PSI Center for Photon Science

EPFL

Manuel Guizar-Sicairos :: Head of the Computational X-ray Imaging group :: Paul Scherrer Institute
Associate Professor :: École Polytechnique Fédérale de Lausanne

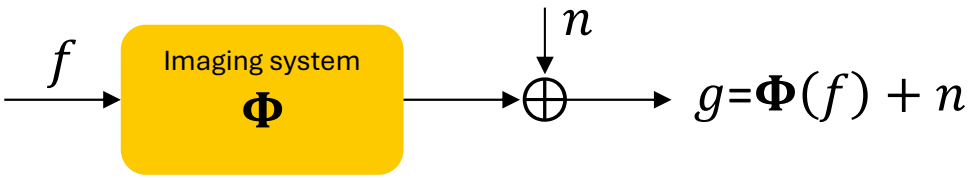
Course introduction

PHYS-715 Physical Optics and Advanced Imaging 2025

CXI

Introduction to imaging

A simple model for imaging



Optical microscope

Infrared telescopes

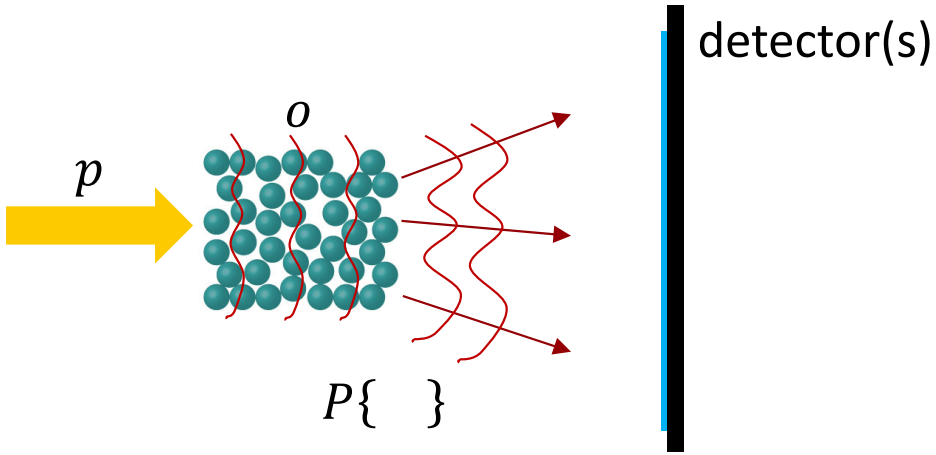
Electron microscope

CT scan - Computed X-ray tomography

