EPFL

Course material

Course:

Micro and Nanofabrication (MEMS)

Video:

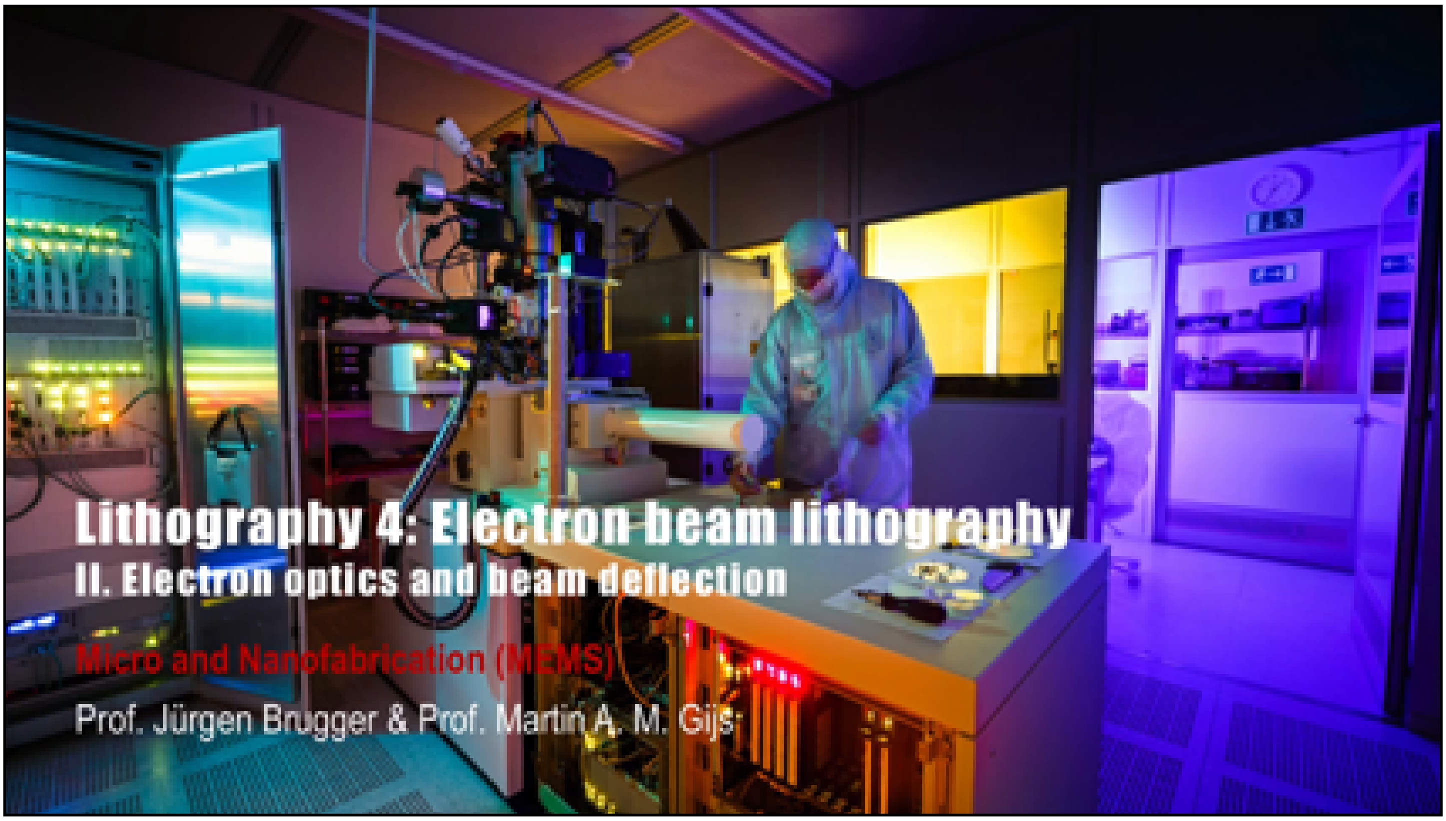
4.9 Lithography 4, Electron beam lithography, II Electron optics and beam de

Concepts (extracted from automatically generated subtitles):

Electric field. Magnetic field. Beam blankers. Small deflection. Main fields. Beam step size. Electron beam. Electron trajectory. Dielectric lenses. Different methods. Step size. Lorentz force. Charged particle. Larger area. Electrons.

to video sequence search
(within Micro and Nanofabrication (MEMS).)

