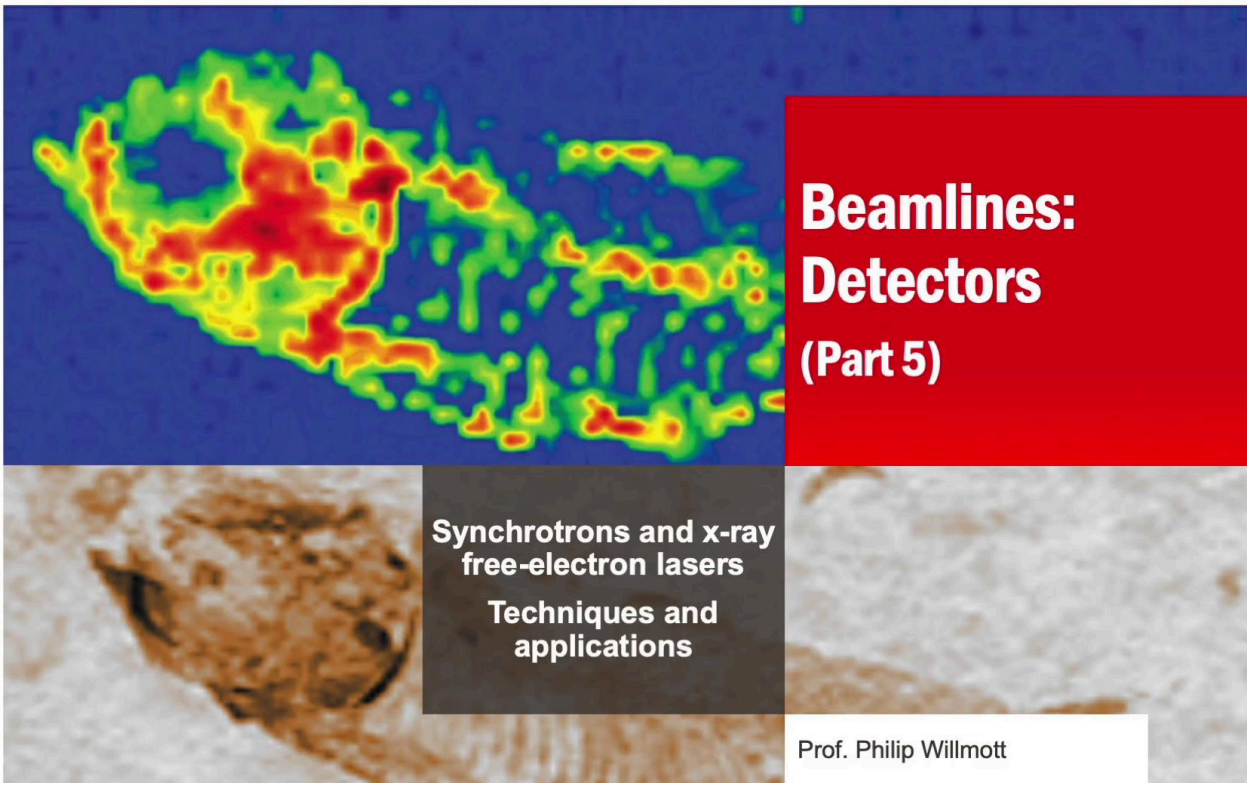
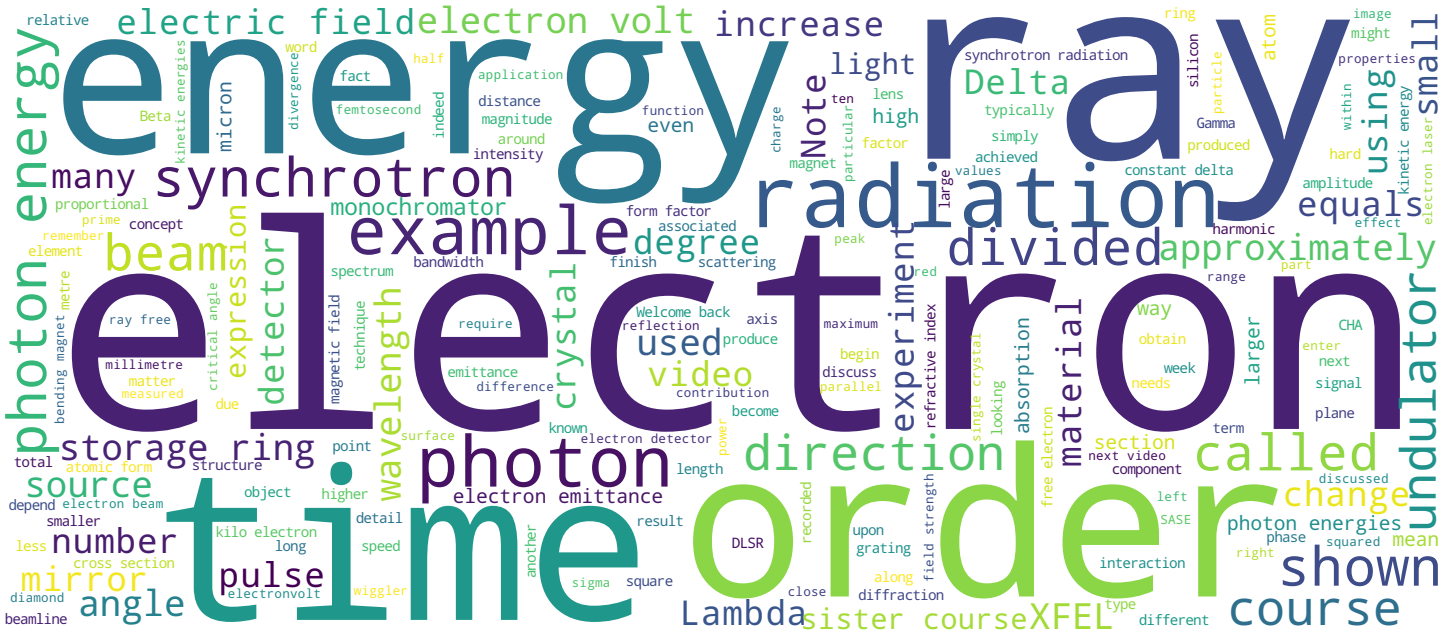



