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FACULTY OF SCIENCES

DEPARTMENT OF PHYSICS AND ASTRONOMY
UGCT RADIATION PHYSICS

DOCTORAL SCHOOL 2021

Introduction to computed X-ray tomography – Jaianth Vijayakumar

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Flanders
State of the Art

UGCT

MODALITIES OF X-RAY TOMOGRAPHY

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X-RAY TOMOGRAPHY

Radiography image → absorption/shadow image

Other information to extract

- Chemical contrast
- Phase contrast
- Local crystallinity
- Local scattering vector
- Refractive index
- Low spatial resolution

X-RAY GENERATION

Lab based

Filament – Cu

K alpha

Synchrotron based

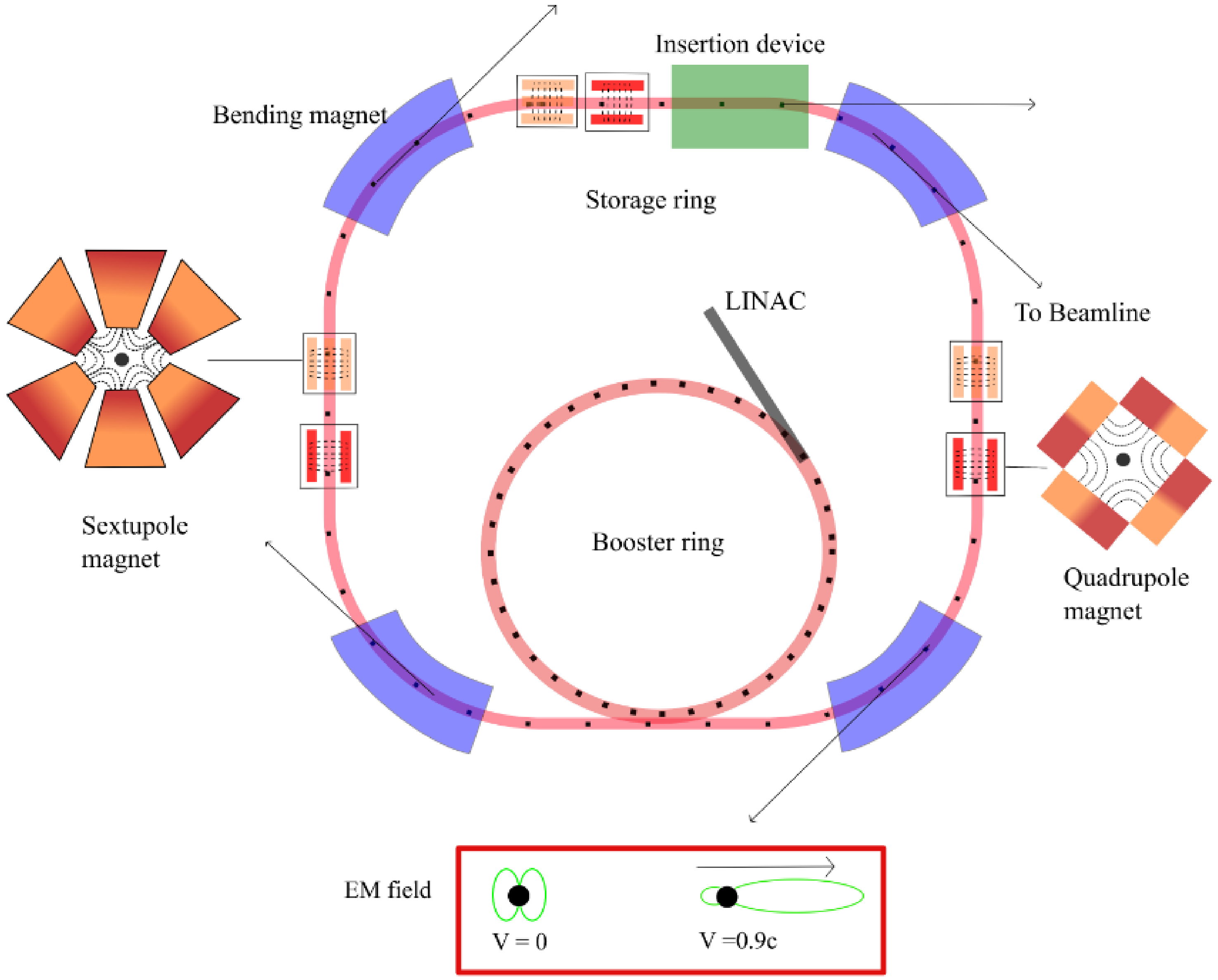

Figure 3.7: Schematic representation of a synchrotron facility.

