Methoden moderner Röntgenphysik: Streuung und Abbildung

Lecture 1	Vorlesung zum Haupt- oder Masterstudiengang Physik, SoSe 2019
	G. Grübel, L. Müller, O. Seeck, L. Frenzel, F. Lehmkühler, M. Martins, W. Wurth
Location	Lecture hall AP, Physics, Jungiusstraße

Date	Tuesdays	12:30 - 14:00	(starting 2.4.)
	Thursdays	8:30 - 10:00	(until 11.7.)

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Lecture:	4 SWS	Tuesday and Thursday
Tutorial/Übungen:	2 SWS	Tuesday (if agreed on)

Proseminar: *For Bachelor students*

8 creditpoints For Master students

Fixed dates:	Tuesday	12:30 - 14:00
	Thursday	8:30 - 10:00
First meeting “Tutorial”:	Tuesday, April 9	14:15 - 16:00
Location:	Seminar room 5	

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Lecturers: Gerhard Grübel (GG), Felix Lehmkühler (FL), Oliver Seek (OS), Leonard Müller (LM),

Part I:	**Basics of X-ray Physics**	(GG)
Part II:	**Soft Matter Studies**	(FL)
Part III:	**Magnetism - Thin Films**	(LM)
Part IV:	**Surfaces and Interfaces**	(OS)

Site Visit

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Part I:

Basics of X-ray Physics

by Gerhard Grübel (GG)

[2.4.] Organisation and Introduction
[4.4.] X-ray Scattering Primer
[9.4.] Sources of X-rays, Synchrotron Radiation
[11.4.] Refraction and Reflection
[16.4.] Kinematical Scattering Theory (I)
[18.4.] Kinematical Scattering Theory (II), Applications
[23.4.] Small Angle Scattering and Soft Matter
[25.4.] Anomalous Scattering
[30.4.] Introduction: Coherence I
[2.5.] Coherence II; Applications of Coherent X-ray Beams

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Part II:

Soft Matter Studies

by Felix Lehmkühler (FL)

[7.5.] Soft Matter studies I: Methods & experiments
[9.5.] Soft Matter studies II: Structure
[14.5.] Soft Matter studies III: Dynamics
[16.5.] Case study I: Glass transition
[21.5.] Case Study II: Water and Ice
[23.5.] Simulations (XPCS and XCCA)

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Part III:

Studies on Magnetic Nanostructures

by Leonard Müller (LM)

[28.5.] Ferromagnetism in a Nutshell
[4.6.] Interaction of Polarized Photons with Ferromagnetic Materials
[6.6.] X-ray Magnetic Circular Dichroism (XMCD) and Resonant Magnetic Small Angle X-ray Scattering (mSAXS)
[18.6.] Femtomagnetism
[20.6.] Imaging of Magnetic Domains

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Part IV:

Surfaces and Interfaces

by Oliver Seeck (OS)

[25.6.] Site Visit

[27.6.] Crystal Truncation Rods
[2.7.] X-ray Reflectivity
[4.7.] Grating incidence diffraction
[9.7.] Surface diffuse scattering
[11.7.] Outlook

Literature

Basic concepts:

Elements of Modern X-Ray Physics
J. A. Nielsen and D. McMorrow, J. Wiley&Sons (2001)

X-Ray Diffraction
B.E. Warren, DOVER Publications Inc., New York

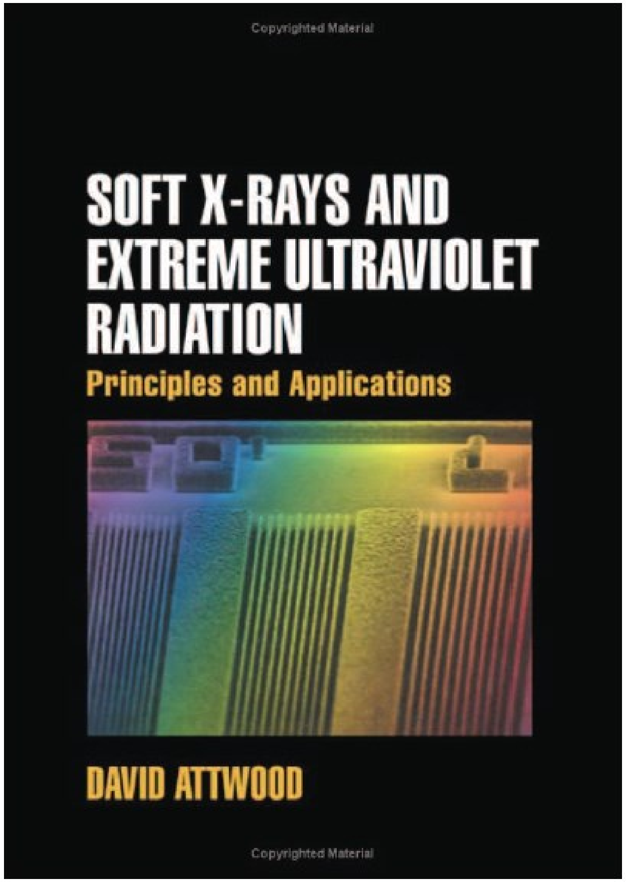
Principles of Optics
M. Born and E. Wolf, Cambridge University Press, 7th ed.