École polytechnique fédérale de Lausanne




Search MOOC

Video

EPFL

# Contents and objectives of this video

- Dispersive detectors
  - Photon detectors
  - Electron detectors
- Taster of and connections to the second course

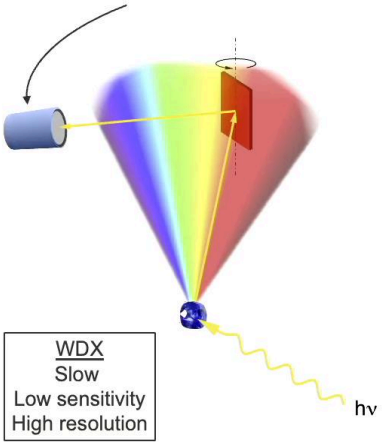
Welcome back to this, the last video, of this first course on synchrotron radiation and its applications. We begin by looking at detectors that distinguish photon energies to provide spectral information, and the electron detector called a concentric hemispherical analyzer, which is used to determine electrons kinetic energies. We will finish by taking a brief look at the contents of the second course and how the contents of this course is applied.

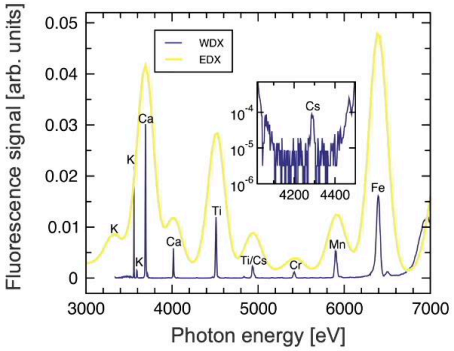
Notes

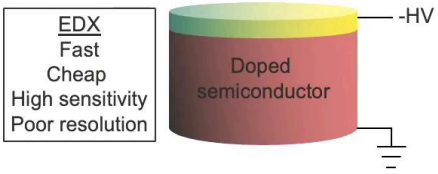
Summary

0m 05s

# Dispersive photon detectors



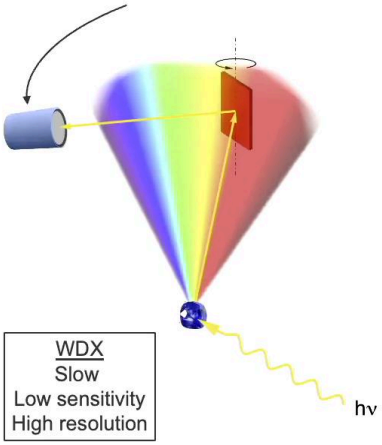

In many spectroscopic experiments. Not least in X-ray fluorescence, the spectrum emitted by an Irradiated sample is of interest, for which one requires a dispersive set up. Spectral analysis of an X-ray spectrum, such as in X-ray fluorescence is achieved in one of two ways. In wavelength dispersive spectrometers WDX or WDS. The photon energy is selected by diffraction on a single crystal or a grating in much the same way as in crystal or grating monochromators. In the most rudimentary form, WDX spectrometers are both slow because of the need to scan the brag angle and produce weak signals. Due to the fact that only a very small fraction of the fluorescence is emitted in a direction which meets the brag condition on the spectrometer crystal or grating. In most cases, however, the signal to noise ratio can be improved by using spherically or cylindrically curved diffraction crystals or gratings, such as described in last week's videos. Its main advantage is that it has a high resolution. In contrast, energy dispersive spectrometry. The photon energies are converted into voltage spikes with amplitude, which are proportional to the photon energy. Within doped semiconductor devices.

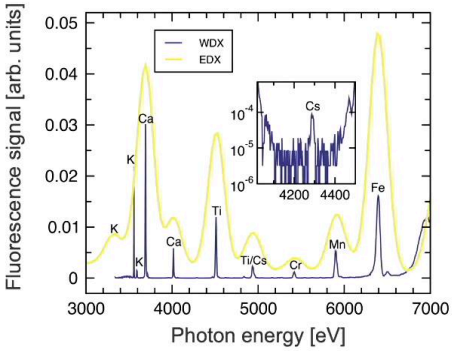
Notes

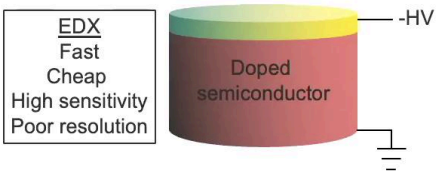
Summary

0m 39s

# Dispersive photon detectors



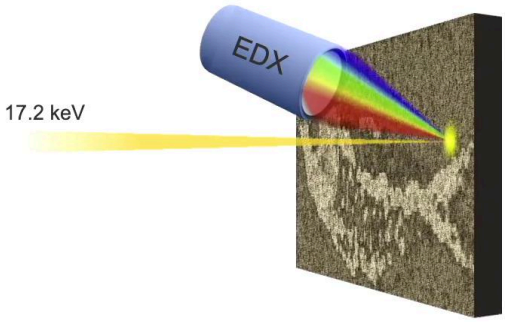

Different energies can be recorded in parallel, and the detector can capture a large angular cross section. EDX is as cheap, fast and highly sensitive though it has a resolution two orders of magnitude worse than in WDX. A comparison between EDX and WDX spectra for a claim mineral shows this dramatic difference.

