EPFL

Introduction to synchrotron techniques

Synchrotrons and x-ray free-electron lasers

Techniques and applications

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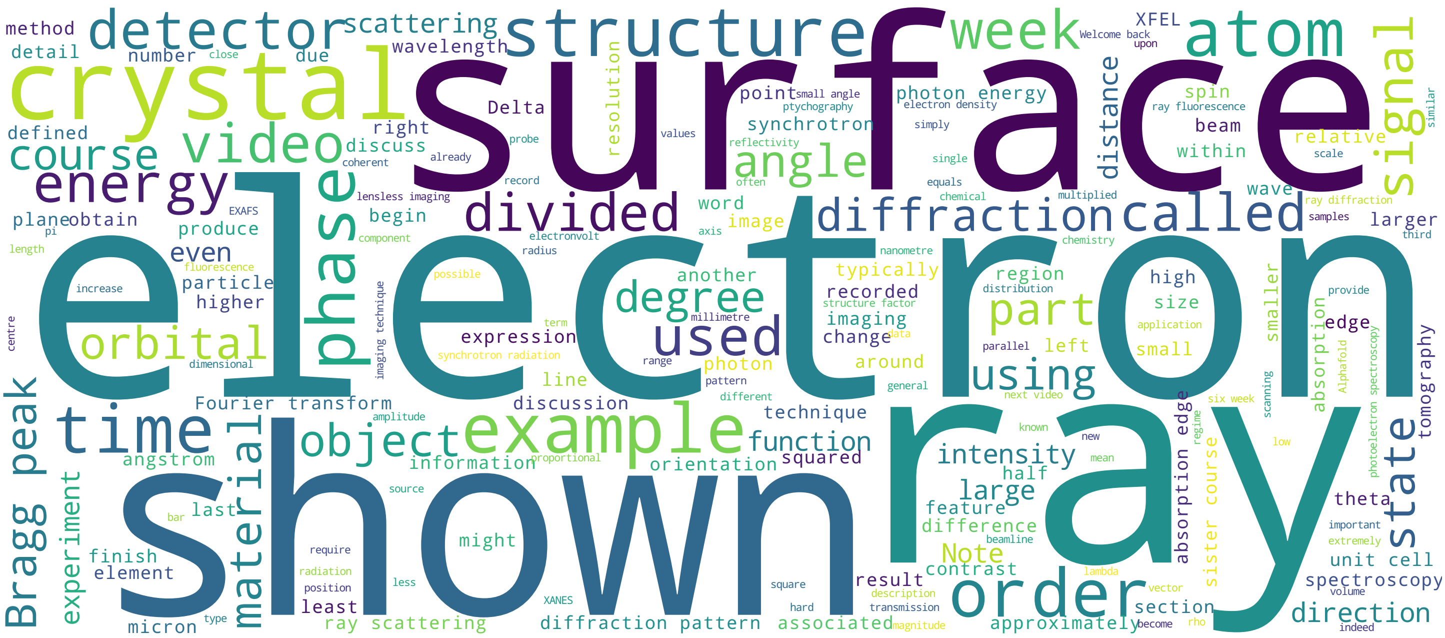