to video

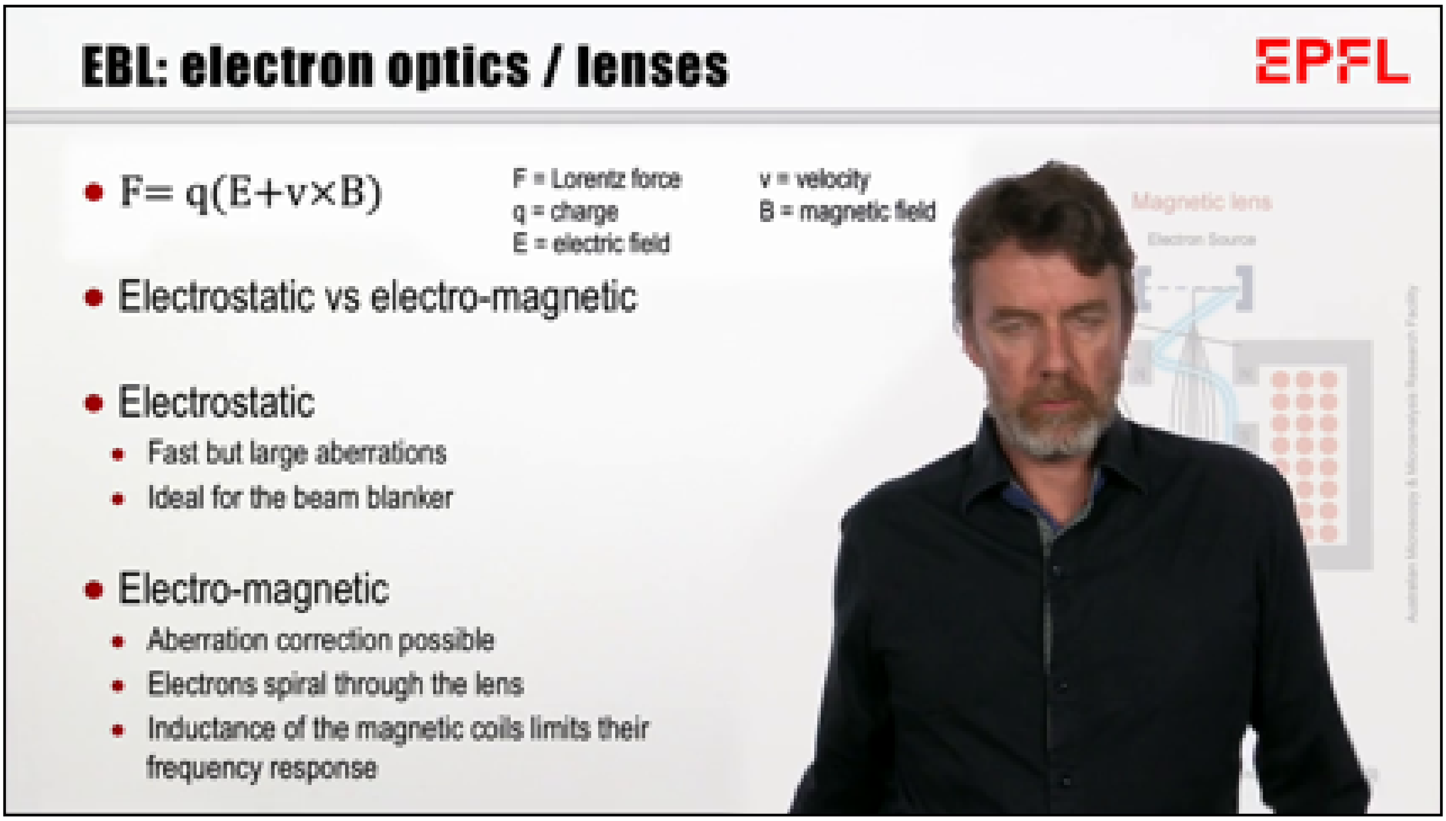


...