Notes

Summary

2m 15s

# Dispersive photon detectors




EDX scan, selecting Th Kα @ 12.97 keV

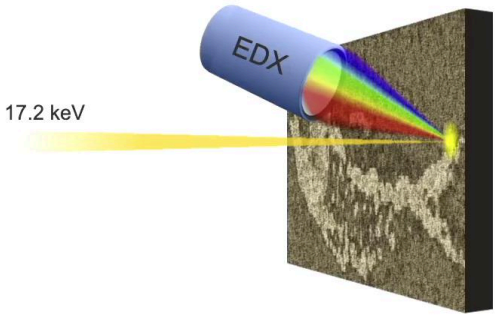
A nice example of an experiment using EDX is shown here of a fossil fish excavated from the Green River formation of Fossil Lake in Wyoming. The sample was irradiated with focused 17.2 kilo electron vault X-rays and the fluorescent signal recorded as the fossil sample was rested.

Notes

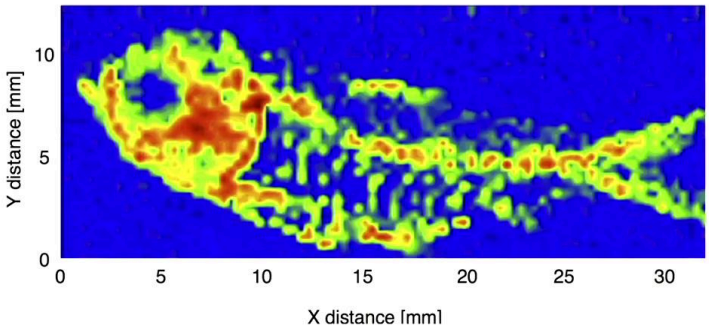
Summary

2m 39s

# Dispersive photon detectors




EDX scan, selecting Th Kα @ 12.97 keV




Fluorescence map @ 12.969 keV, Th Lα emission line

Courtesy Prof. Troy Rasbury, Stony Brook University

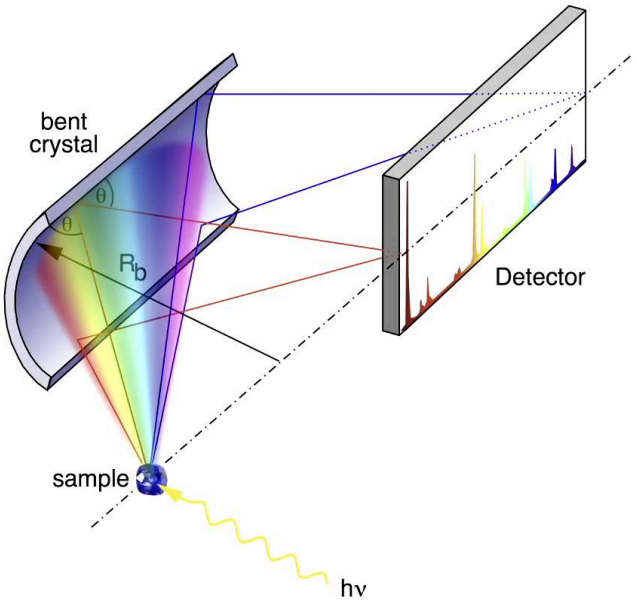
Shown here is the result of selecting a narrow section of the EDX spectra at 12.97 kilo electron volts corresponding to the thorium L Alpha fluorescence signal. The high levels of thorium are caused by its substitution for calcium in the phosphate mineral that composes the bone floor appetite, seen prominently around the gills and along the backbone.

Notes

Summary

3m 04s

# Von Hamos detectors




- Cylindrically bent analyzer crystal
  - Radius $R_b$
- Sample and detector lie on cylinder axis
- Bragg diffraction ⇒ spatial dispersion of fluorescence signal
- Used for high-resolution and time-resolved x-ray emission studies

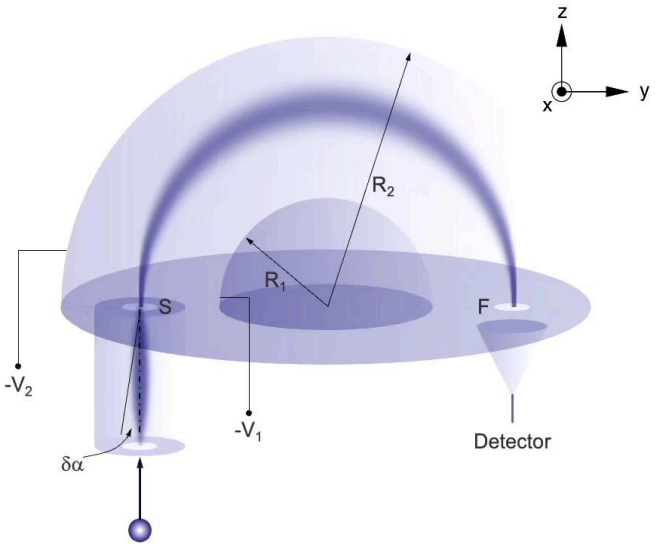
The Von Hamos detector uses a geometry shown schematically here. It combines significant light gathering and spatial dispersion capabilities, allowing parallel spectral data acquisition. This geometry thus lends itself to high resolution, time resolved X-ray emission studies. The emission source and a strip or area detector lie on the cylinder axis of a Crystal bent to a radius Rb. The spectrum of the source is spatially dispersed onto the detector by the different incident brag angles theta on the crystal surface. Bending the crystal improves the guides light gathering power.

