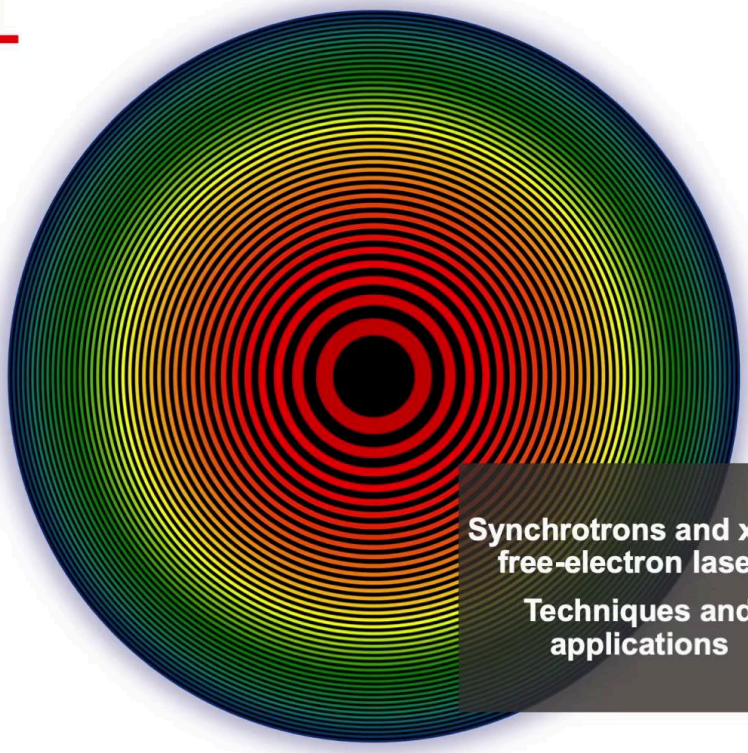
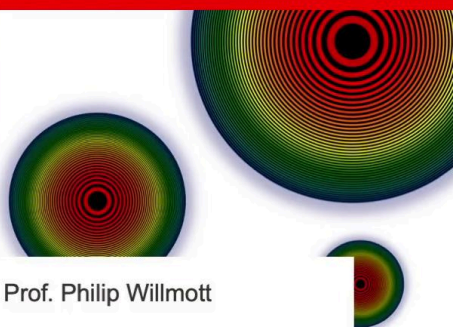
EPFL

Beamlines: Secondary optics (Part 3)