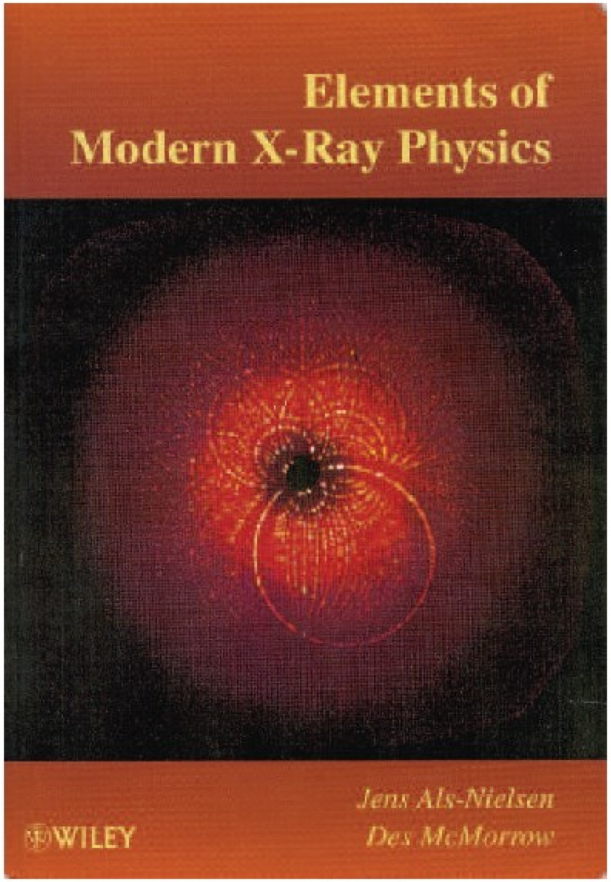
Soft X-rays and Extreme Ultraviolet Radiation
D. Attwood, Cambridge University Press (2000)
http://www.coe.berkeley.edu/AST/sxreuv/

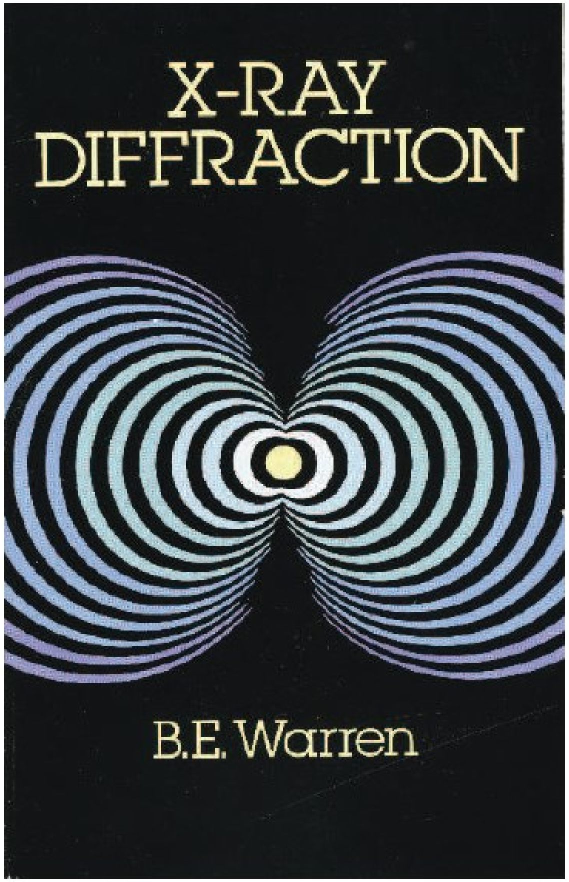
Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen
K. Wille, Teubner Studienbücher 1996

Lecture Notes

http://photon-science.desy.de/research/students__teaching/lectures__seminars/ss19







*** some of the slides are courtesy of M. Tolan, C. Gutt and A. Hermmerich**

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Part I:

Basics of X-ray Physics

by Gerhard Grübel (GG)

Introduction
Overview, Introduction to X-ray Scattering

X-ray Scattering Primer
Elements of X-ray Scattering

Sources of X-rays, Synchrotron Radiation
Laboratory Sources, Accelerator Bases Sources

Reflection and Refraction from Interfaces
Snell's Law, Fresnel Equations

Kinematical Diffraction (I)
Diffraction from an Atom, a Molecule, from Liquids, Glasses, …

Kinematical Diffraction (II)
Diffraction from a Crystal, Reciprocal Lattice, Structure Factor, …

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Small Angle Scattering, and Soft Matter
Introduction, Form Factor, Structure Factor, Applications, ...

Anomalous Diffraction
Introduction into Anomalous Scattering, ...

Introduction into Coherence
Concept, First Order Coherence, ...

Coherent Scattering
Spatial Coherence, Second Order Coherence, ...

Applications of Coherent Scattering
Imaging and Correlation Spectroscopy, ...