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Video

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About this course

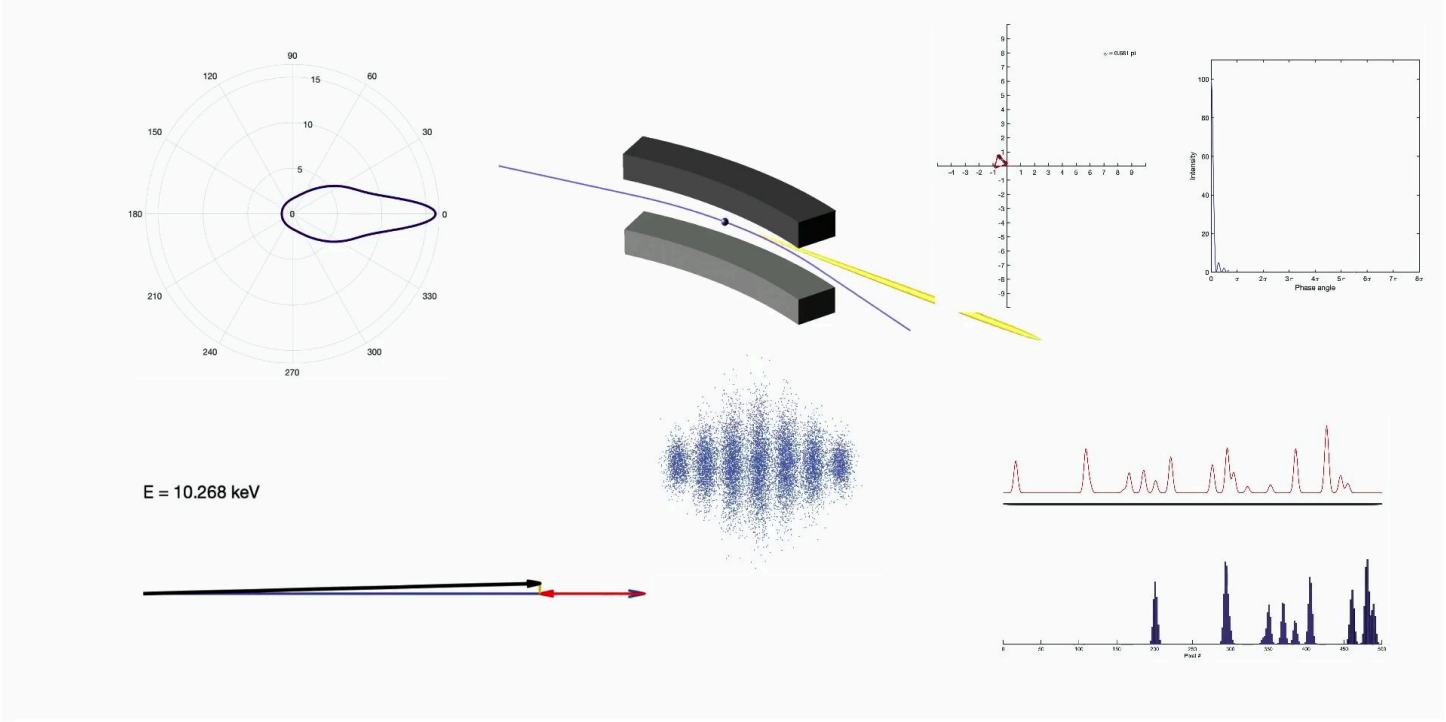
Welcome to part two of this introductory course on synchrotrons and X-ray free electron lasers. This six-week series of videos is the sister course to the first part, which concentrated on the basic interactions of X-rays with matter. Synchrotron and XFEL or machine physics and beamline components and instrumentation. With this necessary background knowledge, the student should now be armed with the requisite tools to begin actual experiments at synchrotron and XFEL beamlines. The purpose of this series is to present the manifold techniques available at the modern synchrotrons and XFELs. The six weeks are divided equally into two weeks each, in which elastic scattering and diffraction, spectroscopy, and imaging are covered. Now, the last of these, imaging, is a somewhat arbitrary title in its contents. Synchrotrons are often sold to the public as being gigantic microscopes. I think one could argue that, for example, protein crystallography is an imaging technique insofar that what one obtains at the end is an atomically resolved image of the structure of a macro molecule. Or one could argue that scanning techniques such as scanning X-ray fluorescence or scanning transmission X-ray microscopy are also imaging techniques.

Notes

Summary

0m 05s

About this course



These will, however, be covered in weeks three and four as part of our discussion of X-ray spectroscopies. Nonetheless, methods such as phase-contrast X-ray tomography cannot easily be lumped together with diffraction or spectroscopy. Because other tomographies based on lensless imaging or other physical phenomena use similar approaches to conventional full-field tomographies, they are included in weeks five and six. One can profit from this course without recourse to the sister course if one already has a solid background in X-ray physics. For those of you who are less familiar with this branch of science or who would like to refresh their knowledge, I strongly recommend you at least look at part one. As I just mentioned, this first part covers one, the basic interactions of X-rays with matter; two, the generation of synchrotron and XFEL radiation and related aspects of machine physics; and three, the control, manipulation, and detection of X-rays and subsequent products after their absorption at beamlines.