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X-RAY GENERATION

Lab based

- Conical beam
- Non-coherent
- Polychromatic
- Affordable in labs

Synchrotron based

- Parallel beam
- Coherent
- Monochromatic
- $$$ - can be used based on proposal approval

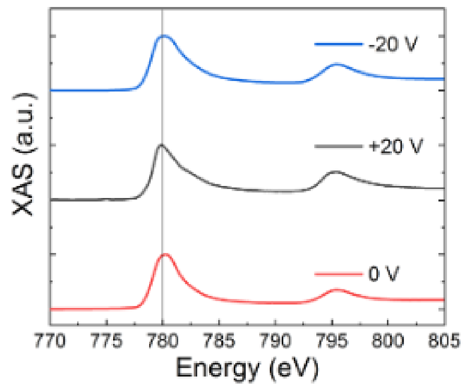
INTERACTION OF X-RAY WITH MATTER

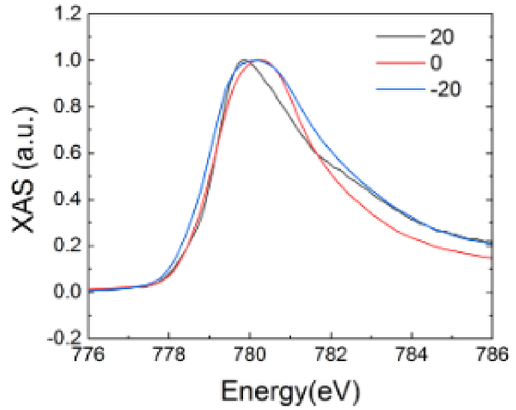
Microscopic interaction of X-ray with matter

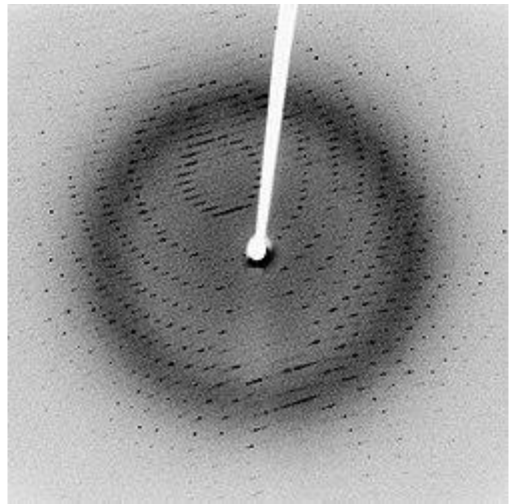
Elastic (Rayleigh), inelastic (Compton) scattering, ejection of electrons due to photoelectric effect and pair production such as electron and positron, or nuclear absorption.