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Part II:

Soft Matter Studies

by Felix Lehmkühler (FL)

Soft Matter studies I: Methods & experiments

Soft Matter studies II: Structure

Soft Matter studies III: Dynamics

Case study I: Glass transition

Case study II: Water and Ice

Simulations: XPCS and XCCA

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Part III/1:

Studies on Magnetic Nanostructures

by Leonard Müller (LM)

Ferromagnetism in a Nutshell

Introduction to magnetic materials, magnetic phenomena, Magnetic Free Energy, Perpendicular Magnetic Anisotropy, Magnetic Domains and Domain Walls

Interaction of Polarized Photons with Ferromagnetic Materials

Charge and Spin X-ray Scattering by a Single Electron, Absorption and Resonant Scattering of Ferromagnets (Semi-Classical and Quantum-Mechanical Concepts)

X-ray Magnetic Circular Dichroism (XMCD) and Resonant Magnetic Small Angle X-ray Scattering (mSAXS)

XMCD Effect, Role of Spin-Orbit Coupling and Exchange Splitting, Sum Rules, XMLD and Natural Dicroisms, mSAXS of Magnetic Domain Patterns

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Part III/2:

Studies on Magnetic Nanostructures

by Leonard Müller (LM)

Femtomagnetism

Introduction to Ultrafast Magnetization Dynamics Induced by Femtosecond Infrared Pulses, Pump-Probe Experiments of Nano-Scale Magnetic Domain Patterns, All-Optical Switching, Manipulating Magnetism by XUV and THz Pulses

Imaging of Magnetic Domains

Fourier Transform Holography (FTH), Scanning Transmission X-ray Microscopy (STXM), Coherent Diffraction Imaging (CDI)

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Part IV/1:

Surfaces and Interfaces

by Oliver Seeck (OS)

Crystal Truncation Rods

Concept of surfaces scattering as convolution of the surface structure factor with the bulk structure factor, Scattering from single crystal surfaces and epitactic films, Example: 2x1 surface reconstruction of Si 004 surfaces

X-ray Reflectivity

Concept of surface scattering as deduced from the kinematic approximation (Born Approximation), X-ray reflectivity of multilayers in Born Approxmiation and following dynamic scattering using Parratt, Refractive index, Example: Low densitity interfaces in Polymers

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Part IV/2:

Surfaces and Interfaces

by Oliver Seeck (OS)

Grating incidence diffraction

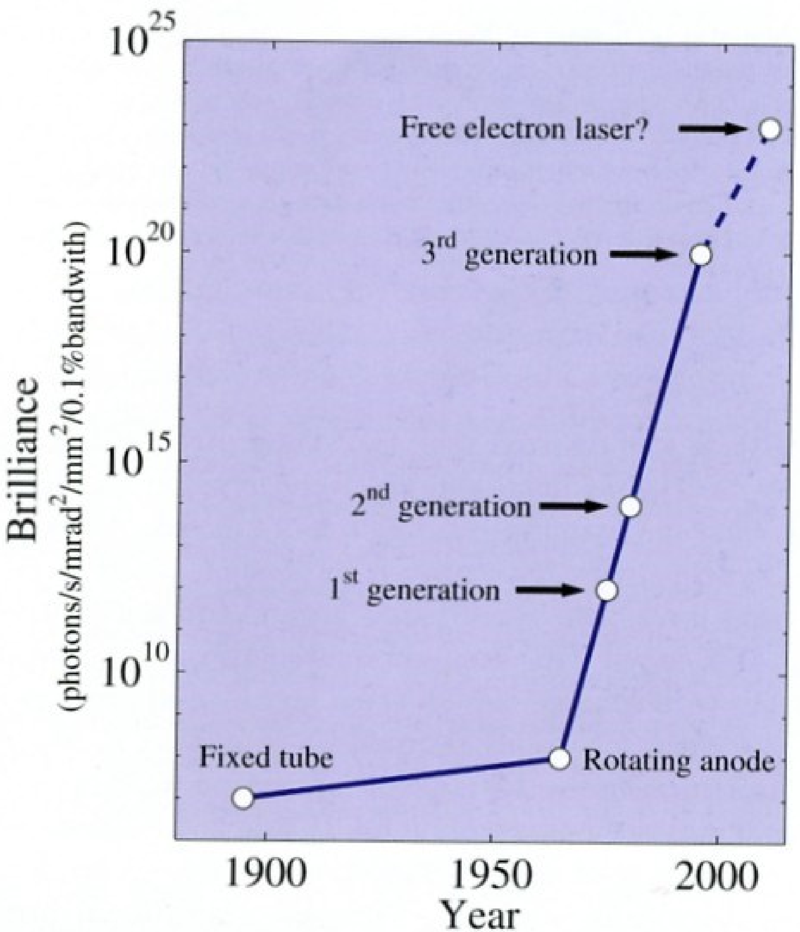
Concept of evanescent waves, Penetration depth of X-rays, Example: Surface Phase Transition of Ising type NH4Cl crystals

