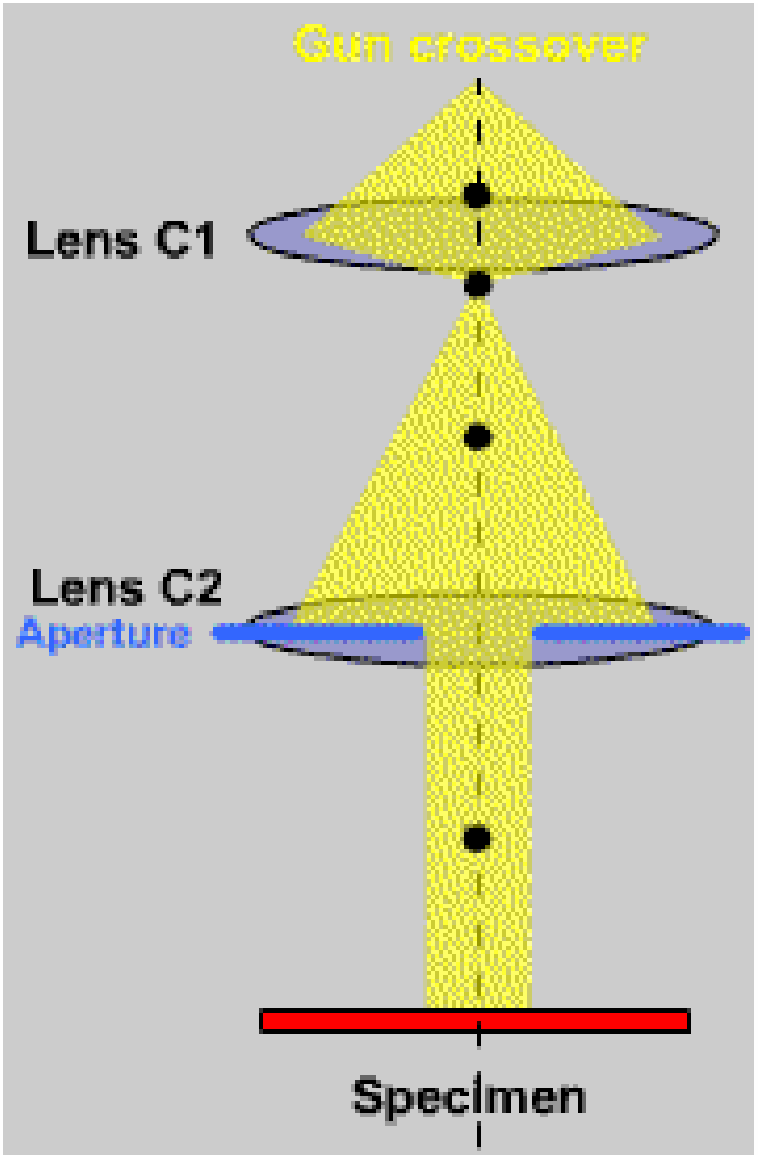
- An electron beam is used to view the sample
- Electromagnetic lenses made from metal
- To magnify and focus our image we change the current running through a coil around a soft metallic core, which changes the strength of the resulting magnetic field surrounding the electron beam

- **Optical microscope**

- Light is used to see the sample
- Glass lenses
- We physically move the lenses up and down to change the focus and intensity of the image
- To increase the magnification we have to change lenses

1. Condenser lenses:

- This lens is used to form the beam and limit the amount of current in the beam and it is also used to control the diameter of the electron beam.
- The purpose of the condenser lens is to focus the beam onto the specimen. The stream is condensed by the condenser lens.