notes

summary

0m 0s

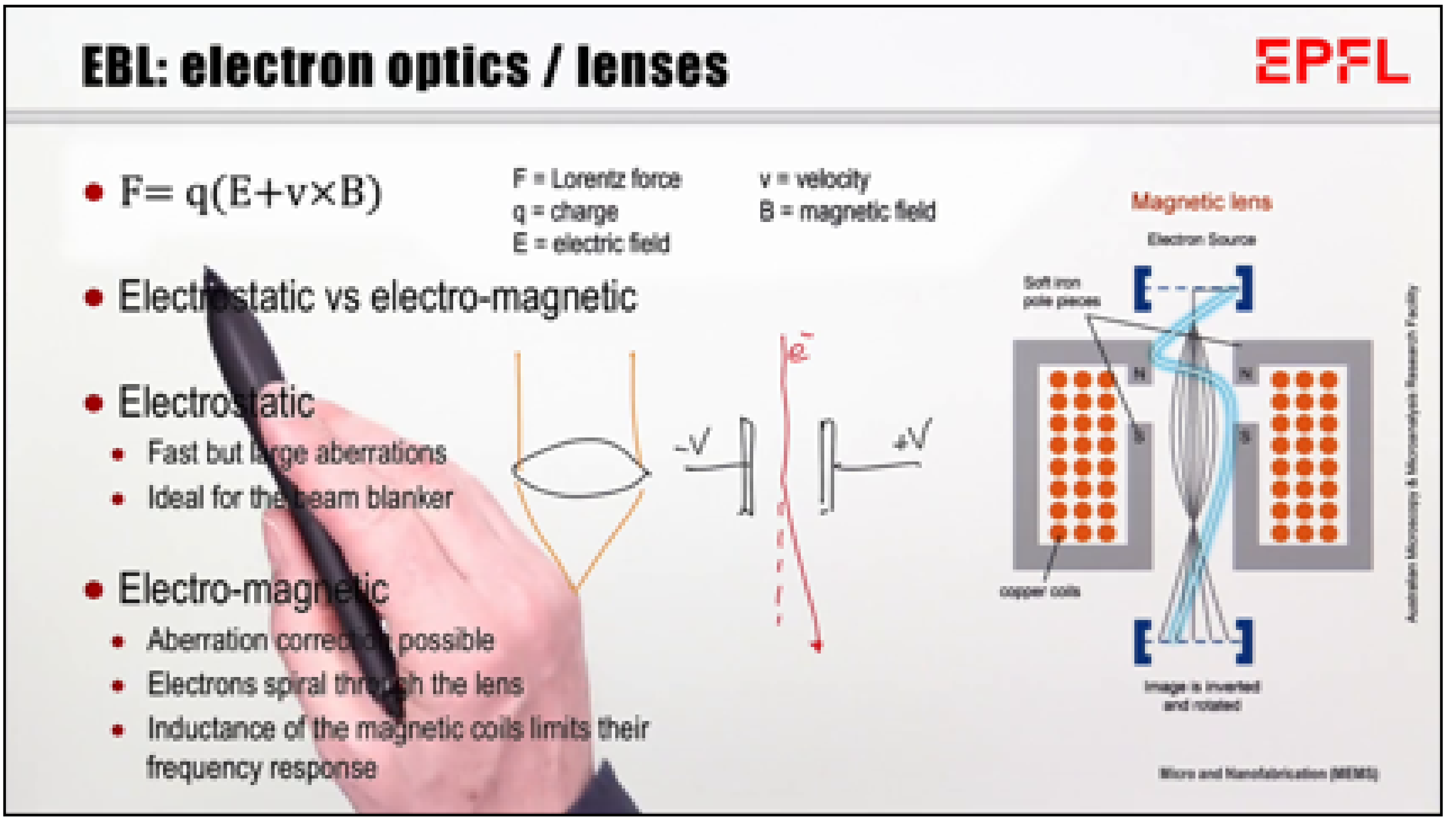


So now let's have a look how we can control

notes

summary

0m 1s

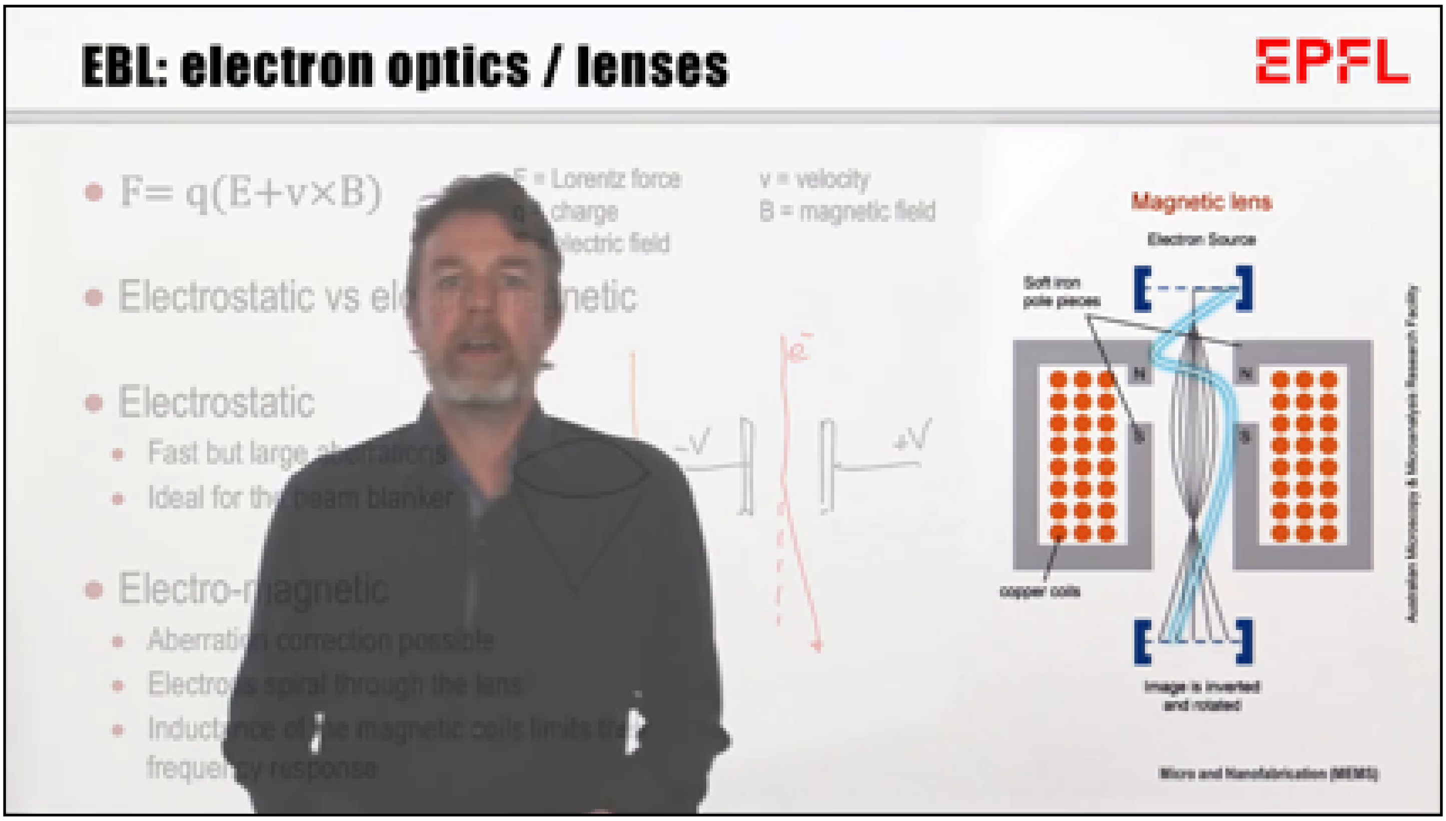


and focus the electrons. Typically, light in optical systems is focused by dielectric lenses, like shown here. We have here the lens, and if you come with the light... it will focus on the focal point here, further down. Electron trajectory, on the other hand is controlled by electrostatic or electromagnetic lenses, according to the Lorentz force, shown here.

notes

summary

0m 5s

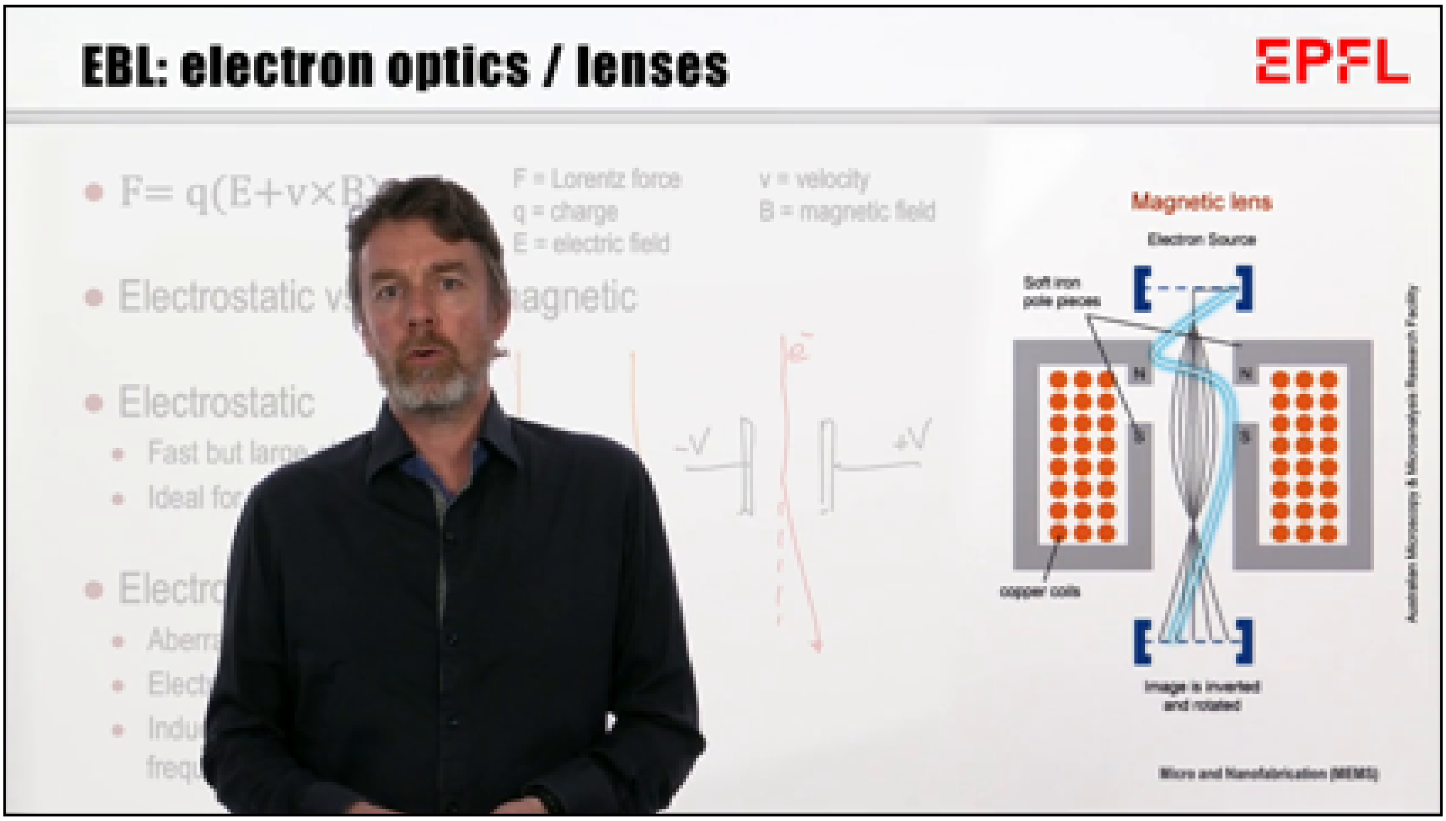


And you can see that we can exert a force on a charged particle, either by an electric field or by a magnetic field and the velocity of the particle.