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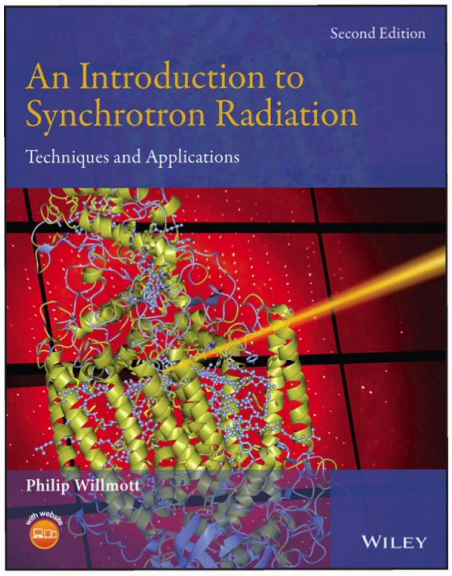
Summary

1m 31s

Literature



https://www.wiley.com/en-us/An+Introduction+to+Synchrotron+Radiation%3A+Techniques+and+Applications%2C+2nd+Edition-p-9781119280392

Before we begin with first thoughts about scattering and diffraction techniques, it behoves me to highlight resources related to and useful to the material in this course. First, both this and the sister course are based on my introductory textbook, An Introduction to Synchrotron Radiation, Techniques and Applications published through John Wiley & Sons.

Notes

Summary

2m 45s

Online resources

- 400+ figures from book
  - https://wiley.mpstechnologies.com/wiley/BOBContent/searchLPBobContent.do
    Type “Willmott” into author field
- Center for x-ray optics CXRO: http://www.cxro.lbl.gov
  - Interactions of x-rays with matter – plots, databases, x-ray data booklet
  - Educational material on x-ray optics, nanofabrication, coatings, etc.

- X-ray cross-section database
  - https://physics.nist.gov/PhysRefData/Xcom/html/xcom1.html
- Atomic form factors
  - http://lamp.tu-graz.ac.at/~hadley/ss1/crystaldiffraction/atomicformfactors/formfactors.php
- Protein data bank
  - https://www.rcsb.org
- XAS data base
  - http://cars.uchicago.edu/xaslib/search
- EXAFS spectra
  - http://www.exafsmaterials.com/Ref_Spectra_0.4MB.pdf
- Anomalous structure factor calculator
  - http://cars9.uchicago.edu/dafs/diffkk/
- Darwin-width calculator
  - https://www.chess.cornell.edu/users/calculators/x-ray-calculations-darwin-width
- X-ray optics intro
  - http://www.x-ray-optics.de/index.php/en/

The images within the book used repeatedly in this course are freely available from the book's website. Moreover, there are some 140 problems with the ideal solutions provided in the appendices. Other very useful resources include the Centre for X-ray Optics or CXRO website given here, as well as databases for X-ray cross-sections and atomic form factors. More technique-specific websites are listed here on the right. I also provide supplementary material about certain topics where I believe that you, the student, will profit significantly by looking into certain aspects at a deeper level that is maybe beyond the level at which this course is pitched.