Synchrotrons and x-ray free-electron lasers

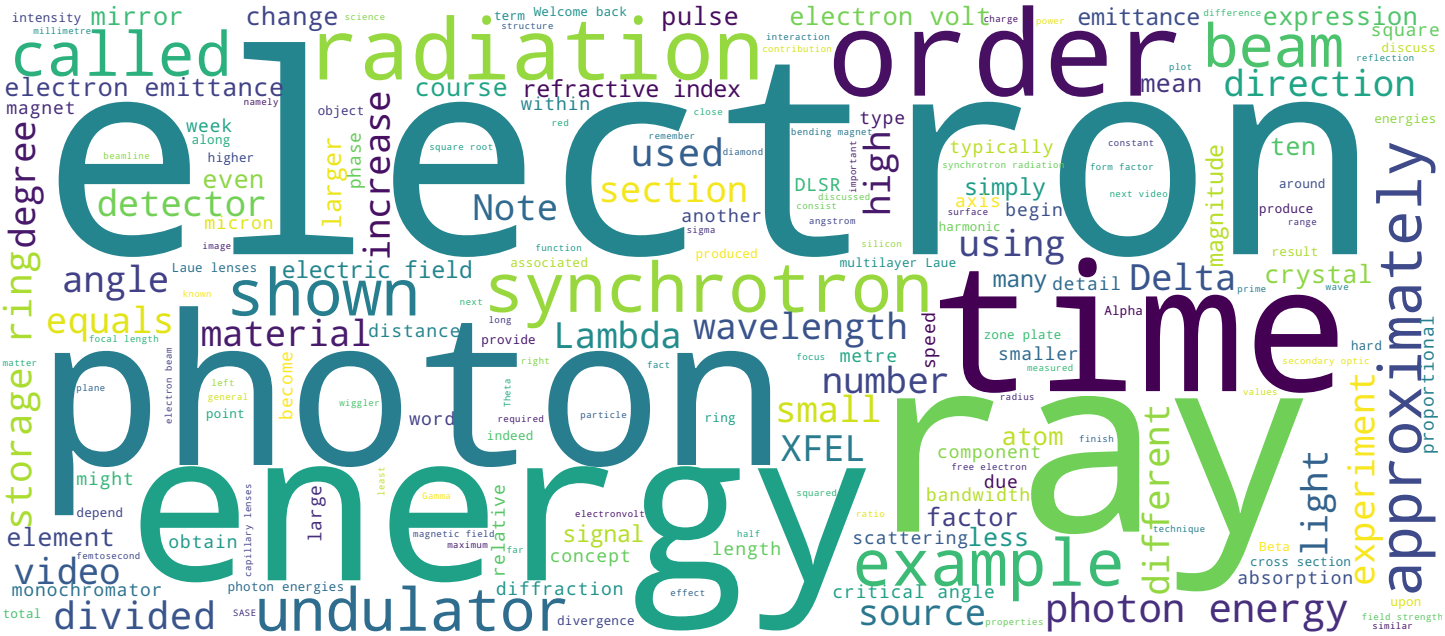
Techniques and applications





École polytechnique fédérale de Lausanne

Prof. Philip Willmott



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Contents and objectives of this video

- Capillary lenses
  - Tapered
  - Parabolic
  - Polycapillaries
- Multilayer Laue lenses

Welcome back again. In this last video about secondary micro focusing optics, we discuss capillary lenses, of which there are three major types, and multilayer Laue lenses.

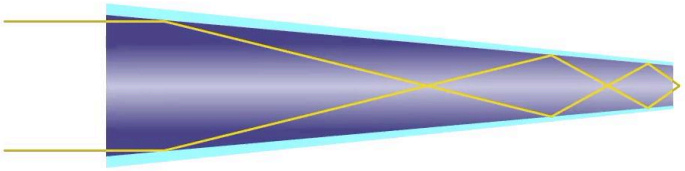
Notes

Summary

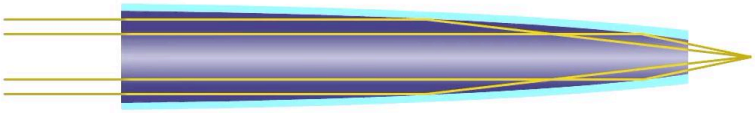
0m 04s

Capillary lens types

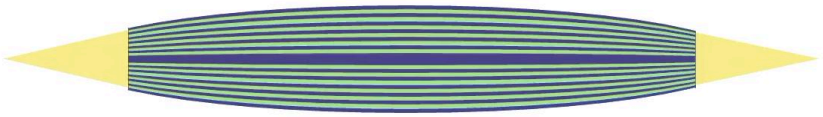
- Tapered



- Ellipsoidal/paraboloidal



- Polycapillary



The three capillary lens types are: One, the tapered or funnel type; two, the ellipsoidal or paraboloidal type; and three, the polycapillary.