notes

summary

0m 37s

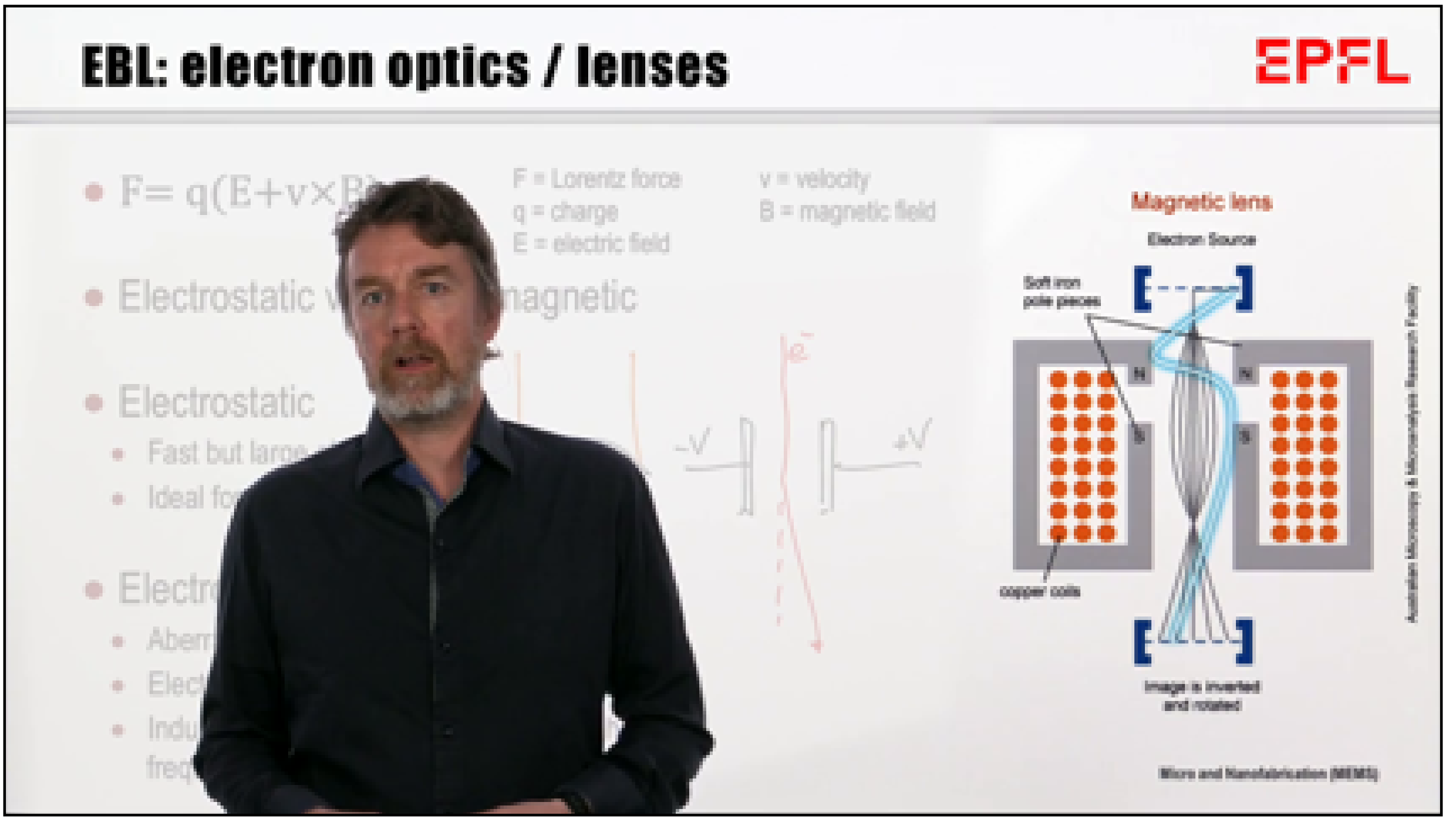


Electrostatic lenses are typically used for beam blankers or the gun region.