MRI – Magnetic resonance imaging

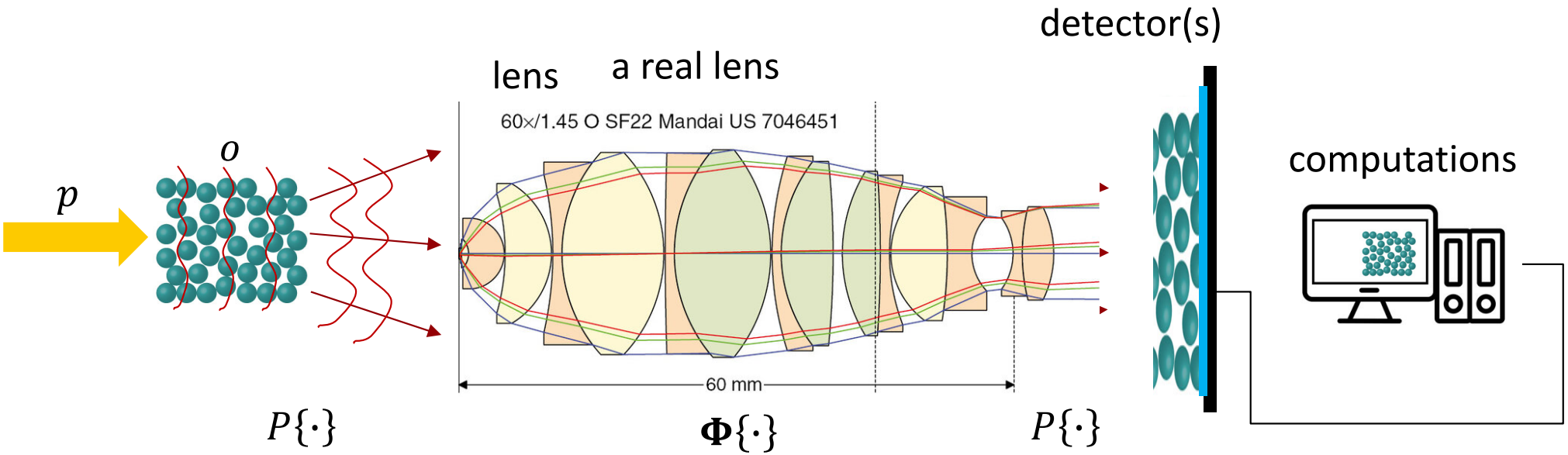
Introduction to imaging

A more detailed model

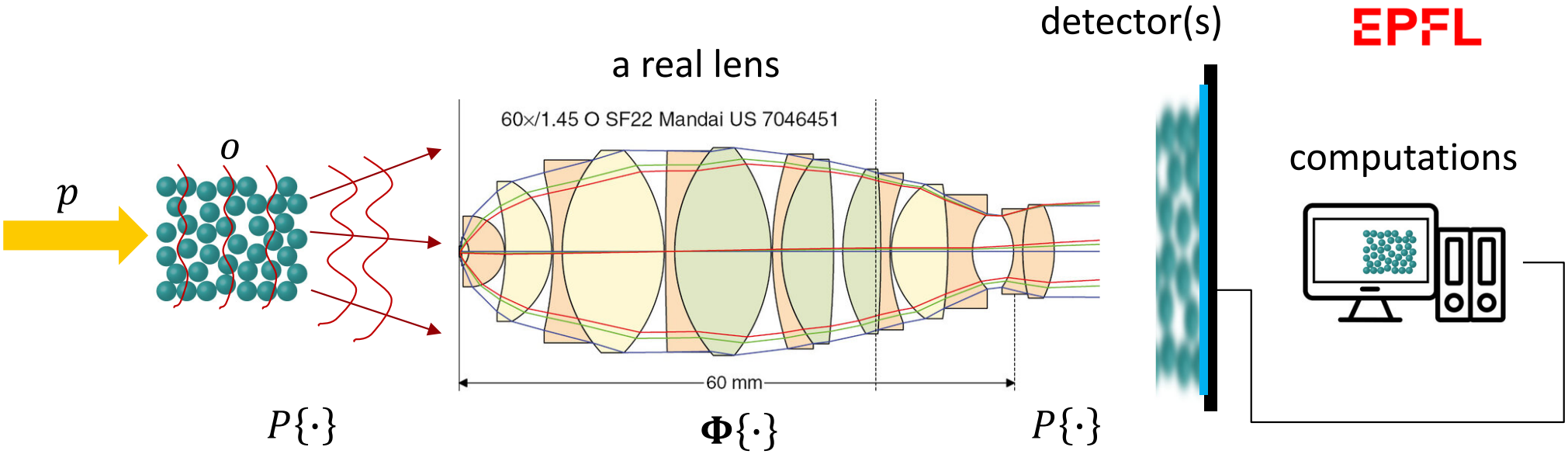


Introduction to imaging

A more detailed model



Introduction to imaging



Chapter 1
Wave – sample interaction

Chapter 2
Fourier optics and Imaging

Chapter 4
Numerical propagation

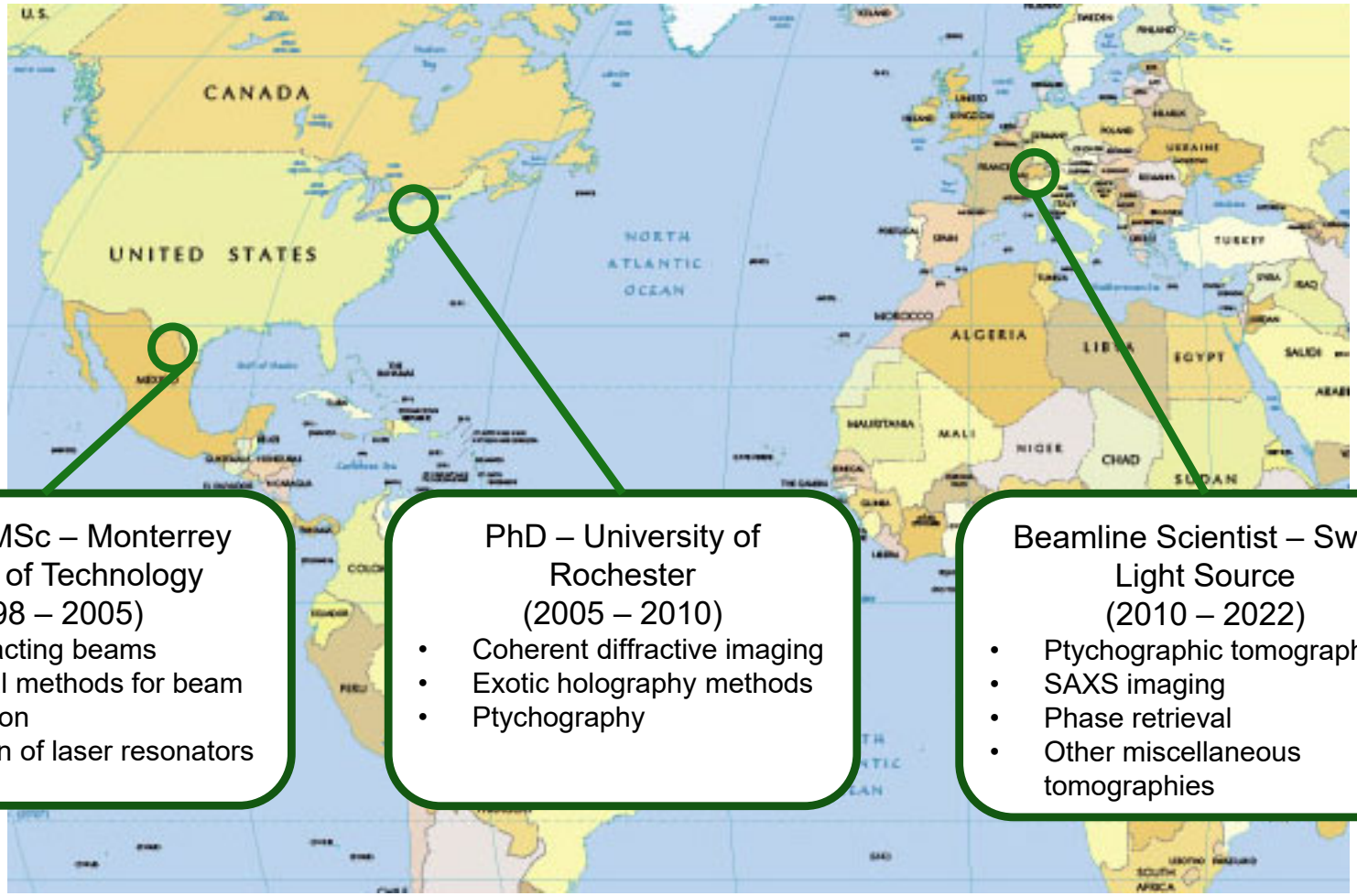
Chapter 3
Detector and phase imaging

Chapter 5
Phase retrieval and ptychography
Mini-project: Lensless imaging by coded aperture
Random phase retrieval: theory, algorithms, applications
External lecturers

Introductions – a bit about myself

PSI

EPFL



BSc and MSc – Monterrey Institute of Technology
(1998 – 2005)

- Non-diffracting beams
- Numerical methods for beam propagation
- Simulation of laser resonators

PhD – University of Rochester
(2005 – 2010)

- Coherent diffractive imaging
- Exotic holography methods
- Ptychography

Beamline Scientist – Swiss Light Source
(2010 – 2022)

- Ptychographic tomography
- SAXS imaging
- Phase retrieval
- Other miscellaneous tomographies