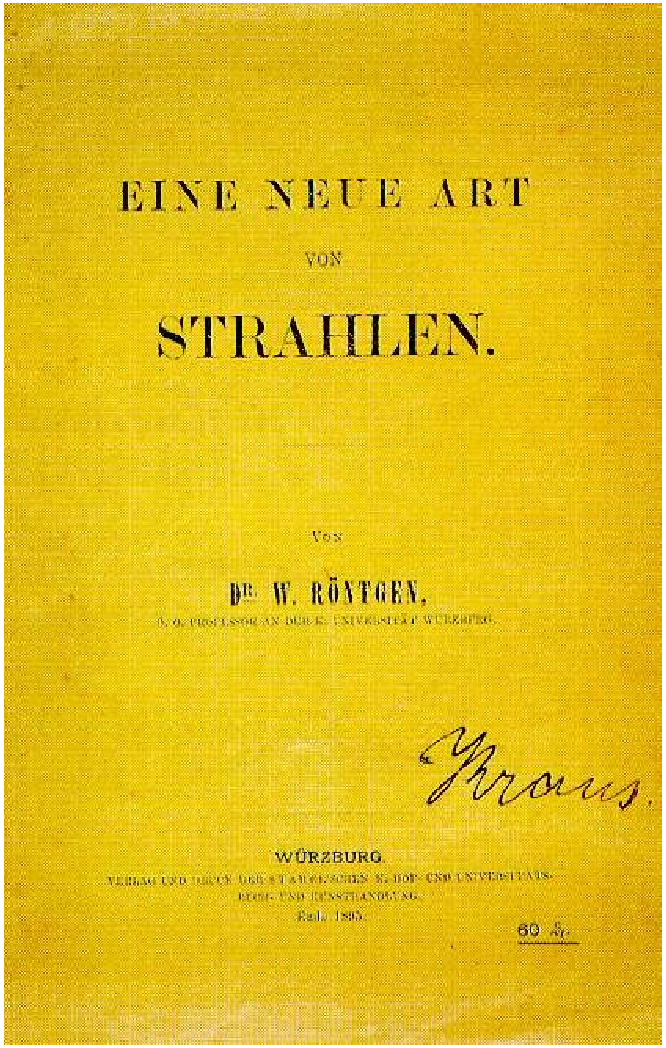
Surface diffuse scattering

Concept of scattering from disordered surfaces, Auto-correlation function and spectral power density, diffuse scattering in Born Approximation, Example: Capillary wave roughness on liquid ethanol

Introduction by Gerhard Grübel

1895	X-ray discovered by W.C. Röntgen
1901	Nobel Price; since then, unprecedented success in unraveling the structure of materials
1970	Synchrotron radiation revolutionizes the field
2005	Start operation FLASH (first SASE based FEL)
2009	Free Electron Lasers (XFEL)