Notes

Summary

3m 30s

# Electron energy detectors - CHAs




- Concentric hemispherical analyzer
  - Two hemispheres $R_1$ and $R_2$ at potentials $-V_1$ and $-V_2$

$$\Delta V = V_2 - V_1$$

- Note: electron can enter CHA at S at any angle in the *x-z* plane

$$e\Delta V = E\left(\frac{R_2}{R_1} - \frac{R_1}{R_2}\right)$$

$$E = \kappa e \Delta V \qquad \kappa = \frac{R_1\, R_2}{R_2^2 - R_1^2}$$

- Acceptance angle $\delta\alpha$ in *y-z* plane determines spectrometer resolution

$$\frac{\Delta E}{E} = \frac{2W}{R_1 + R_2} + (\delta\alpha)^2$$

The kinetic energies of electrons can be determined using, concentric hemispherical analyzers, or CHAs. A schematic of a CHA is shown here. Two metallic hemispheres of radius R1 and R2 are positioned concentrically. The inner and outer hemispheres are floated to the negative potentials minus V1 and minus V2, respectively. An electron entering the CHA approximately parallel to the equity potential surfaces with a kinetic energy E will be focused at the exit to the detector. If the expression provided here is met. Note that the electrons can enter the spectrometer at any angle in the X-Z plane and still arrive exactly at the exit to the detector. This is not so for the perpendicular Y-Z plane. Suppose that the electrons are injected at an angle Delta Alpha to the entrance aperture normal in the Y-Z plane. For entrance and exit apertures of the same width W. The resolution of the spectrometer is given by the equation highlighted here.

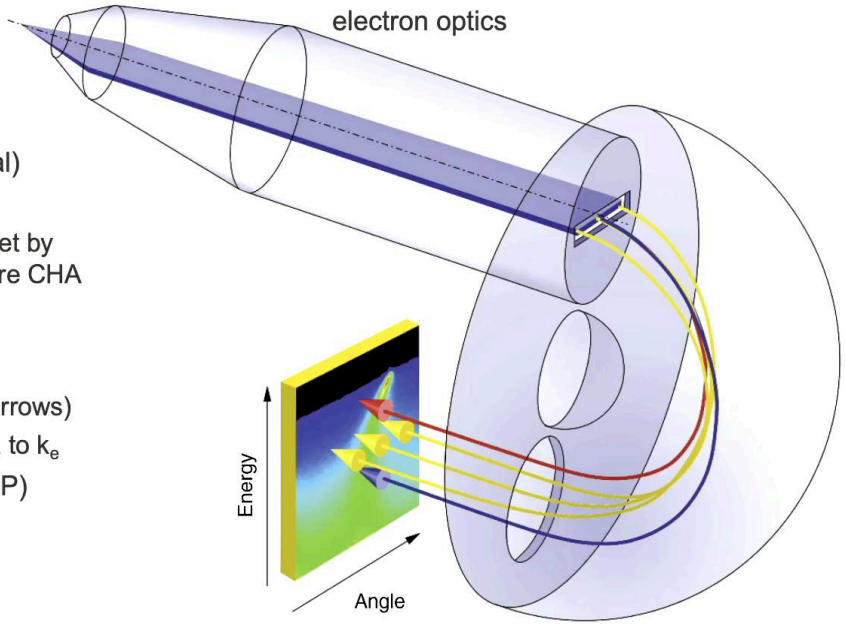
Notes

Summary

4m 17s

# Electron energy detectors - CHAs

- Recording modes
  - Constant ΔE/E (unusual)
  - Constant ΔE
    - Pass energy $E_{pass}$ set by electron optics before CHA
- New developments
  - Area detector
    - Angle ≡ $k_e$ (yellow arrows)
    - Different energies ⊥ to $k_e$
  - Multichannel plate (MCP)
    - Resolution ~ meV
  - Large increase in data collection rates




Spectra of electron energies can be recorded with either a constant delta E divided by E or a constant delta E. Spectra taken with a constant delta E upon E therefore show signals with wits that are directly proportional to their electron energies. More commonly, it is desired that the instrumental peak which remain constant in any given spectrum, and the constant delta E mode is chosen. This is achieved by accelerating or decelerating the electrons within the electron optics immediately before entering the CHA to a fixed energy value known as the past energy, which typically lies at around 50 to 100 electron volts. Hence, the energy selection is not performed by varying delta V, between the hemispheres in the CHA. This is instead kept constant and the voltage used to change the electron energy is scanned. For example, if one choses a pass energy of 70 electron volts and is measuring electrons with kinetic energies of 1000 electron volts, a negative potential of minus 930 volts must be applied with respect to the electrons as they enter the electron optics unit. Electrons with lower energies will be more deviated by the electric field between the concentric domes while those of higher energies less so.