The Coherent X-ray Imaging lab

Development of novel imaging methods

Phase retrieval, CDI, ptychography

Tomography (brain, integrated circuits)

Manuel Guizar-Sicairos
Abraham Levitan
Wenxuan Fang
Tina Halimi
Aknur Karabay
Wenhui Xu
Amirehsan Khorashadizadeh
Pengju Sheng

Brief introduction of students and their projects

Please do not distribute material. Including lecture slides, videos, exercises, nor code

Material for the course

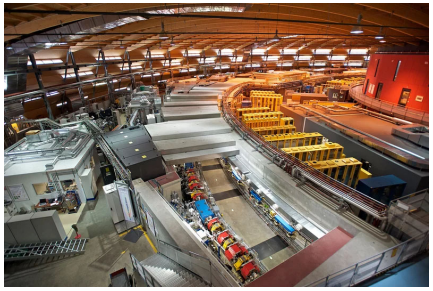
Password: phys715

https://drive.switch.ch/index.php/s/JaLkuolZNl8j4YR

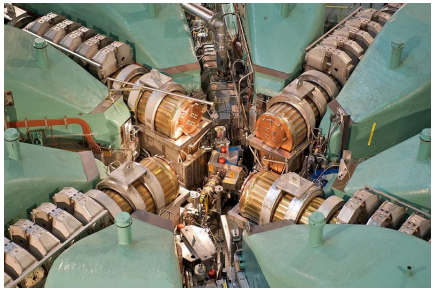
Visit to Paul Scherrer Institute

Nov 19 ~ 2.5 hour train ride

Don't forget your official ID/Passport



Swiss Light Source (SLS) currently in upgrade



Swiss Spallation Neutron Source (SINQ)

Swiss free-electron laser (SwissFEL)

Center for proton therapy

www.psi.ch

SwissFEL video 5 mins https://www.youtube.com/watch?v=sMWnA-vUlw0&t=1s

TA and guest lecturers

M. Sc. Aknur Karabay
Computational X-ray Imaging, PSI
TA

Dr. Jonathan Dong
Biomedical Imaging, EPFL
Random phase retrieval: theory, algorithms, applications
Oct 8

Dr. Abraham Levitan
Computational X-ray Imaging, PSI
Numerical propagation
Nov 5

External lecturers

Dr. Ana Diaz

Coherent X-ray Scattering, Swiss Light Source, PSI

X-ray scattering to probe nanostructures in materials and tissues at the Swiss Light Source