notes

summary

0m 47s

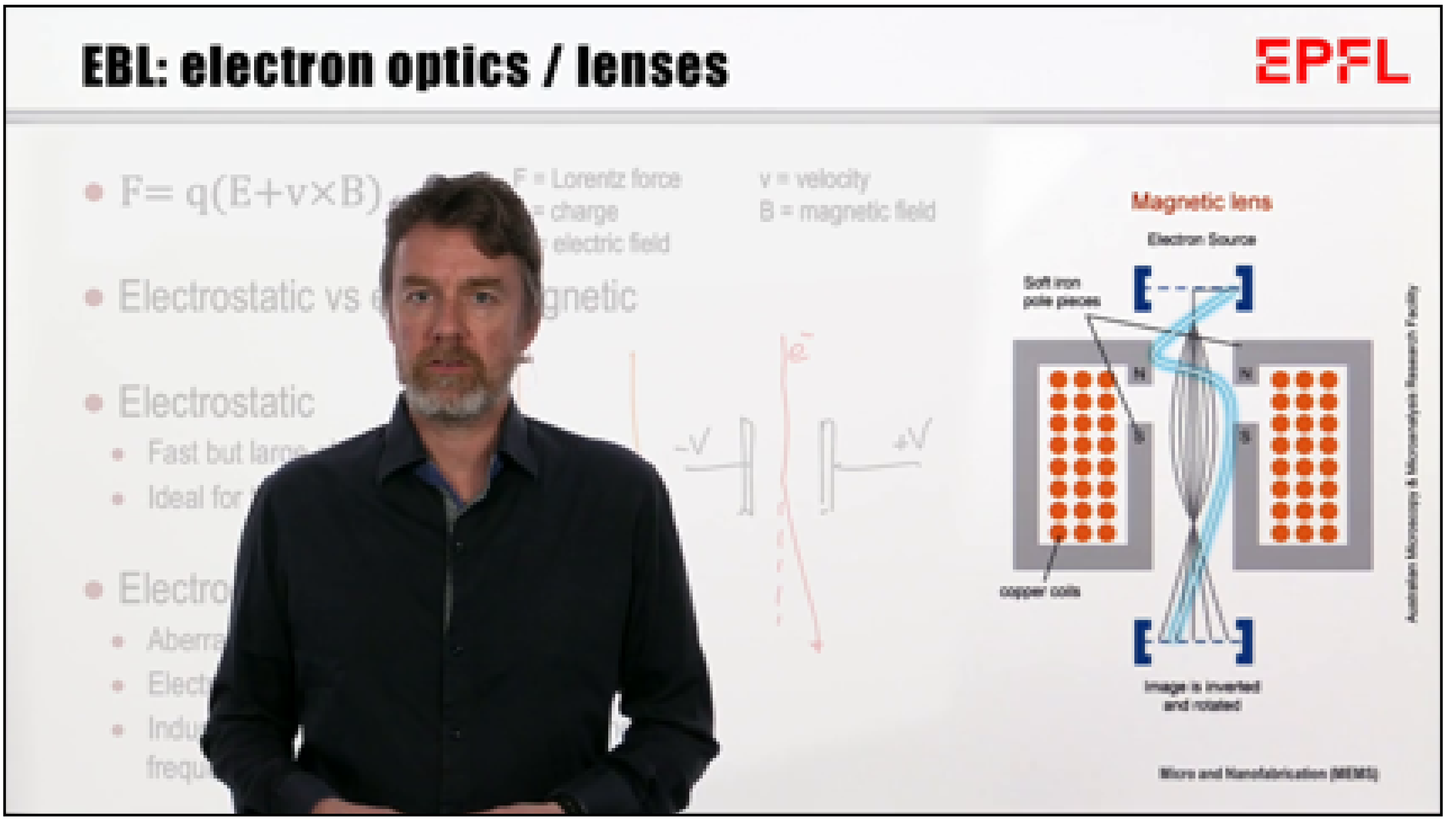


They have a high operation speed, but they have also large aberrations. Therefore, electromagnetic lenses are used for beam shaping. A magnetic lens is formed from two circularly symmetric iron, or some other high permeability material, pole pieces with a copper winding in between. A divergence of the magnetic flux along the z-axis

notes

summary

0m 50s

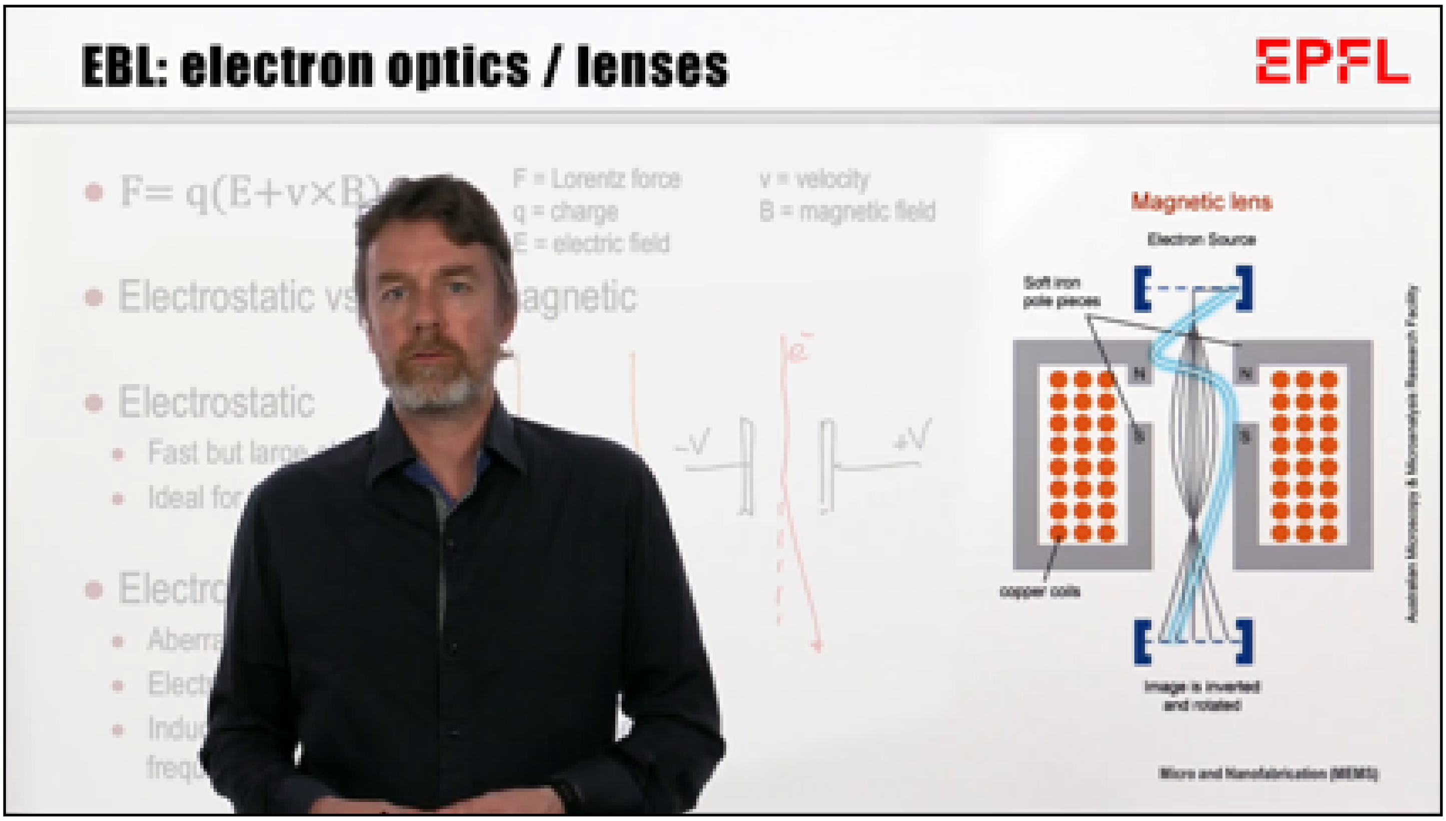


applies a force on the electrons back towards the z-axis, resulting in focusing action.