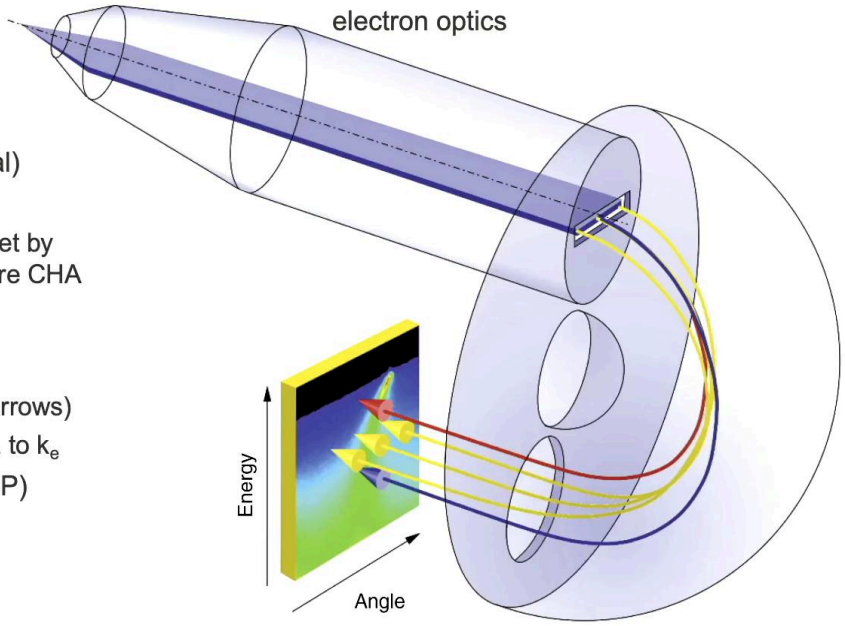
Notes

Summary

5m 34s

# Electron energy detectors - CHAs

- Recording modes
  - Constant ΔE/E (unusual)
  - Constant ΔE
    - Pass energy $E_{pass}$ set by electron optics before CHA
- New developments
  - Area detector
    - Angle ≡ $k_e$ (yellow arrows)
    - Different energies ⊥ to $k_e$
  - Multichannel plate (MCP)
    - Resolution ~ meV
  - Large increase in data collection rates



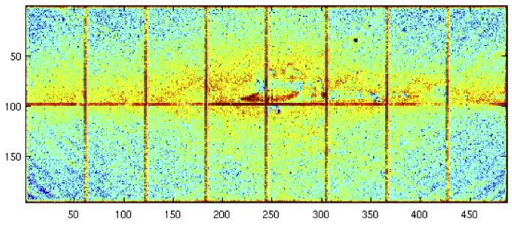

By using a larger exit aperture and an area electron detector, such as a multichannel plate, a two dimensional plot can be recorded in which the energy is dispersed in one direction, and angular differences in a mission are distinguished in the perpendicular direction. In this manner, large regions of both energy and momentum can be simultaneously recorded accelerating data acquisition, particularly in the technique of angular resolved photo electron spectroscopy, or ARPES.