Oct 29

Dr. Claire Donnelly

Three-dimensional magnetic systems, Max Planck Institute

Multidimensional coherent imaging of magnetic nanosystems

Nov 12

Prof. Andreas Schaefer

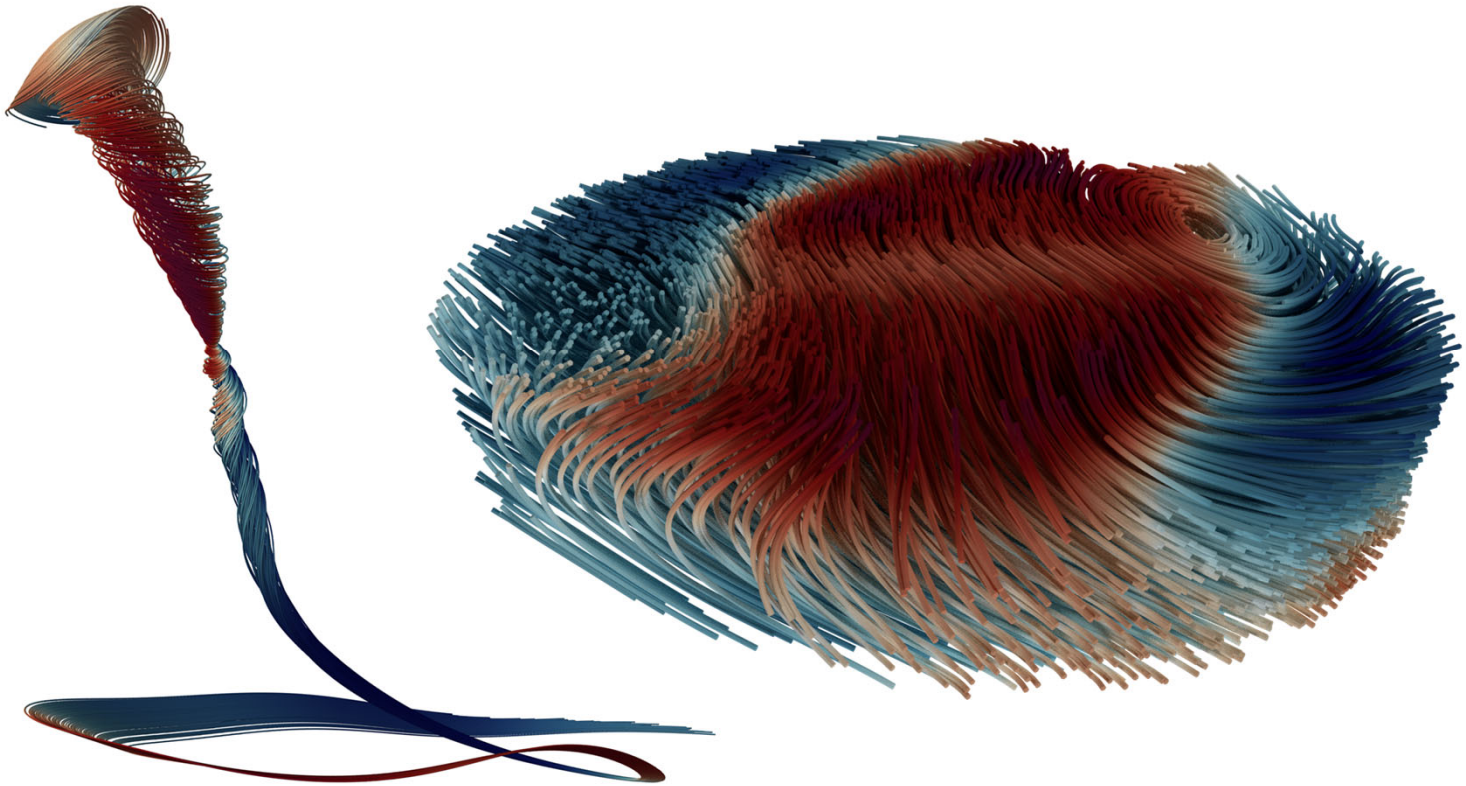
Sensory circuits and Neurotechnology Laboratory, University College London

Leveraging coherent X-ray imaging to unravel the neural networks in the mammalian brain

Dec 3

https://www.crick.ac.uk/research/labs/andreas-schaefer
https://www.cpfs.mpg.de/spin3d
https://www.psi.ch/en/coherent-x-ray-scattering