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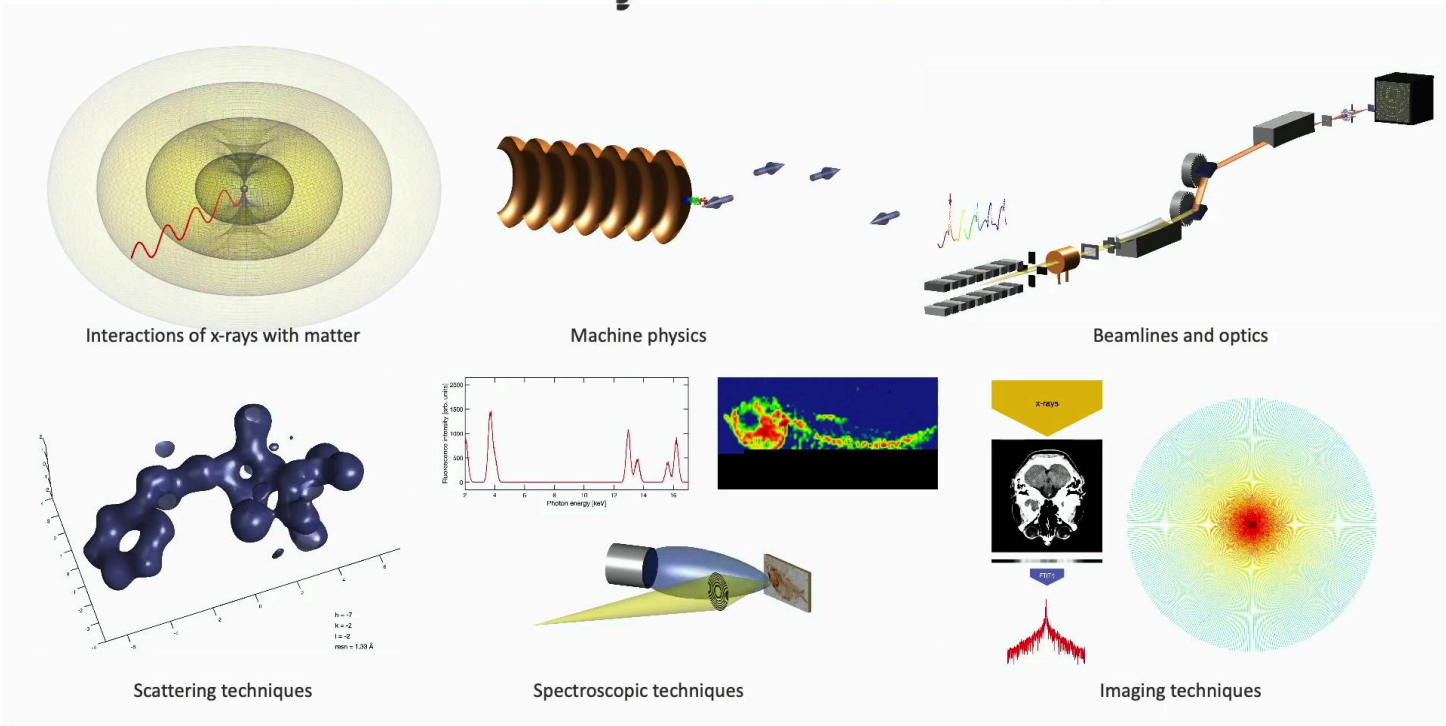
Summary

3m 09s

Online resources – synchrotronmovies.com



Lastly, both this and the sister course contain many animations that I have created using MATLAB, covering all aspects of both series. These are all freely available along with the very often dodgy MATLAB codes from my website, synchrotronmovies.com. Please feel free to use these and adapt them as you see fit.