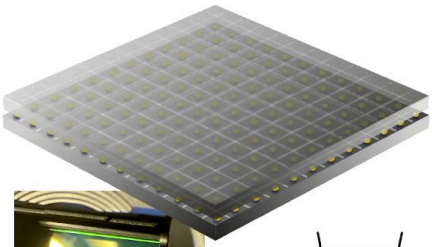
Notes

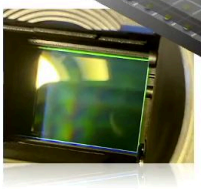
Summary

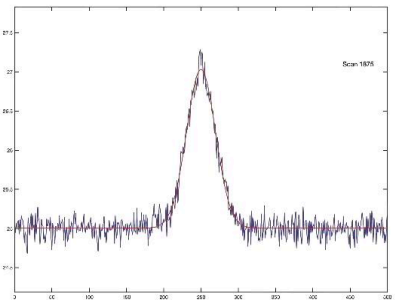
7m 06s

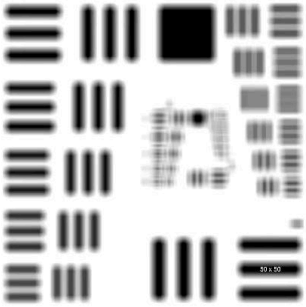
# Summary of this section

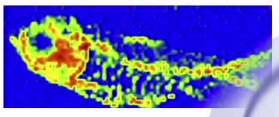


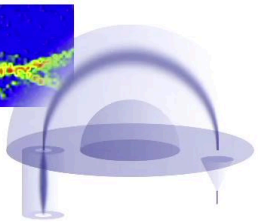













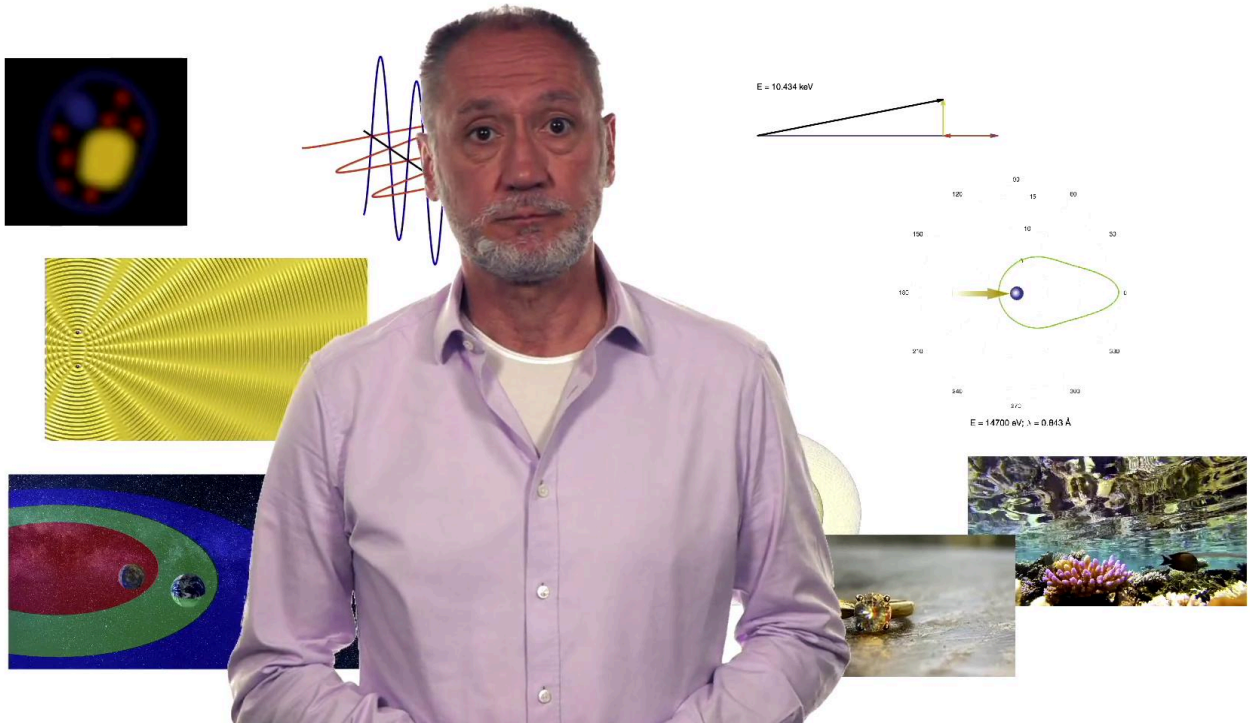
Summarising this last section of the first course, we first looked at sources of noise and how to describe them mathematically and considered the measures one needs to consider to extract the desired information with the necessary accuracy. We then considered sources of systematic errors and related phenomena such as point spread functions. We then went on to look at different detector technologies, including photon counting and integrating detectors, before finally looking at dispersive photon detectors, and electron kinetic energy analyzers.

Notes

Summary

7m 42s

# Concluding remarks to the course



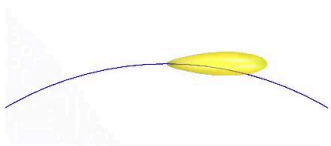
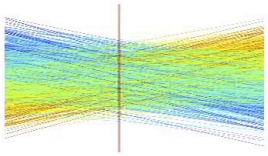

So what I hope you took home with you from these six weeks. We began after a general introduction with a detailed investigation of the basic interactions of X-rays with matter, which led to the concept of the atomic form factor, scattering, refraction, reflection, and absorption.

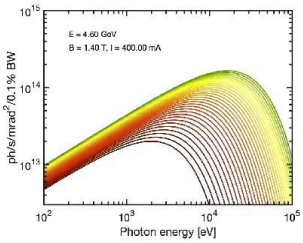
Notes

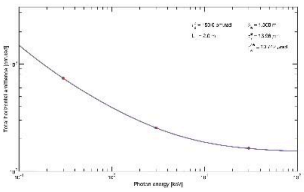
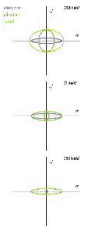
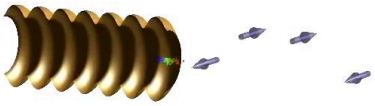
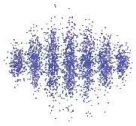
Summary