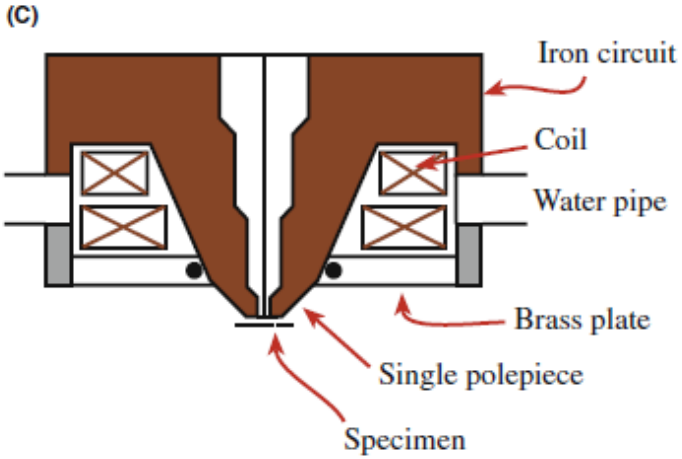


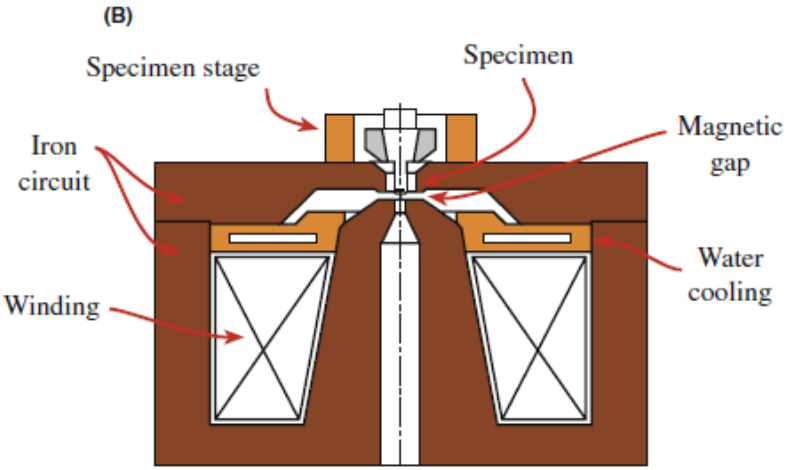
Advantage of Double Condenser Lens:

- Since C1 is closer to the source than C2 it has a larger acceptance angle (aperture) and therefore collects more electrons from the source than C2 alone. The higher efficiency of the double condenser system means that the brightness of the gun can be reduced with consequent increase in filament life.

2. Objective lens:

- A TEM has several lenses (multi-lens system) most of which are weak. The strongest lens is the objective lens which forms the images magnified by other lenses
- This is the first lens of a microscope and it is closest to the specimen being observed.
- The objective lens is designed asymmetrically and is therefore different from the axially symmetrical construction of the condenser lens.
- In the electron microscopy it is not possible to move the position of the lenses, so it is necessary to change the focal length of the objective lens, to focus the specimen. This is done by varying the current through the windings of the electromagnet that makes up the objective lens.





Lens problems

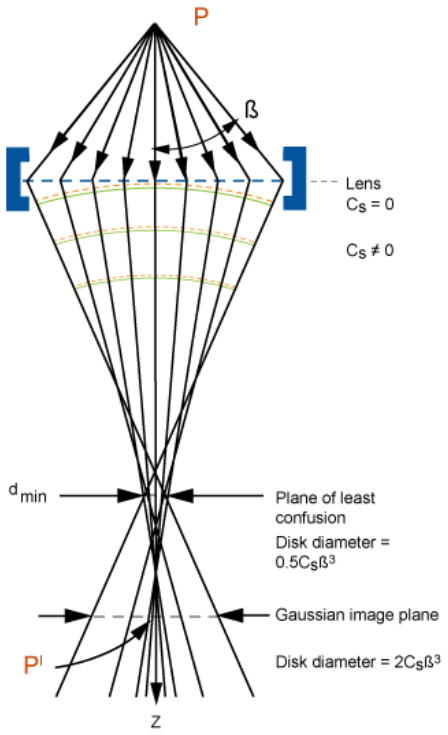
Electromagnetic lenses have many imperfections which limit the resolution the microscope but paradoxically help us get a better depth of field and focus.

The main defects that electromagnetic lenses experience are:

- Spherical aberration
- Chromatic aberration
- Astigmatism

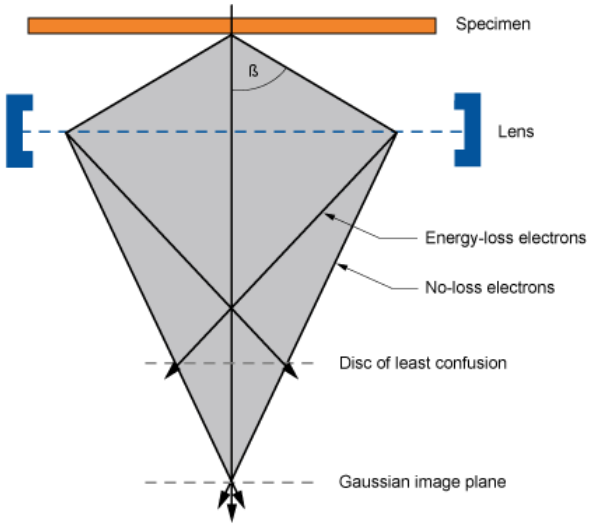
1. Spherical aberration:

The spherical aberration occurs when the lens field behaves differently for the off-axis rays. In other words, the rays which are "parallel" to the optic axis but at different distances from the optic axis fail to converge at the same point. The further off-axis the electron is, the more strongly it is bent back toward the axis. As a result, a point object is imaged as a disk of finite size.



2. Chromatic aberration:

The term chromatic aberration is related to the energy of the electrons. Electrons are not monochromatic. Electrons emerge from the gun at a whole range of energies and are bent by the objective lens to different degrees; electrons that have lost energy are bent more strongly. Thus, once again, electrons from a point on the specimen form a disk image, as for spherical aberration.



3. Astigmatism:

The aberration called astigmatism occurs when the electrons in the primary beam are exposed to a non-uniform magnetic field as they spiral round the optic axis. Astigmatism has several causes. It arises because the soft iron pole pieces comprising the electromagnetic lens cannot be fabricated with perfect cylindrical symmetry. The soft iron may also have micro-structural inhomogeneities which cause local variations in the magnetic field strength.


Thank You!