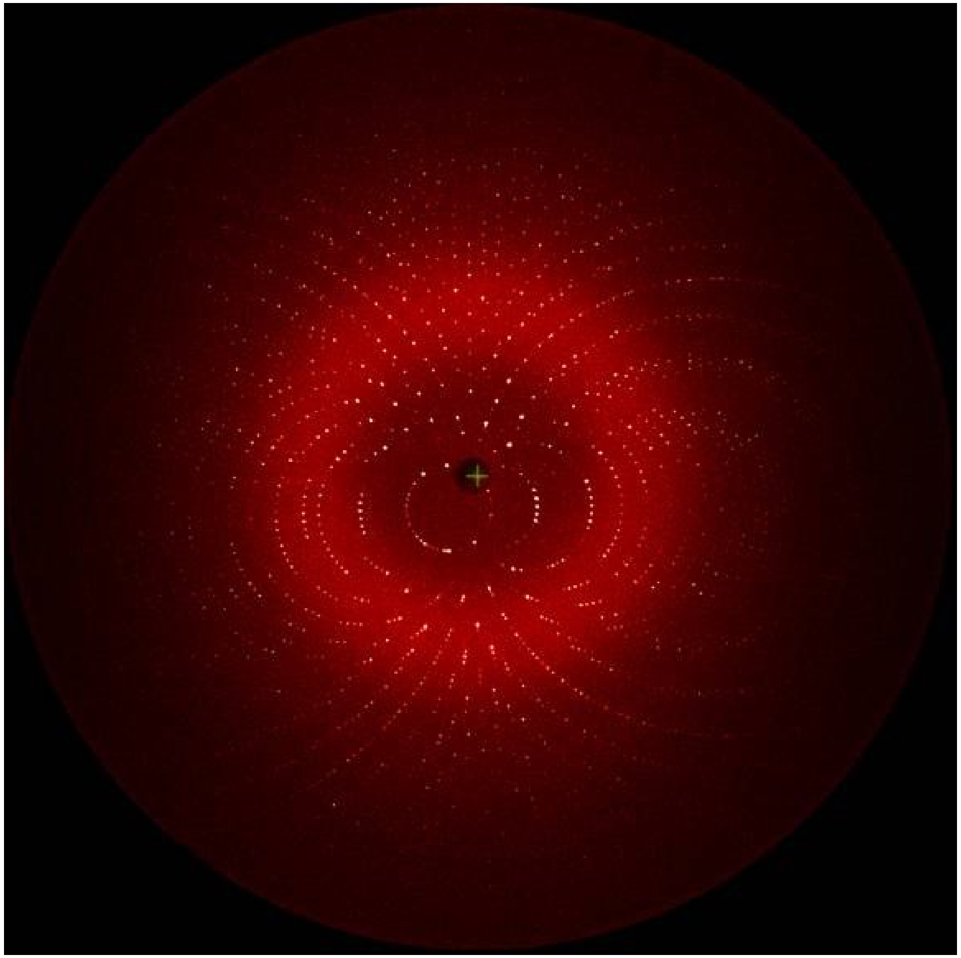

EINE NEUE ART
VON
STRAHLEN.
VON
DR. W. RÖNTGEN,
WÜRZBURG.
60 ₰

Nobel Prices

1901 W.C. Röntgen in **Physik** für die **Entdeckung der Röntgenstrahlen**
1914 M. von Laue in **Physik** für **Röntgenbeugung an Kristallen**
1915 W.H. Bragg und W.L. Bragg in **Physik** für Bestimmung der **Kristallstruktur mit Röntgenbeugung**
1917 C.G. Barkla in **Physik** für die **charakteristische Strahlung der Elemente**
1924 K.M.G. Siegbahn in **Physik** für **Röntgenspektroskopie**
1927 A.H. Compton in **Physik** für **Streuung von Röntgenstrahlen durch Elektronen**
1936 P. Debye in **Chemie** für **Beugung von Röntgenstrahlen und Elektronen in Gasen**
1946 H.J. Muller in **Medizin** für die Entdeckung von **Mutationen durch Röntgenstrahlung**
1954 L. Pauling in **Chemie** für Entwicklungen in der **Strukturchemie**
1956 A.F. Cournand, W. Forssmann und D.W. Richards in **Medizin** für die **Entwicklung des Herzkatheters unter Röntgenkontrolle**
1962 J. Watson, M. Wilkins und F. Crick in **Medizin** für die **Strukturaufklärung des DNA-Moleküls**
1962 M. Perutz und J. Kendrew in **Chemie** für die **Strukturaufklärung von Hämoglobin**
1964 D.C. Hodgkin in **Chemie** für die **Röntgenstrukturanalyse von Penicillin** und wichtigen biochemischen Substanzen
1976 W.N. Lipscomb in **Chemie** für **Röntgenstrukturuntersuchungen an Boranen**
1979 A.M. Cormack und G.N. Hounsfield in **Medizin** für **Computertomographie**
1981 K.M. Siegbahn in **Physik** für **hochaufgelöste Elektronenspektroskopie**
1985 H.A. Hauptman und J. Karle in **Chemie** für die Entwicklung direkter Methoden zur **Bestimmung von Röntgenstrukturen**
1988 J. Deisenhofer, R. Huber und H. Michel in **Chemie** für die **Bestimmung der dreidimensionalen Struktur von Proteinen für die Photosynthese**
1997 P.D. Boyer, J.E. Walker und J.C. Skou in **Chemie** für **Aufklärung der Funktion des Enzyms ATP**
2002 R. Giacconi in **Physik** für die **Entwicklung der Röntgenastronomie**
2003 R. MacKinnon in **Chemie** für **Röntgenstrukturbestimmung von Ionenkanälen in Zellmembranen**
2009 V. Ramakrishnan, T. A. Steitz, A. E. Yonath in **Chemie** für **Studies of the Structure and Function of the Ribosome**

X-ray Scattering Research Today

Modern Protein Crystallography



BioCARS 14-ID-B station of APS using an undulator with a gap of 25 mm from a crystal of the M37V mutant of CO-bound dimeric clam hemoglobin.

BESCHLEUNIGER | FORSCHUNG MIT PHOTONEN | TEILCHENPHYSIK

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DESY beglückwünscht Ada Yonath zum Chemie-Nobelpreis

Die israelische Forscherin Prof. Ada E. Yonath hat zusammen mit zwei Amerikanern den Nobelpreis für Chemie verliehen bekommen. Ihre Forschungen zur Struktur und Funktion der Ribosomen, denjenigen Molekülkomplexen, die aus der DNA-Erbinformation die für das Leben notwendigen Eiweißmoleküle herstellen, führte sie hauptsächlich an DESYs DORIS-Beschleuniger durch.