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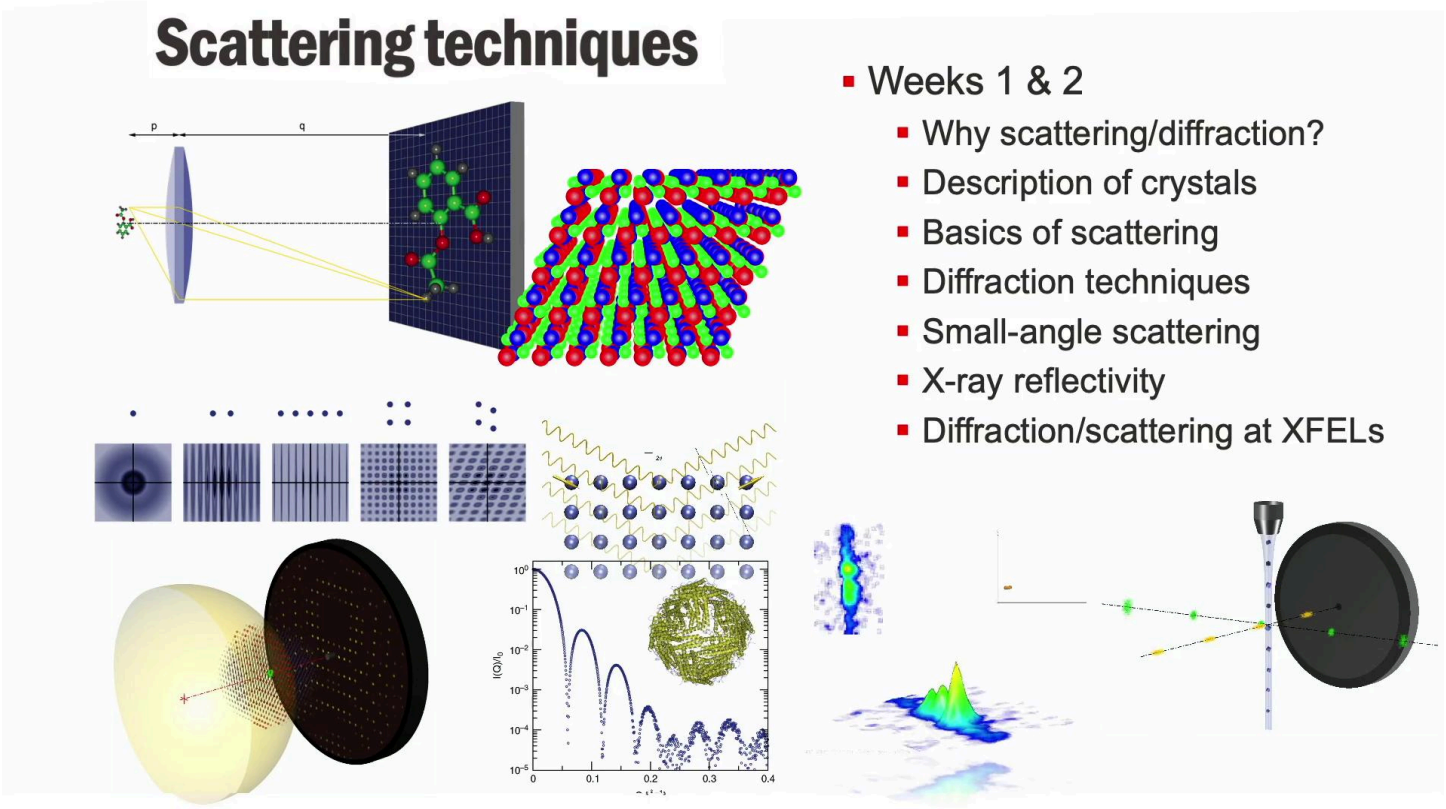
Summary

4m 01s



As already mentioned, the six weeks of this course are divided into the general headings of scattering techniques, X-ray spectroscopies and imaging. In more detail, in this and next week, we will cover basic aspects of X-ray scattering and diffraction, including some introductory remarks about why diffraction is attractive, particularly using synchrotron light. We continue with a description of crystals, fundamental rules of diffraction phenomena, different diffraction techniques, small-angle X-ray scattering, X-ray reflectivity and diffraction at XFELs.

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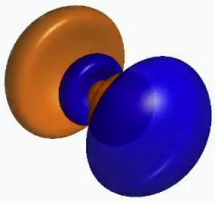
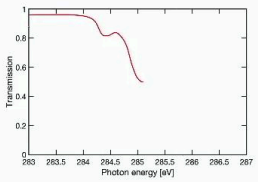
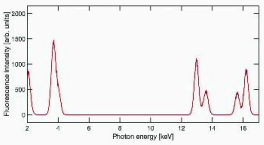
4m 27s

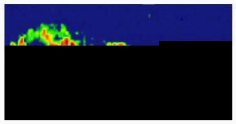
Spectroscopic methods

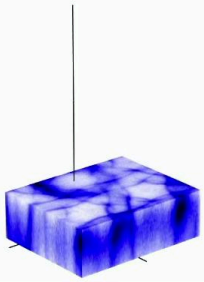


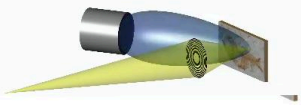
- Weeks 3 & 4
  - Basic considerations
  - Spectroscopy at synchrotrons
  - Absorption spectroscopies
    - XANES, PEEM, STXM, EXAFS
  - Emission spectroscopies
    - XRF, RIXS, XSW
  - Electron spectroscopies
    - ARPES, XPS