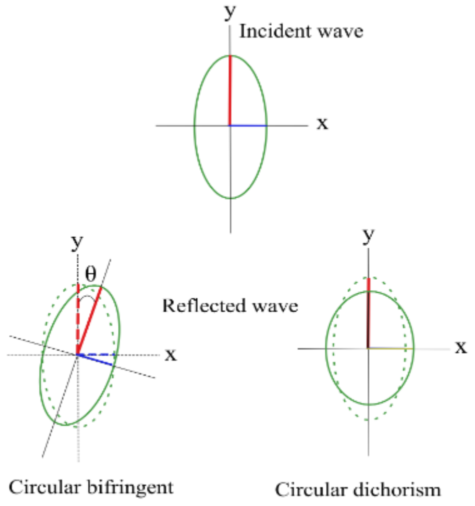
Macroscopic effect

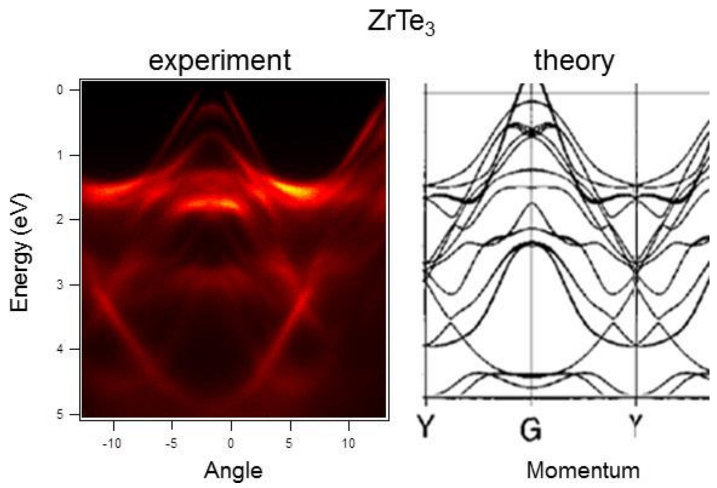
X-ray absorption – Chemical characterization
X-ray diffraction - Structural characterization
Fluorescence - Chemical characterization
X-ray scattering - Atomic properties (form factor, refractive index)
Photoemission - Electronic characterization – band structure











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X-RAY TOMOGRAPHY

Modalities by Imaging method

- Phase contrast imaging
- Dark field imaging
- Holotomography
- Spectral imaging
- Nano – tomography

Zernike phase imaging, interferometery, analyzer based, propagation, edge illumination

Zernike phase imaging, dual grating interferometery

Propagation based

Detector level improvement

Coherent diffraction imaging, cone-based geometry

Modalities by

- Diffraction contrast tomography
- SAXS tensor tomography

PHASE CONTRAST IMAGING

Why Phase contrast imaging?

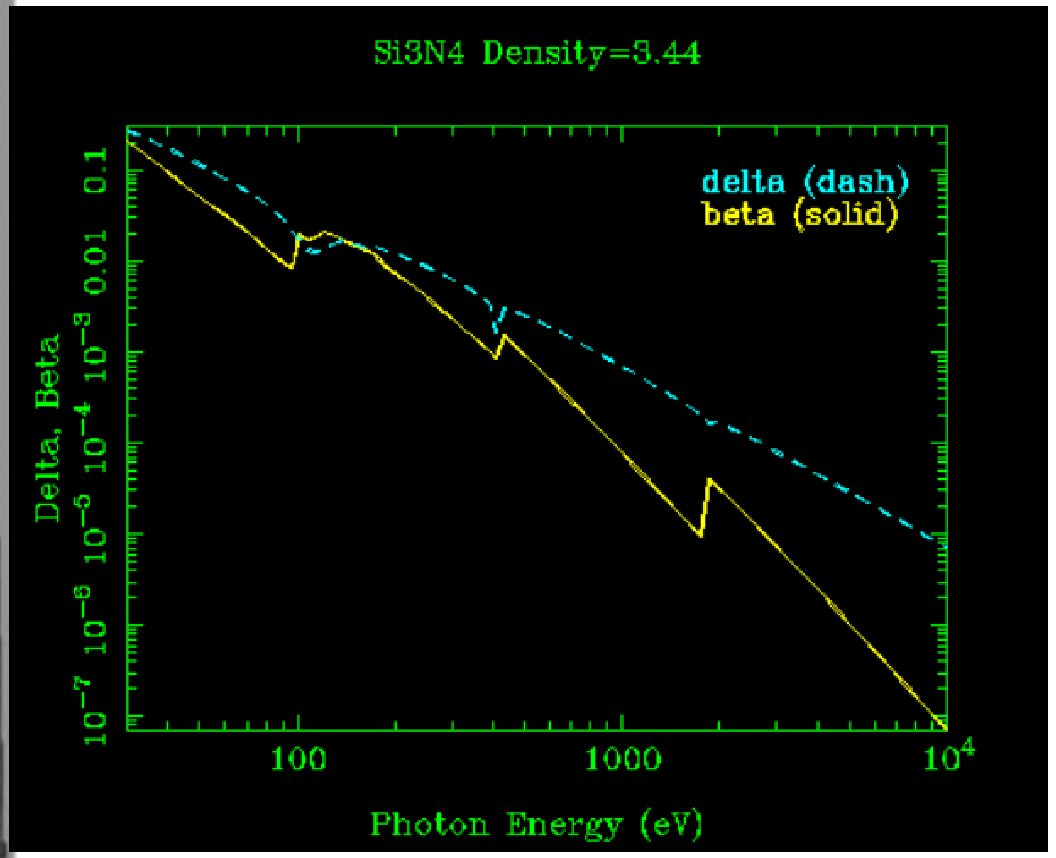
- Measure non-absorbed region
- Suitable for organic materials
- Particularly at high energy