» mehr

50 Jahre DESY

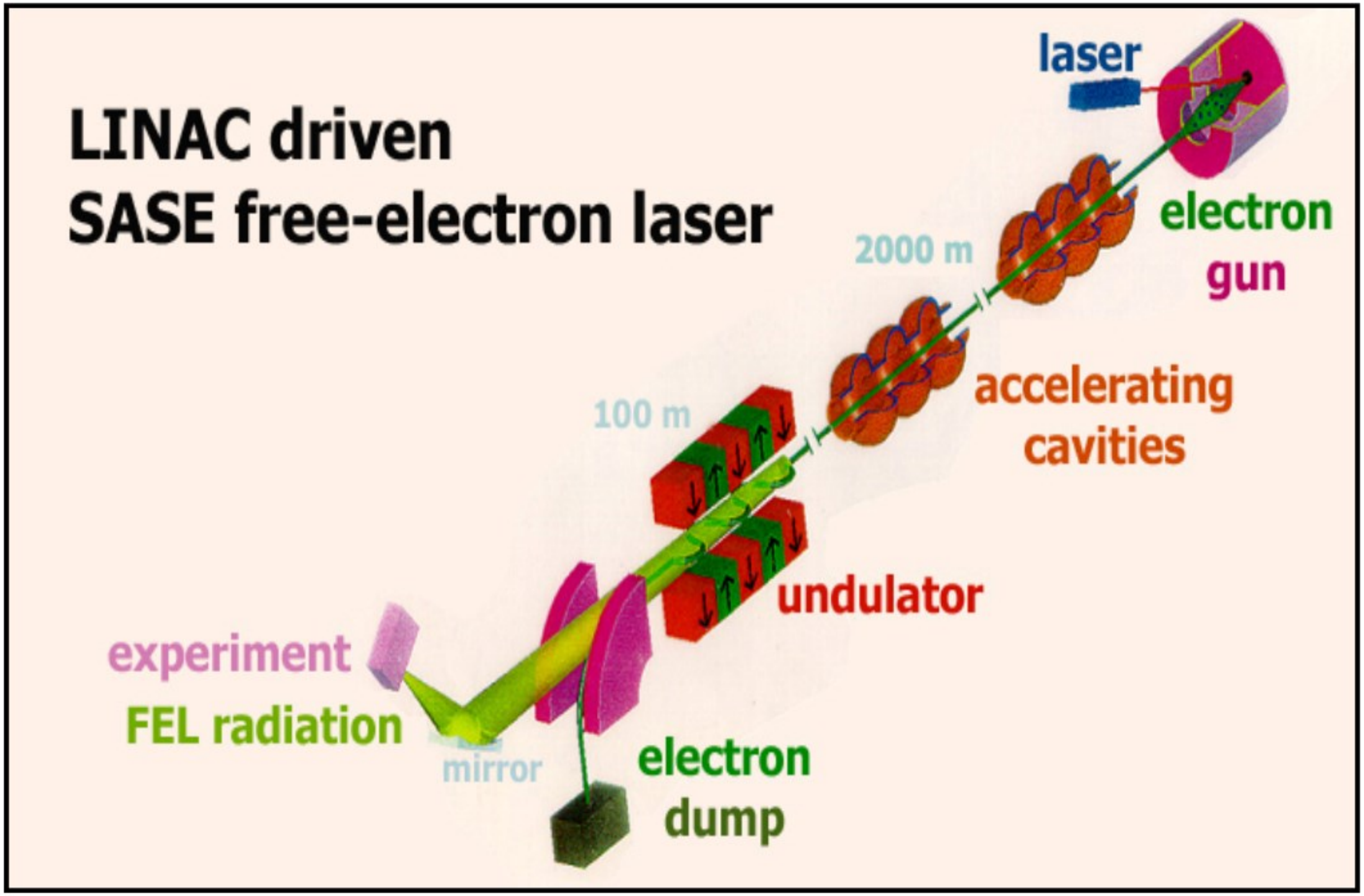
» Alle Infos zum Jubiläumsjahr

Veranstaltungen

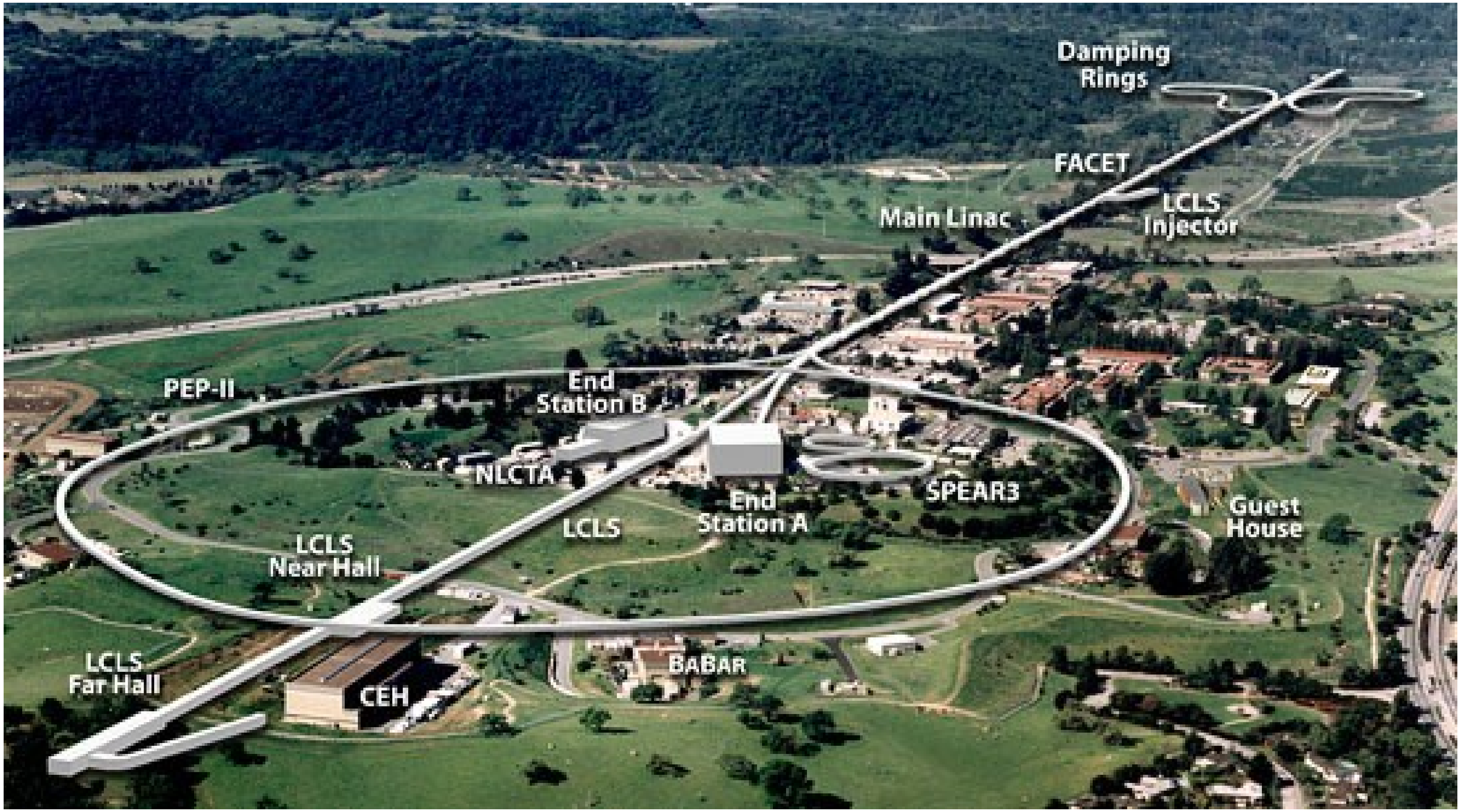
» VERANSTALTUNGSKALENDER FÜR DESY IN HAMBURG UND ZEUTHEN

European Synchrotron Radiation Facility (ESRF)