Multidimensional coherent imaging of magnetic nanosystems

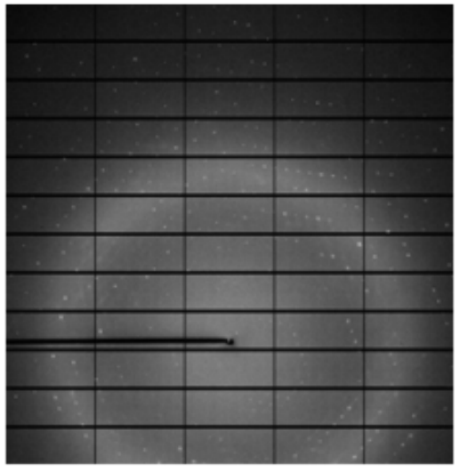


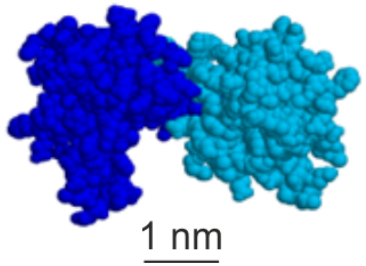
Dr. Claire Donnelly

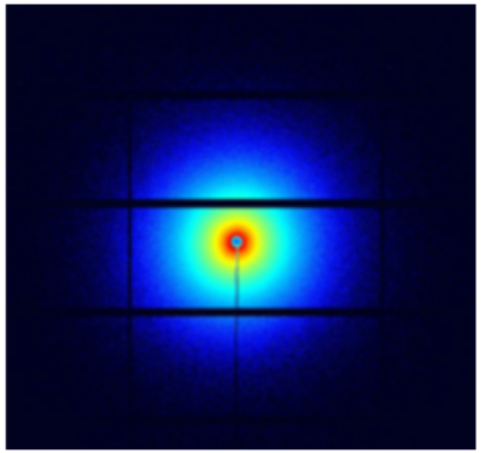
Three-dimensional magnetic systems, Max Planck Institute

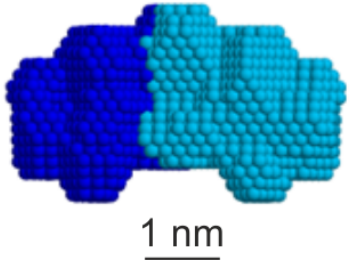
Nov 12

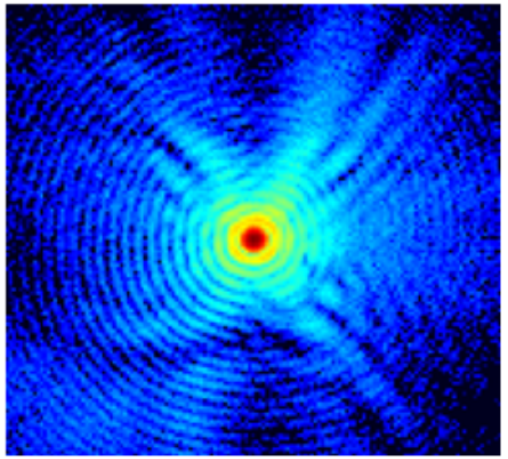
X-ray scattering to probe nanostructures in materials and tissues at the Swiss Light Source