notes

summary

1m 13s

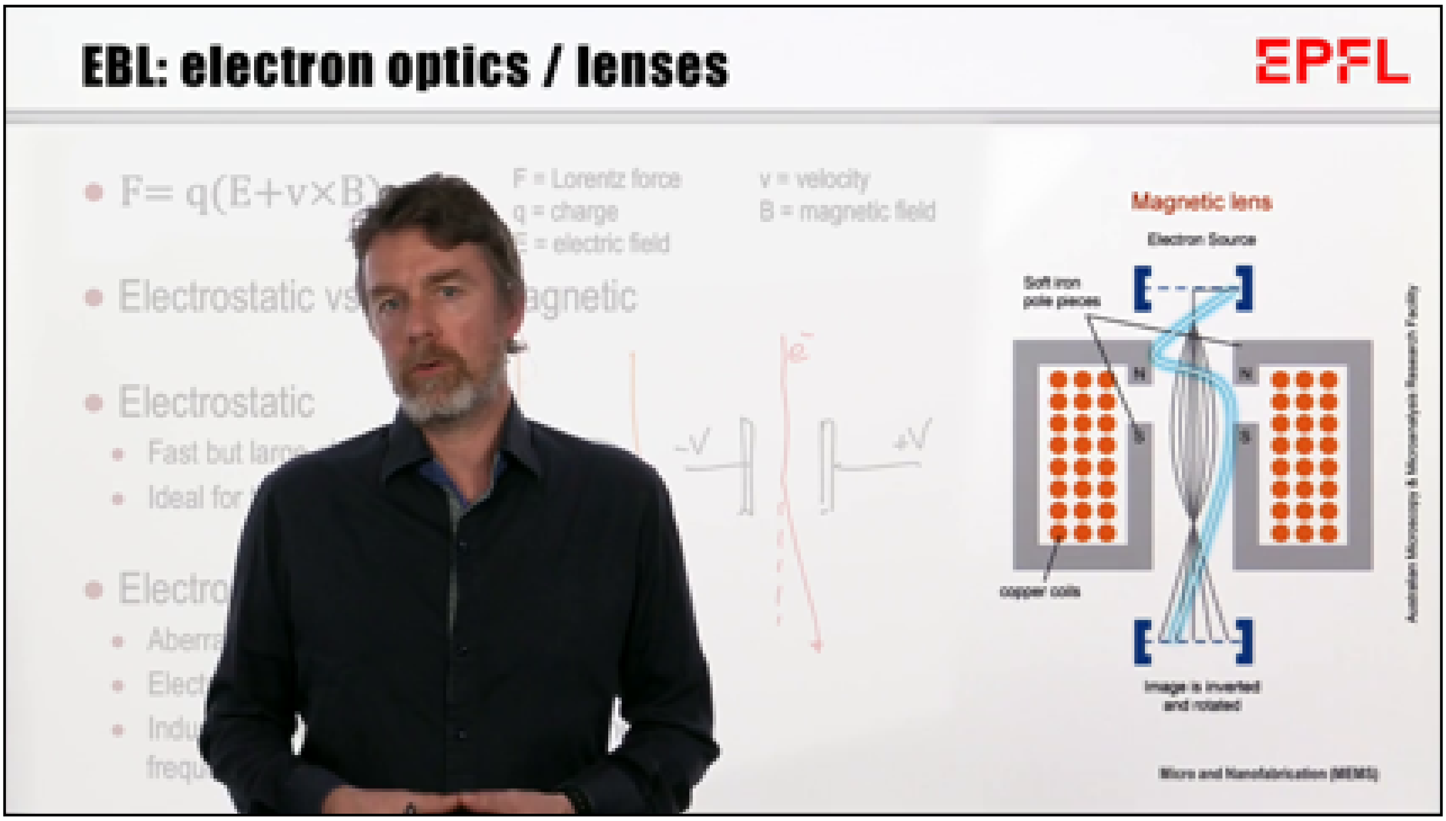


The magnetic field also causes a rotation of the electrons and the image. about the z-axis in a cork screw fashion.

notes

summary

1m 19s

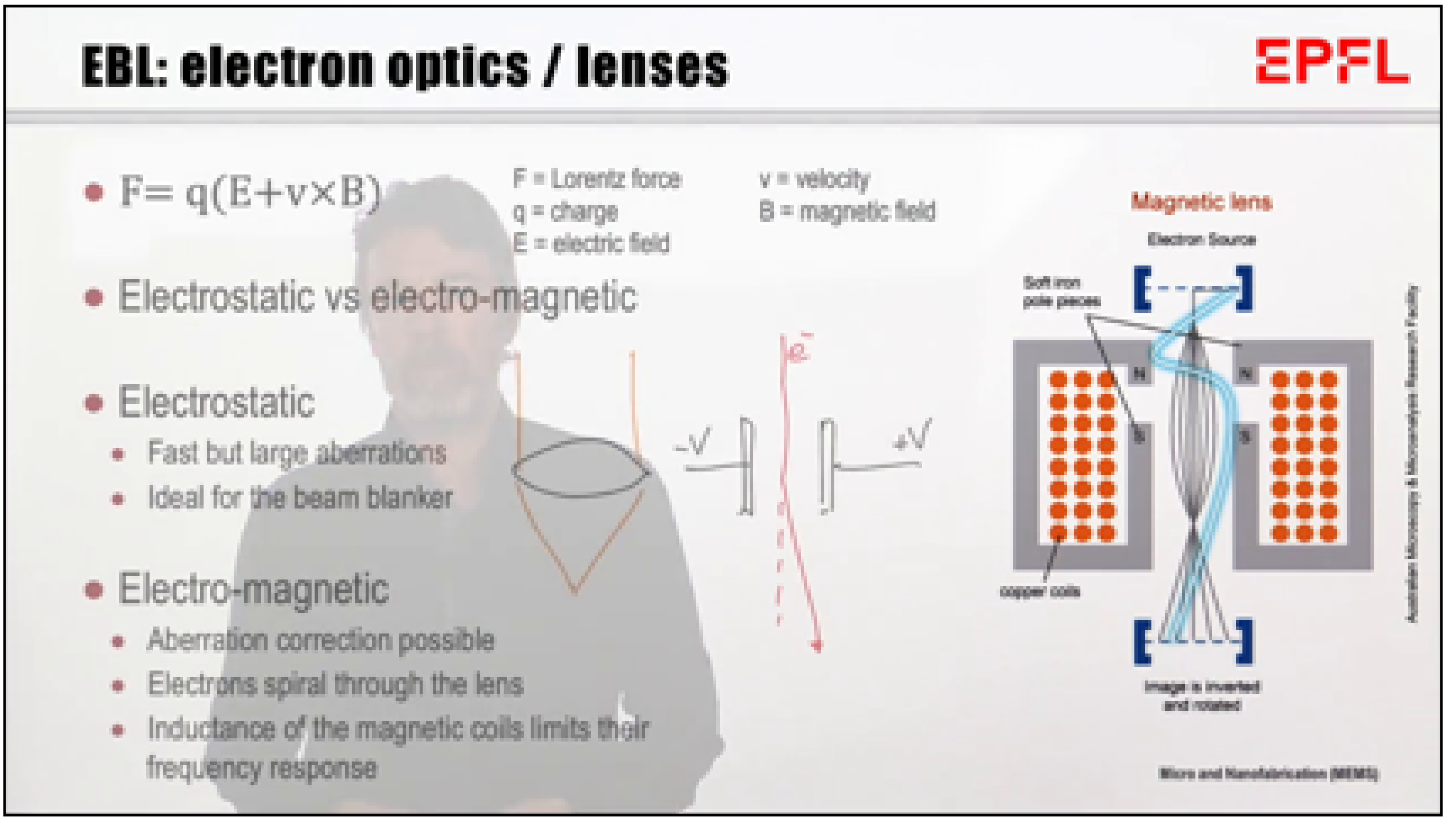


Although this does not affect the performance of the lens, it does impact the design, alignment and operation of the system. For instance, the deflection system must be rotated physically with respect to the stage coordinates. Also when aligning a column, x and y displacement in the upper region of the column will not correspond

