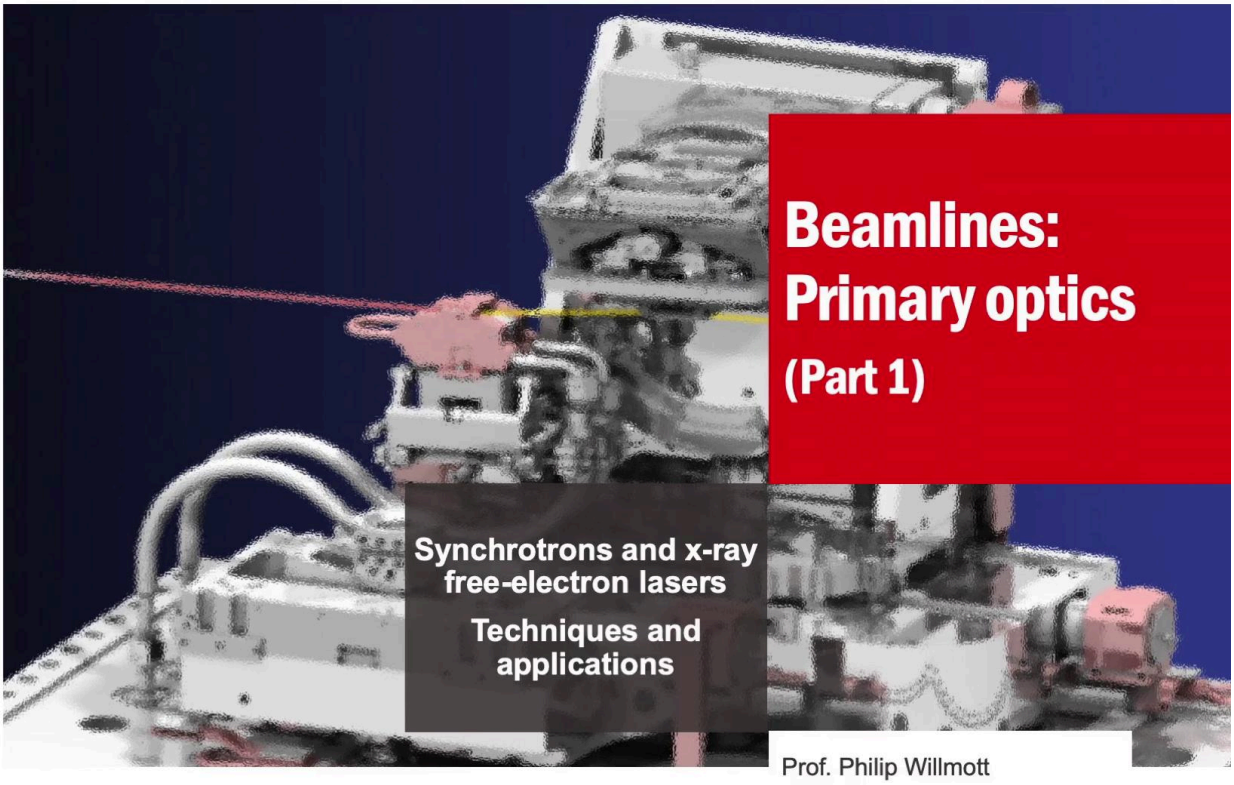

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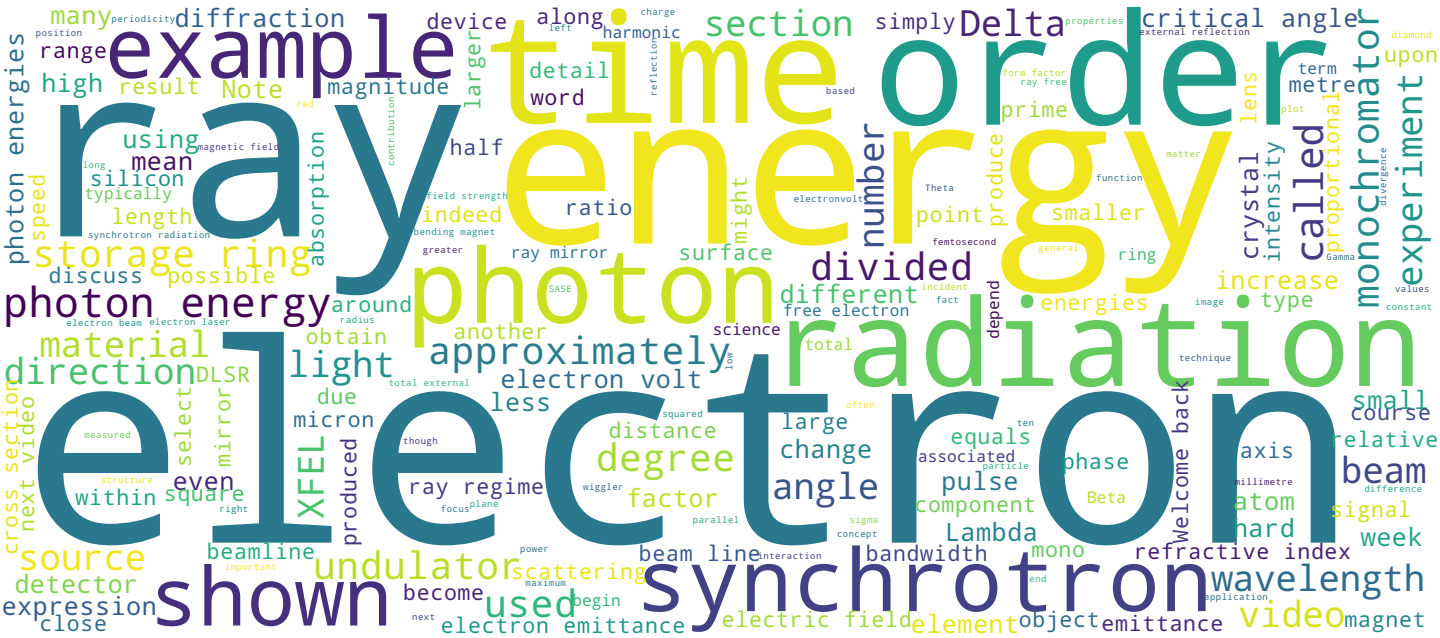


EPFL

Contents and objectives of this video

- Primary optics
  - Function
  - Mirrors
  - Monos

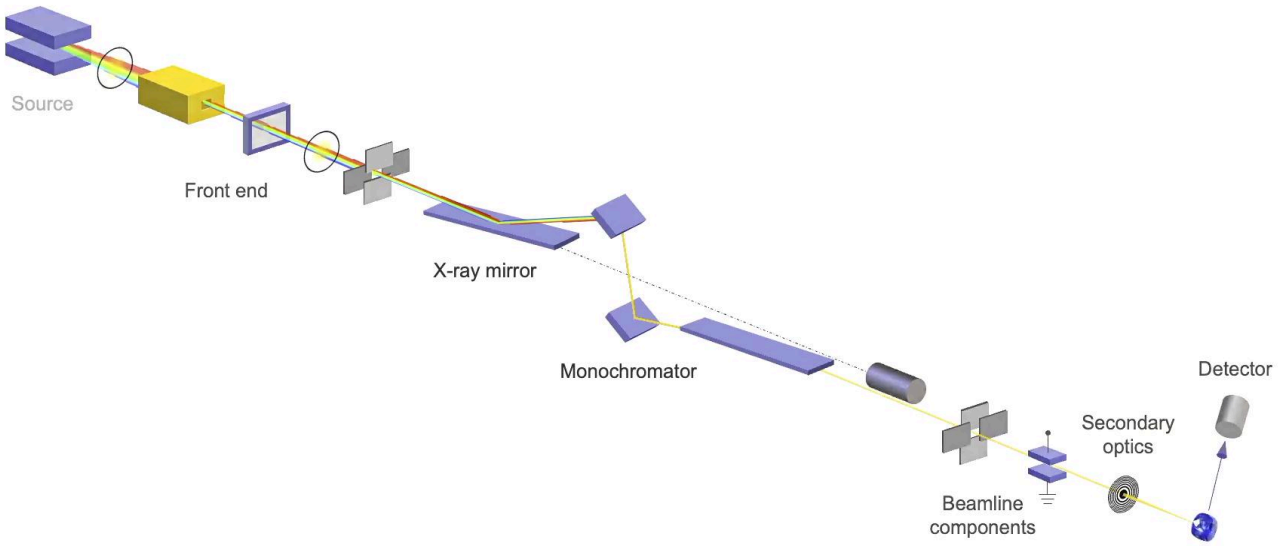
Welcome back. We're now beginning the second section of week five of this course, synchrotrons and X-ray free electron lasers, techniques and applications. We're now going to look at the practical aspects of primary optics design, namely X-ray mirrors and monochromators.