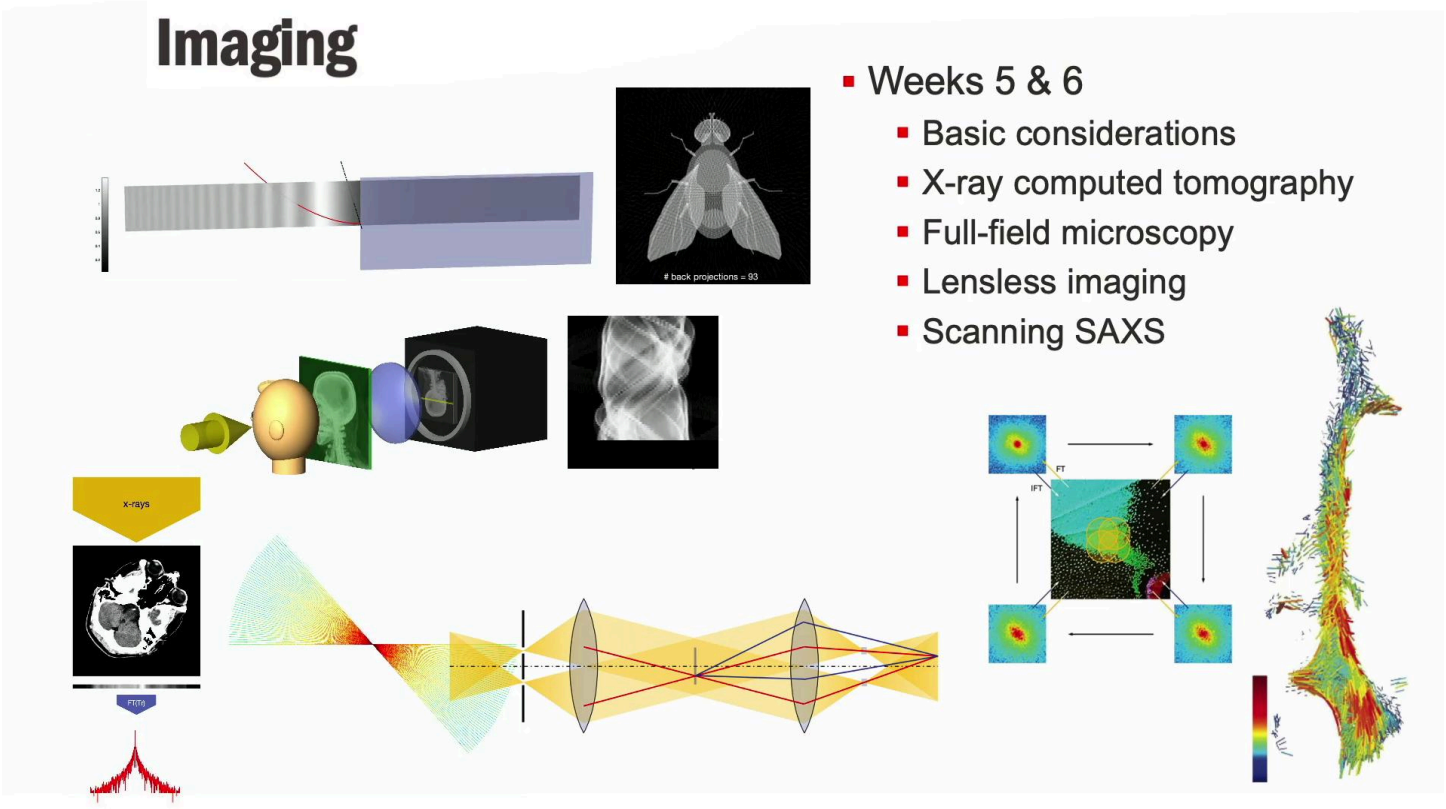


In the third and fourth weeks, we look at some theoretical aspects of spectroscopic relevance, including a description of orbitals and electronic transitions between states and spectroscopy at synchrotrons, different variants of absorption spectroscopies and fluorescence and photon-in-photon-out techniques, finishing with the many available synchrotron-based electron spectroscopies so important for both chemistry and electronic structure.

Notes

Summary

5m 08s



The last two weeks are concerned with X-ray imaging, a field of X-ray science that is becoming increasingly important across many scientific disciplines, not least in the biological sciences, energy, and the environment. We discuss some theoretical background concepts relevant to different types of X-ray tomographies plus Zernike microscopy. We finish with lensless techniques concentrating on coherent X-ray diffraction imaging and ptychography and scanning small-angle X-ray scattering tomography.

Notes

Summary

5m 43s

In the next video, we begin with a general discussion of X-ray scattering techniques and their role in the world of atomic resolution techniques, also investigating the advantages of such methods when using synchrotron radiation.

Notes

Summary

6m 22s