Free Electron Lasers (FELs)



LCLS – Linac Coherent Light Source - SLAC



Serial Femtosceond Crystallography

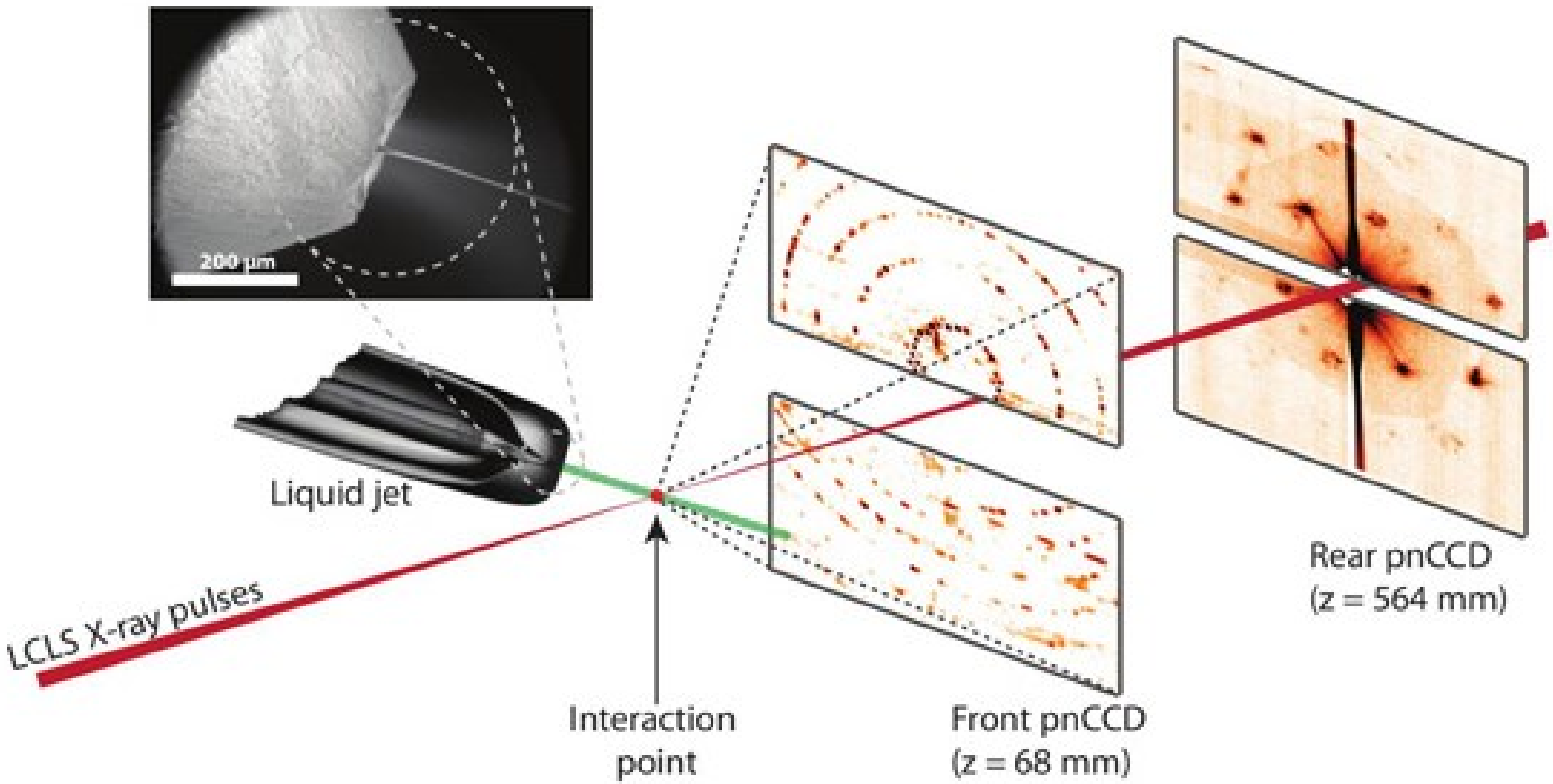


Figure 1
Experimental set-up for serial femtosecond crystallography. First published in Nature 470, 73 – 78 (2011).