Notes

Summary

0m 05s

Primary optics



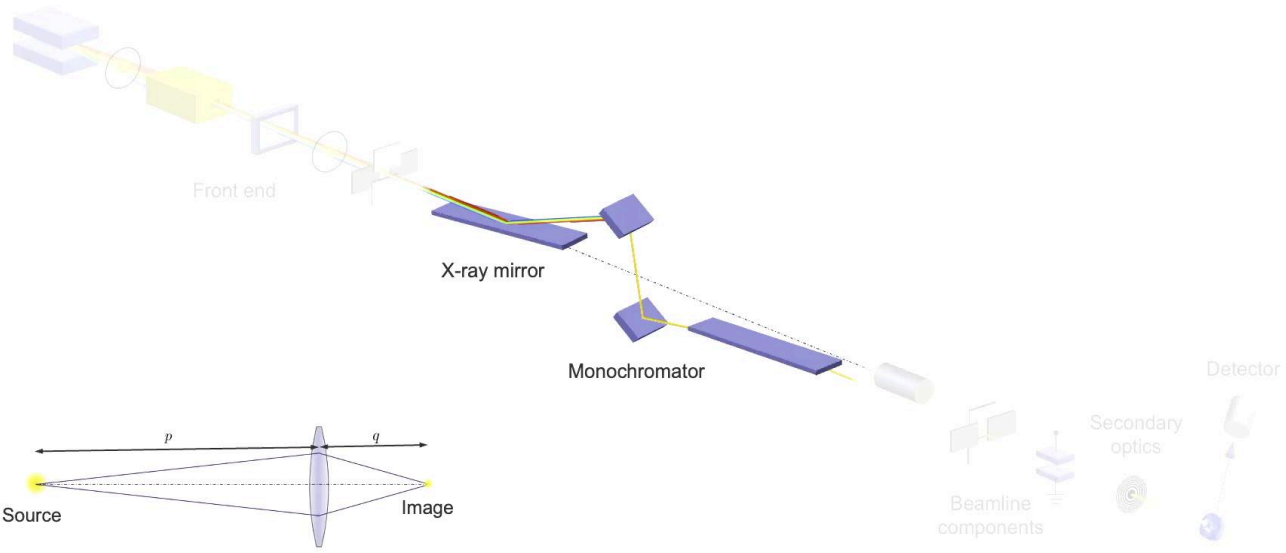
The primary optics are typically placed after the front end.

Notes

Summary

0m 24s

Primary optics



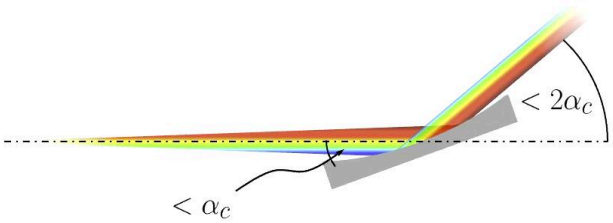
In this schematic shown here, there are two mirrors separated by a single monochromator. Each beam line will have different needs. Some have no mirrors, others have as many as four. Another beam line might not have one, but two monochromators, or different set of crystals within a single monochromator mechanism. Another highly variable parameter is the position of the mirrors and monos. Mirrors that collimate the unfiltered beam might be fairly upstream, close to the front end, and certainly before the monochromator. Mirrors that refocus are often as close to the sample as possible in order to produce as high a de-magnification of the X-ray source as possible. Remember, the ratio of the source to image size when using focusing optics is equal to the ratio of the source to lens distance p, divided by the lens to image distance q.

Notes

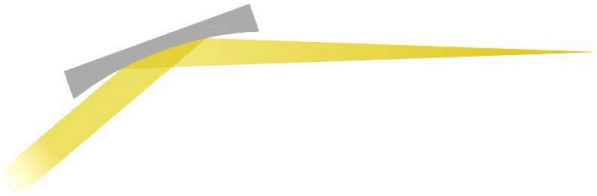
Summary

0m 28s

X-ray mirrors – primary functions



- Before monochromator
  - Change propagation direction (reflection)
  - Higher harmonic/higher photon energy suppression
  - Collimation
  - Thermal management



- After monochromator
  - Change propagation direction (reflection)
  - Focussing
  - Harmonic suppression