notes

summary

1m 27s

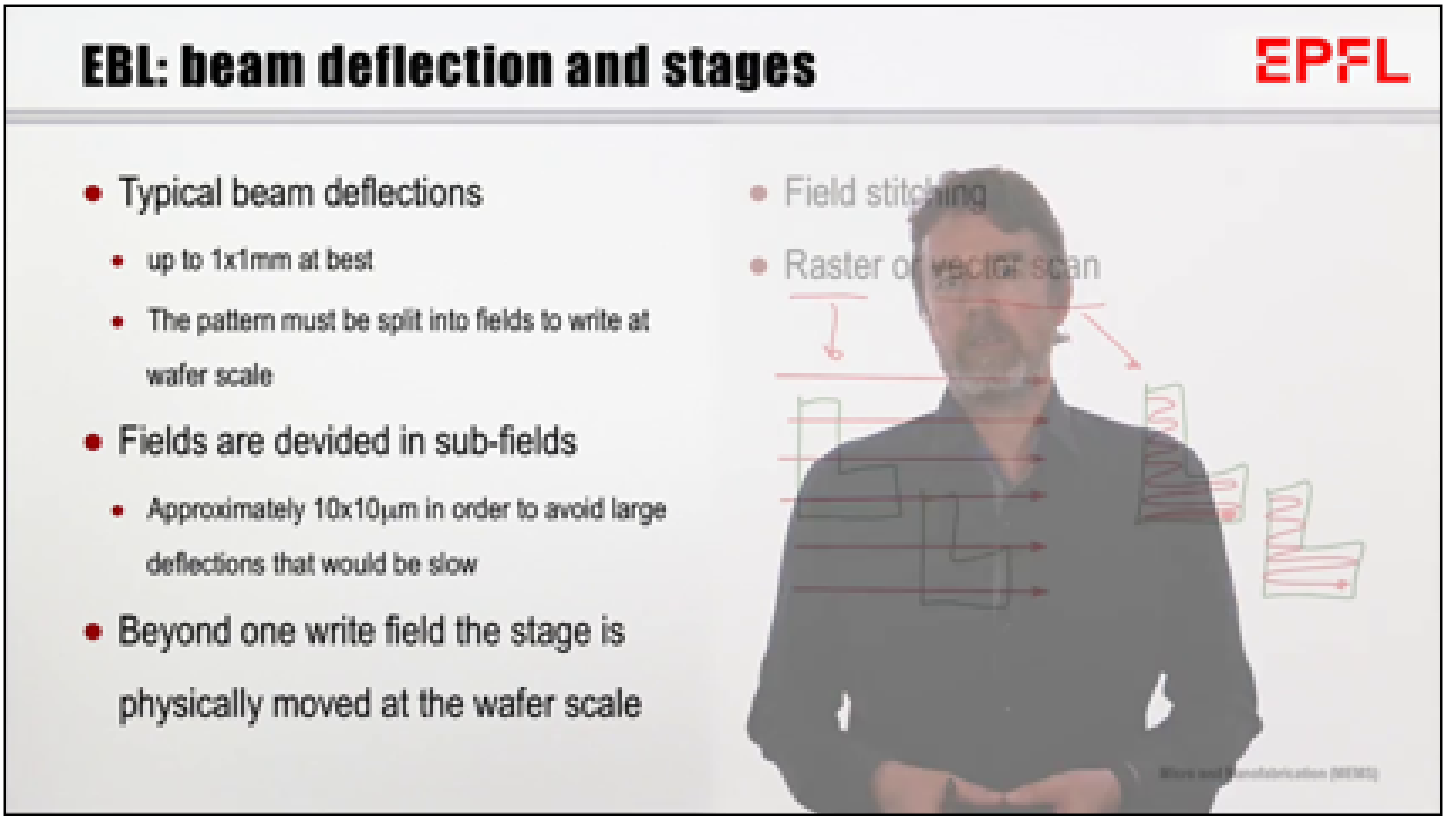


to the same x and y displacement at the target. And finally, changes in focus or changes in the height of the sample can cause a slight rotation in the deflection coordinates.