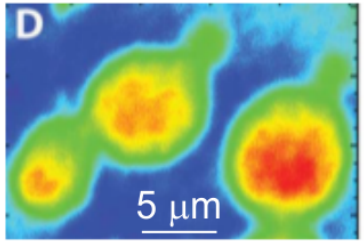










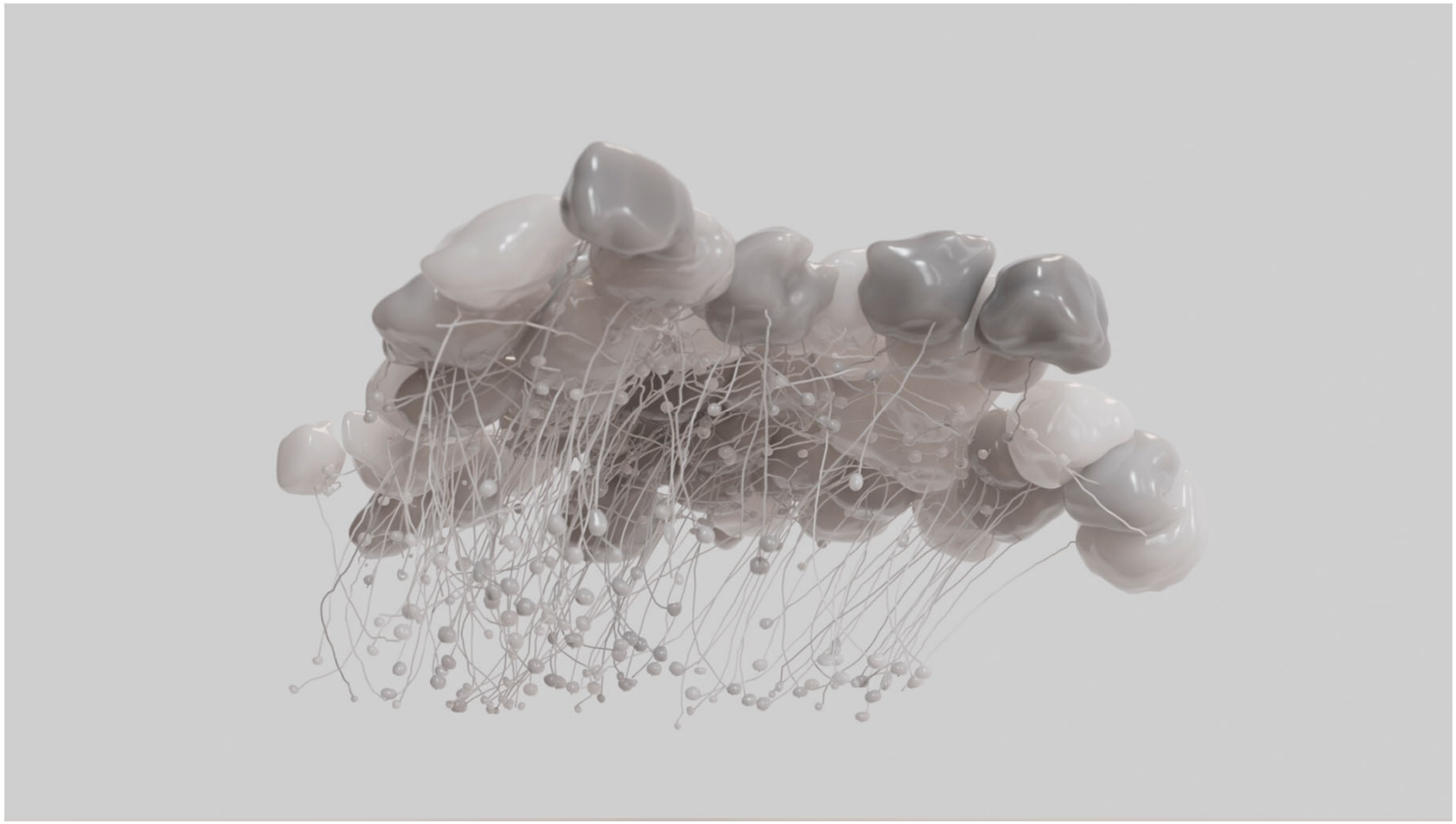


Dr. Ana Diaz

Coherent X-ray Scattering, Swiss Light Source, PSI

Oct 29

Leveraging coherent X-ray imaging to unravel the neural networks in the mammalian brain



Prof. Andreas Schaefer

Sensory circuits and Neurotechnology Laboratory, University College London

Dec 3

Course contents

Cover the unifying concepts of imaging, including with electrons, optics, X-rays. In 2D, 3D, and beyond.

Chapter 1 Interactions of waves with the sample and beyond

- Review of Fourier transform and properties **(today)**
- Helmholtz equation
- Angular spectrum and evanescent waves
- Huygens–Fresnel principle
- Rayleigh-Sommerfeld solution
- Fresnel approximation
- Fraunhofer approximation – the far field
- Paraxial wave equation
- Projection approximation
- Multislice propagation
- Beer-Lambert law

Guidelines

All interactions are to be conducted with respect

Ask questions during the lecture and exercises

Final project and presentation required. No project or presentation for people auditing.

Attendance in person is expected in order to pass

Attendance by zoom may be considered in very special circumstances. There will be a bit of derivations in the board. Request in advance.

Faculty office hours upon request by email

Important dates

Nov 19 – Visit to PSI

Also the deadline for project outline

Oct 29, Nov 12, Dec 3

Guest and external lecturers – please make an extra effort to attend

Final project and presentation

A project, plus term paper and presentation are required. Exploring an advanced imaging topic in depth, possible topics include computer simulations, laboratory experiments, implementing image processing or restoration algorithms.
1 or 2 persons.
Not necessarily a topic covered in the lectures. You are very welcome to bring a problem from your research topic.
Replicate results, or partial results, from a peer-reviewed publication.

Nov 12	1 page outline of the project
Dec 10, 17	Project presentations in conference style (20 minute presentation + 10 questions)
Jan 12	Written report. Maximum 5 pages (calibri font, 11 pts, single space)