8m 25s

# Concluding remarks to the course



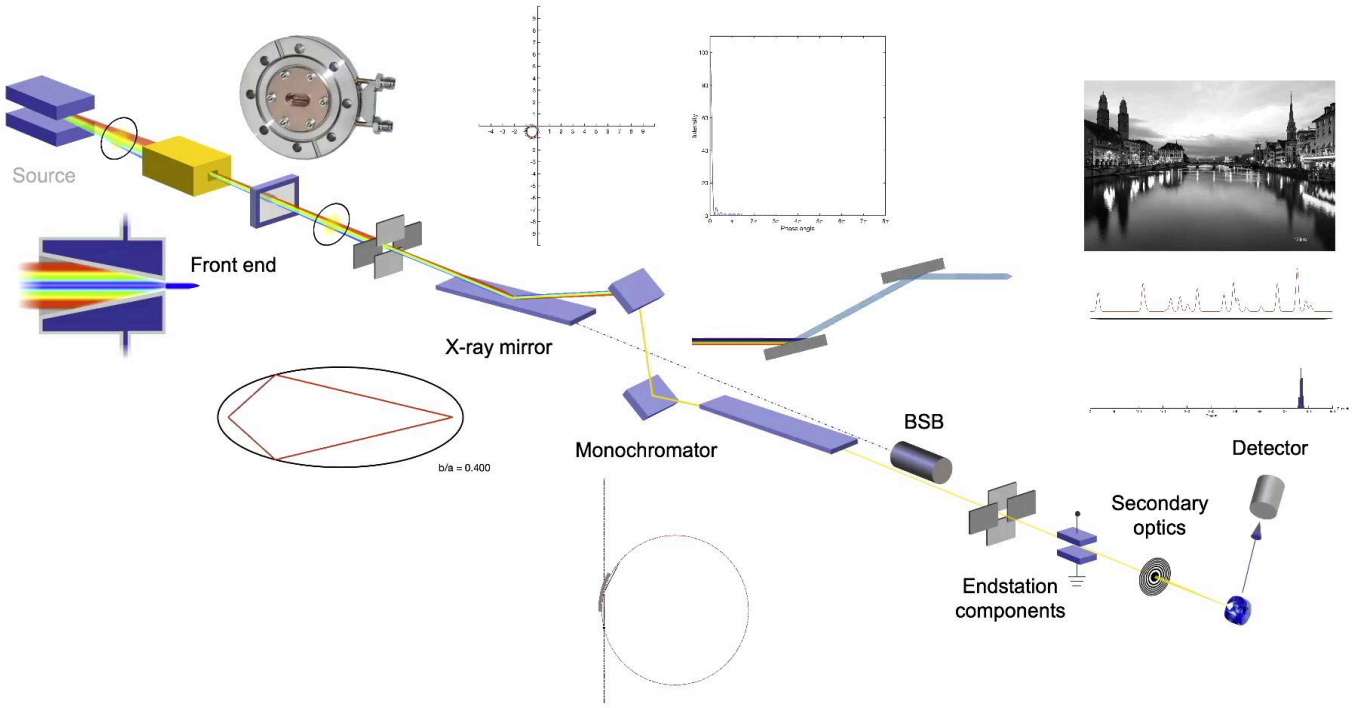
We then moved on to the most important aspects of machine or synchrotron physics, including the transformation of non relativistic dipole radiation to synchrotron radiation. The concept of brilliance emittance, and [inaudible 00:09:05] space. Before taking a closer look at X-ray sources used in synchrotrons, we finish this section by summarising the architecture and operating principles of X-ray free electron lasers and the novel scientific opportunities that they afford.

Notes

Summary

8m 48s

# Concluding remarks to the course



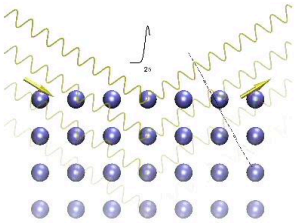

Finally, we followed the photons from their source through the front end and into the beamline, discussing various optical elements along the way, such as mirrors and monochromators plus n station components, including photon and electron detectors. The knowledge gained in the first part of the course involving the interaction of X-rays with matter was invaluable in understanding the reasoning behind the design and construction of many of these components. Under this information, you the student, should now be ready to delve into the world of synchrotron experimentation in all its many varied forms. This will be the goal of the sister course.

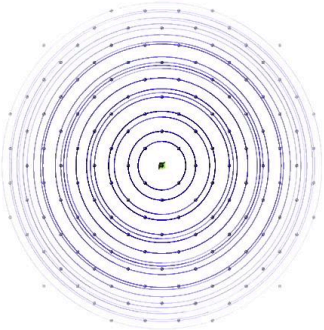
Notes

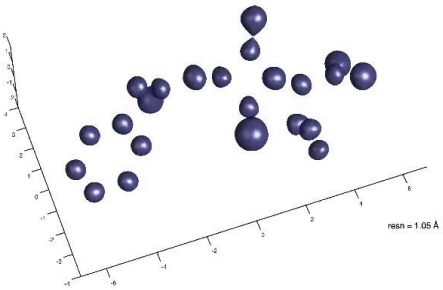
Summary

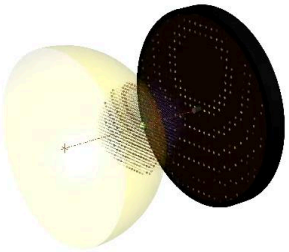
9m 25s

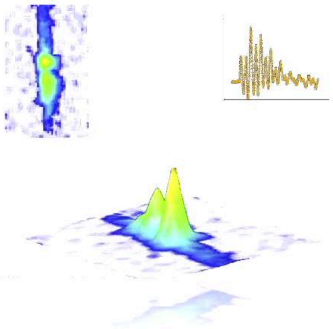
# The sister course

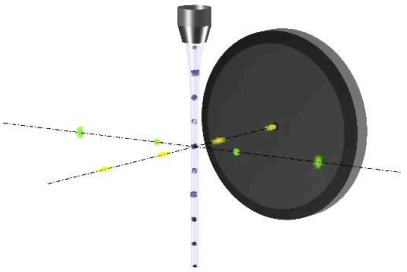










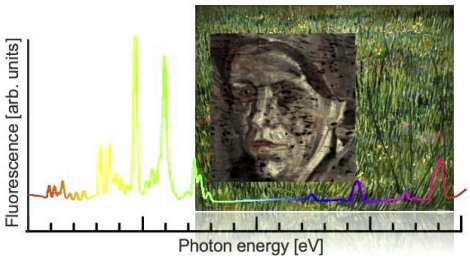
The sister course is divided into three main topics. The first of these diffraction and scatching techniques is among the most venerable and productive enterprises gleaning several Nobel Prizes to date. We will cover the basics of diffraction theory and then consider different flavours of scattering techniques, including single crystal and macromolecular diffraction, powder diffraction, surface X-ray diffraction, X-ray reflectivity, and serial crystallography, this last method being pursued vigorously at both synchrotrons and XFELS.