notes

summary

1m 49s

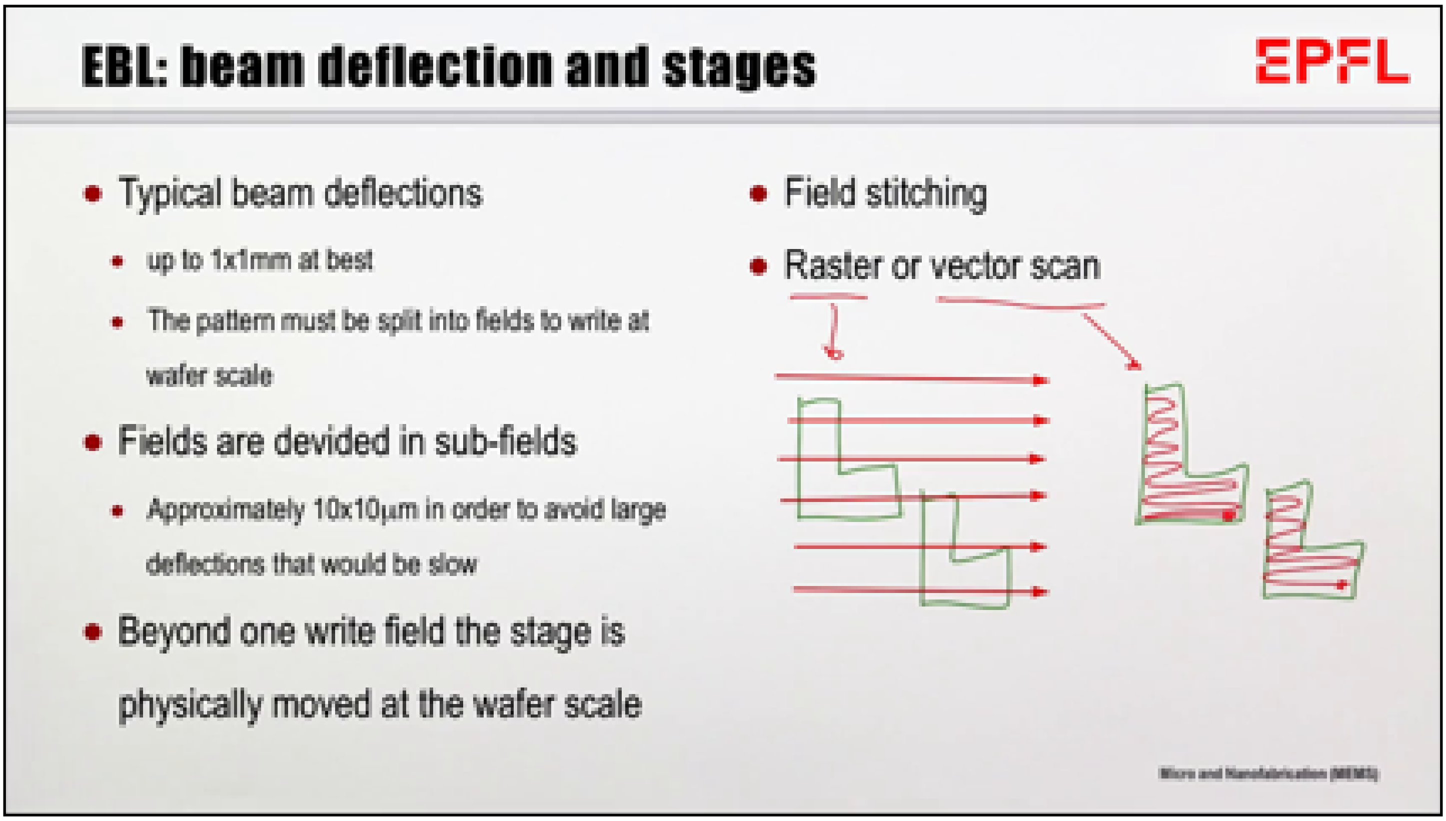


This must be properly corrected or stitching and overlay errors will result. The electron beam may be deflected over a range of typically from a few tens of micrometers up to a millimetre. Writing a larger area requires that the stage is physically moved to reach a neighbouring region and ultimately to write the entire wafer surface. This writing region is called a field that is itself divided into subfields. The main fields correspond to the maximum beam deflection range and if you choose a certain beam step size, the tool can only handle a finite number of pixels. If the step size is too small, then the field size is limited to the beam step size times the maximum number of pixels. Deflecting an electron beam across main fields that are hundreds of microns in size is associated with very large electric or magnetic coils and correspondingly with big settling times due to the larger fields that need to be applied, which at the end will slow down the writing process. In order to increase writing speed, an additional subdivision of the pattern into trapezium subfields is implemented into the system. These fields are approximately two orders of magnitude smaller and inside them, the electron beam is raster scanned at very high speed by another set of coils. These coils are much smaller due to the small deflection they need to exert and thus, their settling time is also much smaller compared to the main field ones. Beyond fields, the sample is mechanically moved, so a high resolution stage is typically allowed for resolutions below the nanometre. However, mechanical stage drifts result in possible mismatch at the field boundaries known as field stitching.

notes

summary

2m 0s

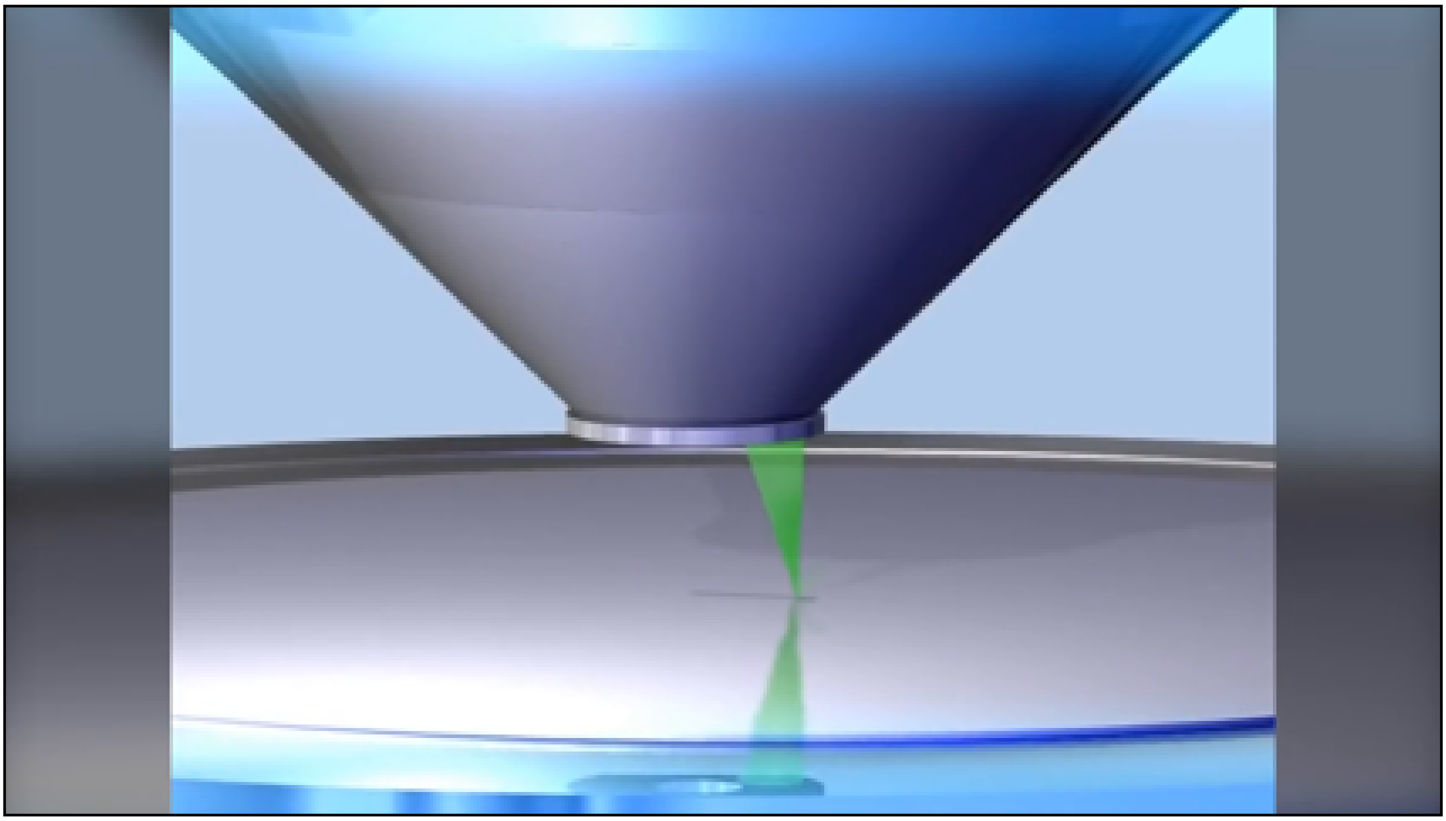


As you will see, different methods exist to manage field stitching and within a single field, different writing strategies are possible.

notes

summary

3m 49s



Either raster scanning, like shown here, or vector scanning, like shown here. The raster scanning, one wants to expose the green parts. One raster scans the electron beam and blanks it on and off when it passes over the design area. Whereas the vector scan is that the electron beam is already steered to only expose the area that has to be written. Here we can see an animation of a field stitching approach, where the stage is mechanically moved between two writing fields and where the alignment is very critical. Another strategy involves a fixed electron beam and a continuous stage movement. This way, no field stitching is involved, resulting in continuous patterns, but this method is much slower.

notes

summary

3m 57s