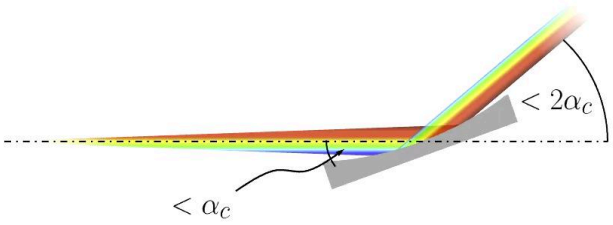
X-ray mirrors are used for different purposes. The first most obvious application is simply reflection of an incoming X-ray beam through an angle up to twice the critical angle for total external reflection. The critical angle is, even for soft X-rays, only a couple of degrees, while it can be less than a 10th of a degree for mirrors made of low Z material such as silicon or quartz in the hard X-ray regime. Importantly, for a given incident angle Alpha, this will be lower than the critical angle Alpha_C for lower energy photons, but greater than Alpha_C at some higher photon energy. This is because, as you might remember, the critical angle for total external reflection is inversely proportional to the photon energy. This means that mirrors can act as a low pass filter and so suppress the higher photon energies. Bendable or fixed parabolic or cylindrical mirrors placed before a monochromator are often used, especially at beam lines that practise X-ray spectroscopy in order to collimate the beam as much as possible to optimise the energy resolution of the monochromator. The monochromator itself has a lower fundamental limit to the angular range it can accept that is not infinitely narrow.

Notes

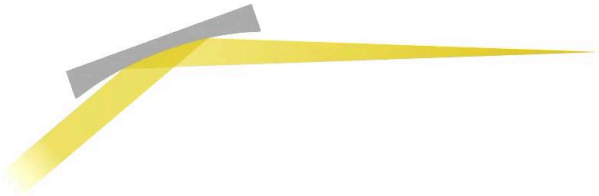
Summary

1m 31s

X-ray mirrors – primary functions



- Before monochromator
  - Change propagation direction (reflection)
  - Higher harmonic/higher photon energy suppression
  - Collimation
  - Thermal management



- After monochromator
  - Change propagation direction (reflection)
  - Focussing
  - Harmonic suppression

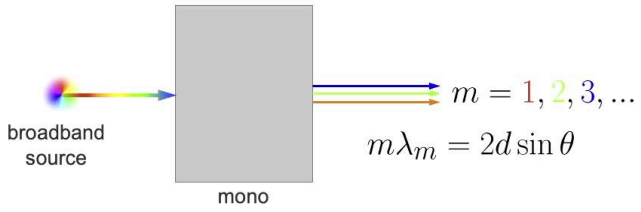
Hence, the degree of collimation of the beam upstream of the monochromator needs only be comparable to the natural acceptance angle of the mono. For example, the natural so called Darwin width of a Silicon 111 monochromator in the hard X-ray regime is approximately 20 micro radians or 0.001 degrees. And therefore, collimation of an incident beam on such a mono does not have to be much superior to this. Maybe 10 micro radians or half a millidegree. Mirrors downstream of the mono can also be used to focus the X-rays either to produce a secondary source or directly onto the sample.

Notes

Summary

3m 01s

Monochromators – primary functions



- Selection of narrow bands of wavelengths from broader-band source
- Bragg's law
  - Describes diffraction
    - Heart of mono is a periodic structure (d)
      - Crystal
      - Grating
      - Multilayer
  - Lowest energy, $\lambda = \lambda_1$ (long wavelength)
  - Integer multiples of energy ($\lambda_m = \lambda_1/m$)
    - "Harmonics"
- Selection of single narrow band using several approaches (see later)

Monochromators are used to select a narrow band of incoming radiation. This is typically achieved by diffraction of the incident broadband source using gratings for beam lines, using soft X-rays or crystals or multilayers in the hard X-ray regime. The selected photon energies of all such devices are based on the famous Bragg equation, m Lambda equals 2d sine Theta, where d is the repetition length or periodicity of the diffracting element. This diffraction phenomenon will not only select one narrow band of energies, but also integer multiples of that energy, in so called higher harmonics. In order to then select only one of these harmonics, usually the fundamental for which m is equal to one, though not always, additional measures need to be taken, which I will describe towards the end of this section.

Notes

Summary

3m 48s

In the next video...

In the next video, we look in more detail at X-ray mirrors.

Notes

Summary

4m 51s