Henry N. Chapman et al., NATURE 470, 73 (2011)

Serial Femtosceond Crystallography

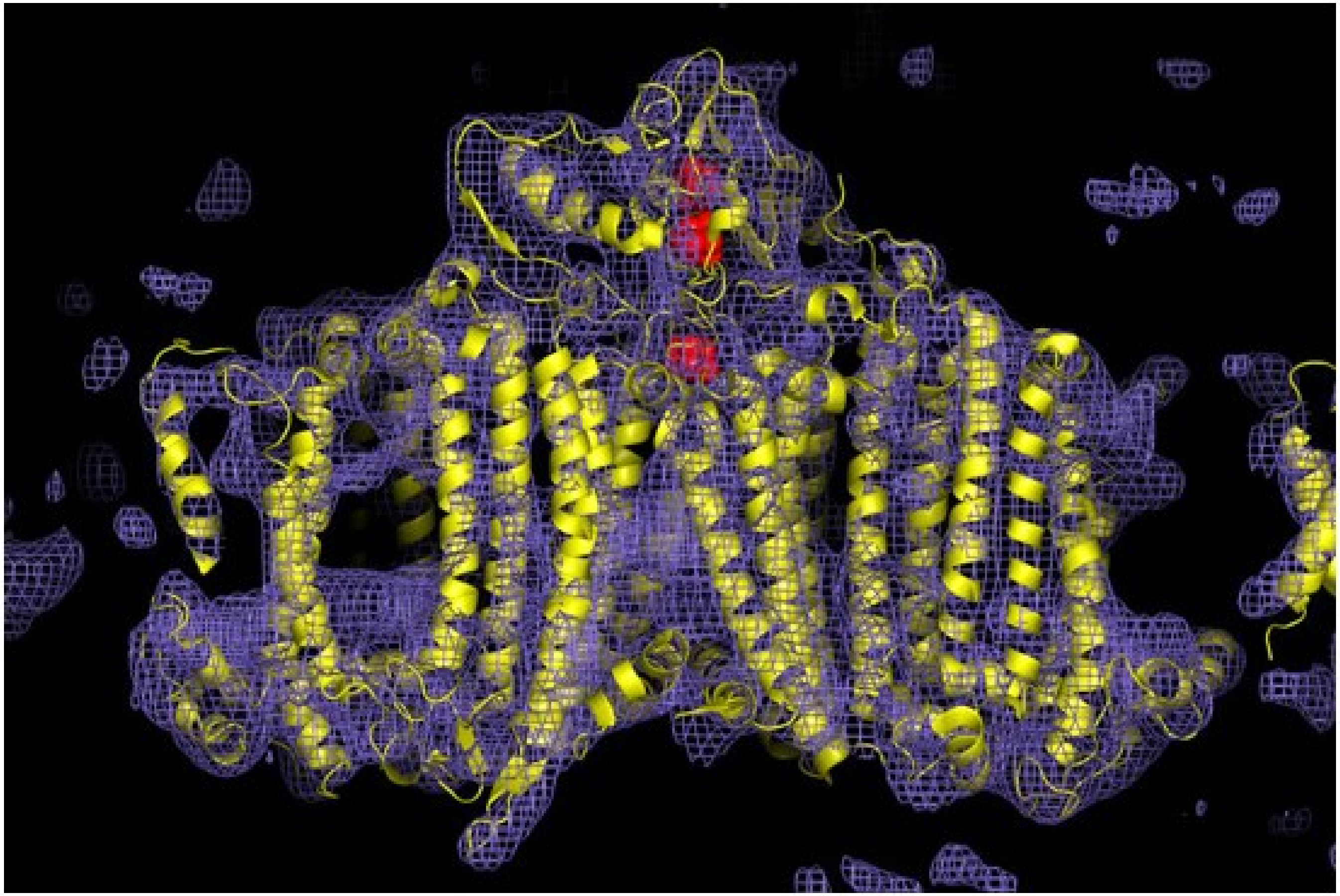


Figure 3
Electron density map of the photosystem I protein complex obtained from the LCLS diffraction data. First published in Nature 470, 73 – 78 (2011). Nanocrystals were grown by Petra Fromme of Arizona State University.

Extracted from 3 million diffraction patterns from photosystem I nanocrystals (200nm to 2 micron size) LCLS:30 Hz at 1.8 keV

European XFEL

BEAMLINES

The European XFEL will provide light sources (beamlines) for X-ray flashes with different properties.

When electron bunches are induced to follow a slalom course in the magnet arrangements—the so-called undulators—of the European XFEL, they emit flashes of X-ray radiation. The European XFEL will comprise different undulators, i.e. different light sources providing X-ray flashes with different properties.