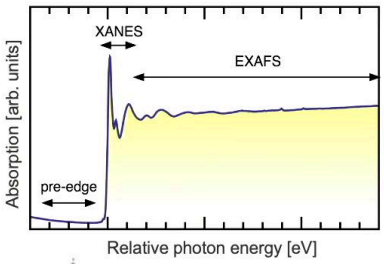
Notes

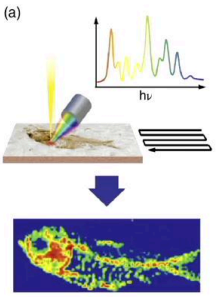
Summary

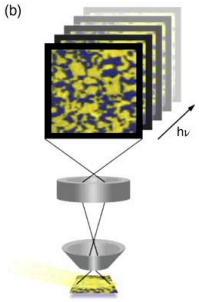
10m 17s

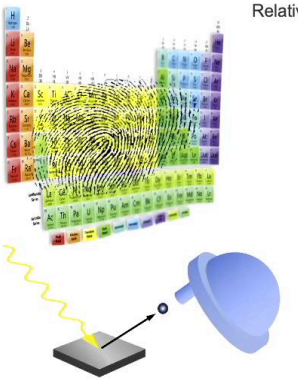
# The sister course

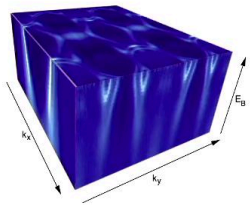




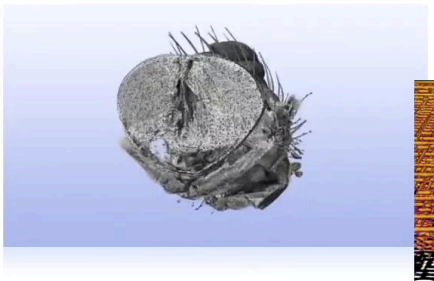
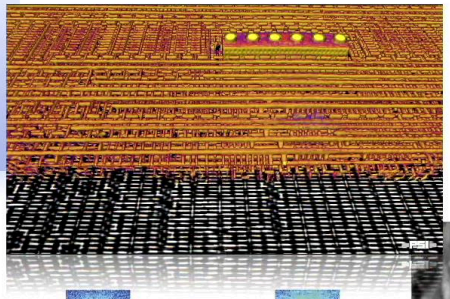

Another general set of techniques with a long and an illustrious pedigree are those based on spectroscopy. Most if not all of these are exclusively synchrotron based methods on account of their requiring full tune ability of the X-ray source photon energy. We discuss techniques in which the incident photon energy is scanned, those which look at their dispersed products of absorption, primarily fluorescence and photo electrons, and also distinguish between micro spectroscopies and Spectro microscopes.

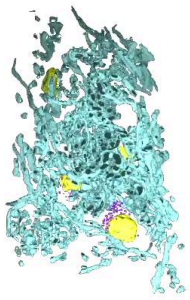
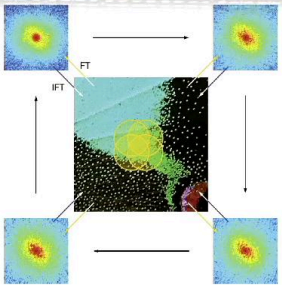
Notes

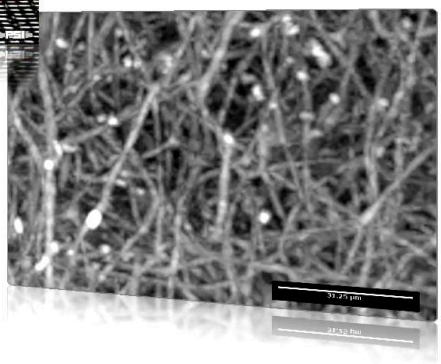
Summary

10m 59s

# The sister course



The last overarching X-ray technique to be discussed in the second course will be X-ray imaging. Many of these methods are relatively new kids on the block, which is quite ironic when one considers the initial results to attract the public's collective conscience more than a century ago, with the striking images of the bones in a living hand shown by Rankin. One can argue, that many of the other techniques discussed in this sister course, can also be in some way or another regarded as being imaging techniques. For example, what is diffraction other than the three dimensional determination of the atomic structure of objects in space. Nonetheless, some techniques sit uncomfortably in either scattering or spectroscopic techniques as they are classically understood at least. Primary among these is X-ray computed tomography. We also include lensless imaging as the scientific goals overlap strongly with tomography, and this latter is a technique that is becoming one of the primary justifications for the construction of synchrotrons, in particular, the fourth generation DLSRs, most notably for the investigation of complex Biosystems at the Micron and nanometer scale.

Notes

Summary

11m 38s

# The sister course

The importance of X-ray science in physics, chemistry, biology, and medicine can hardly be overstated. It seemed certain that X-rays will continue to play a hugely important role in modern science and technology in the 21st century. As ever more materials, compounds and structures in all their varied guises are discovered or indeed designed. The sister course will cover many of the tools now used in modern synchrotron science to meet these challenges. It will also be six weeks long like this course, two weeks each for scattering, spectroscopy and imaging. I look forward enormously to see you there again. Goodbye.

Notes

Summary

13m 05s