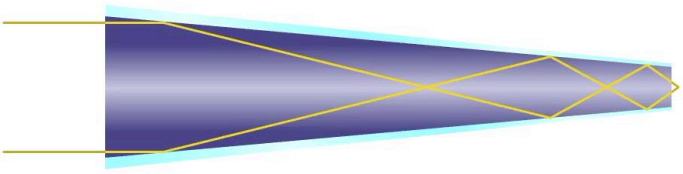
Notes

Summary

0m 18s

Tapered capillary lenses

- Multiple reflections
- $\alpha_n = (2n-1)\alpha_1$ up to α_c
- Coat inner surface with high-Z material
- Cheap
- Poor focus
- Small working distance



Tapered capillaries were the first type to be developed at Cornell University in 1994. The concept is very simple, whereby radiation is funnelled down the conically shaped capillary by multiple reflections. Each reflection increases the incident angle for the next reflection by two Alpha, where Alpha is the incident angle of the first bounce. This can only continue up to the critical angle for total external reflection. Hence, the inner surface tends to be coated with high-Z materials. Tapered capillaries are cheap to fabricate and are achromatic, at least up to the critical angle, making them also low pass filters for broadband radiation. On the negative side, they provide a poor focus quality and have very limited short working distances of a few tens of the exit diameter of the capillary.

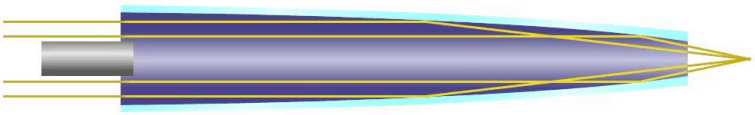
Notes

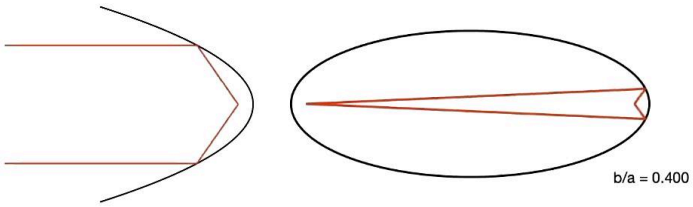
Summary

0m 35s

Ellipsoidal/paraboloidal capillary lenses

- Ellipsoidal for divergent source
- Paraboloidal for parallel incident beam
- Single reflection
- Ray optics predicts point focus ⇒ good focus, limited by wave optics





Parabolic reflective focussing

Elliptical reflective focussing

Recently, ellipsoidal and paraboloidal capillary lenses have come onto the market. They are single bounce devices used for accurate focusing down to the tens of nanometre range, limited primarily by wave optics and diffraction effects. They are highly efficient, although one must block the central part of the incident beam in order to avoid this passing through the capillary without being reflected. Elliptical profiles are used for incident radiation that is divergent, while the paraboloidal form is employed for quasi-parallel incident beams. To manufacture such capillaries with high quality is extremely challenging, and these devices are, consequently, extremely expensive.

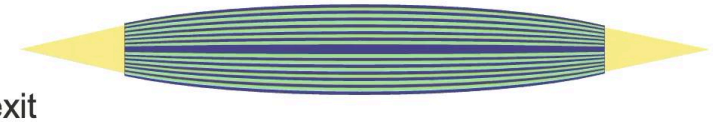
Notes

Summary

1m 40s

Polycapillary lenses

- Also called Kumakhov lenses
- Bundled capillaries
- Ends of bundles point towards source and sample
- Each capillary does not focus – exit radiation has same divergence as entering beam
- “Illumination” optics (c.f. fiberoptic microscope illuminator)



Polycapillary lenses, also known as Kumakhov lenses, are similar in concept to fiberoptic light pipes, such as used for microscope illumination or in endoscopic medical instruments. They consist of channels of low refractive index bundled together, which thus channel X-radiation along them. Each individual capillary doesn't actually focus the X-rays, and the collected radiation has the same divergence as the entering beam. Use of these lenses is relatively rare.