Refractive index → $n = 1 - \delta + i\beta$

Phase shift → $2\pi\delta$ thickness/λ

By Zernike phase imaging, Interferometery, analyzer and propagation based methods

(a) Transmission (b) Phase contrast



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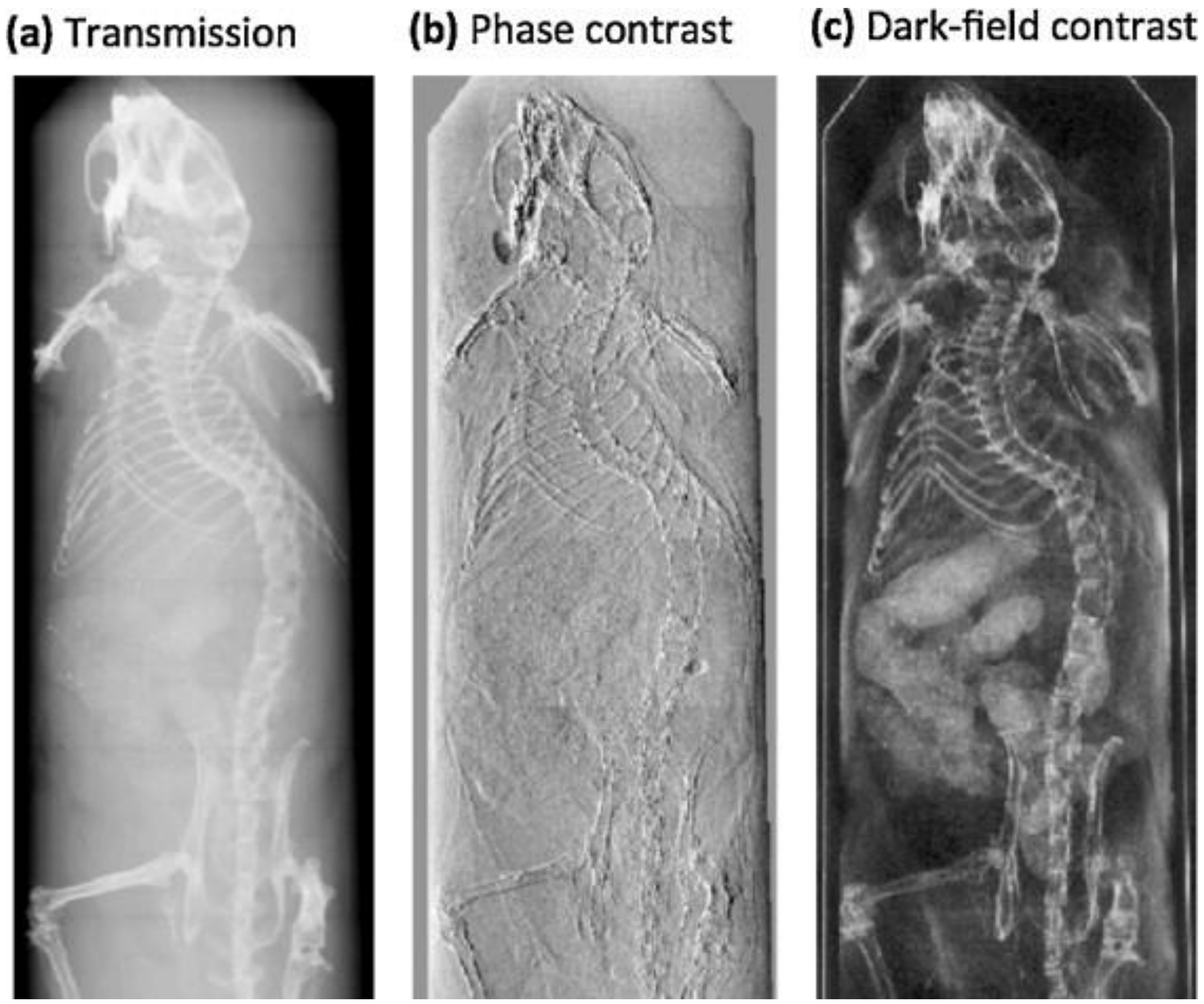
DARK FIELD IMAGING