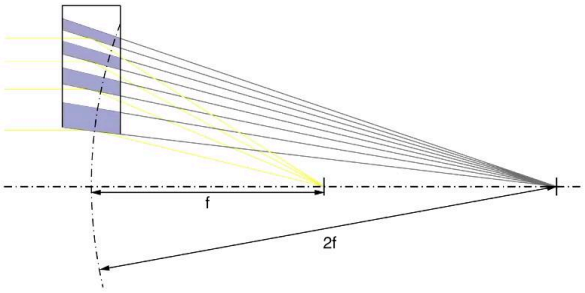
Notes

Summary

2m 33s

Multilayer Laue lenses

- Wedged multilayers
  - Converge @ 2f
  - Focus @ f
  - Wedge thicknesses follow FZP condition (see previous video)
- Fabrication
  - Wedged multilayers by sputter deposition or pulsed laser deposition
  - Slice perpendicular to layers
  - Extremely thin outer layers possible
  - Focus down to nm-range with high NA



See also K. T. Murray *et al.*, https://doi.org/10.1364/OE.27.007120

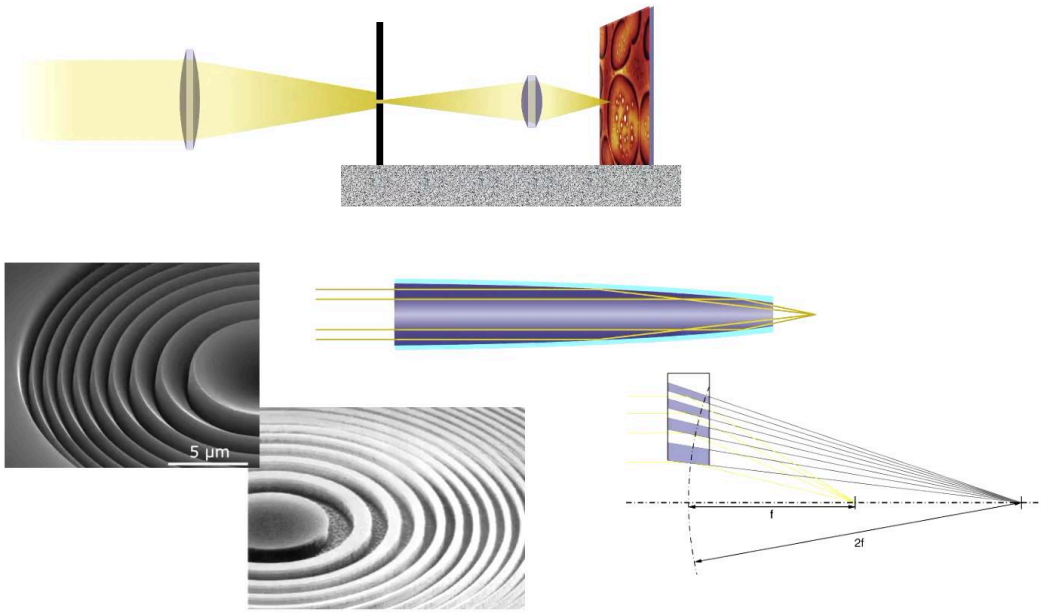
We finish this section on secondary optics with a brief description of multilayer Laue lenses. These consist of wedged multilayers with a common wedge origin positioned at 2f relative to the lens. Reflection from the higher density wedges results in a focus at f. The wedge thicknesses follow the same conditions set by Fresnel zone plates. The fabrication of multilayer Laue lenses is typically through sputter deposition or, less commonly, pulsed laser deposition. The deposited layers are sliced perpendicularly. They allow focal spots down to the nanometre range.

Notes

Summary

3m 11s

Summary of this section



To summarise this section, we have discussed some of the pressing reasons why secondary optics are necessary, including vibrations and the small space often required by the secondary optic element when focal length of less than approximately 10 cm are required. We then looked in detail at the most common micro focusing devices, including compound refractive lenses and kinoform lenses; Fresnel zone plates and phase zone plates; capillary lenses and multilayer Laue lenses.

Notes

Summary

4m 01s

In the next section...

In the following and last section of the first course, we'll look at detectors at synchrotron beamlines, including both photon and electron detectors. We will begin the section with a discussion of noise, and how one should handle it.

Notes

Summary

4m 39s