- Measure only the scattered beam
- Why ? Can be sub-voxel resolution, higher contrast

By Zernike approach, grating interferometry



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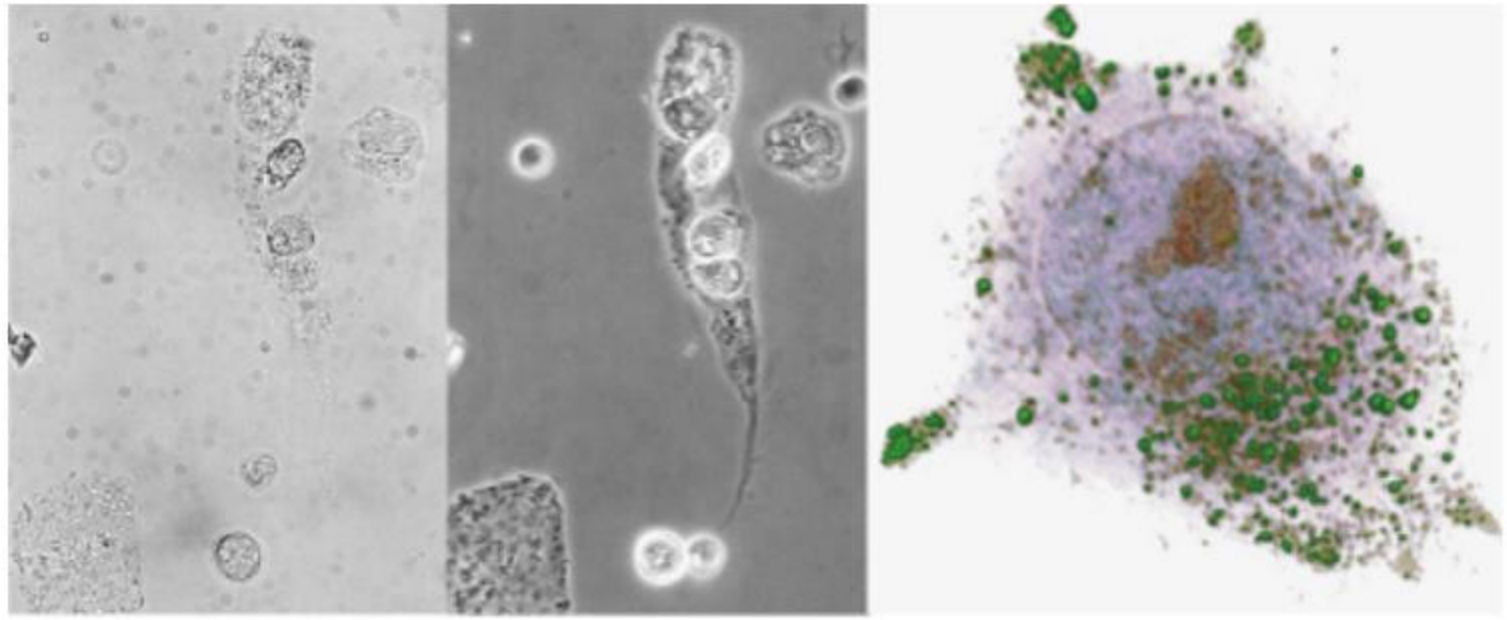
HOLOTOMOGRAPHY

– Similar to Phase contrast tomography

– Measure the local refractive index

$n = 1 - \delta + i\,\beta$



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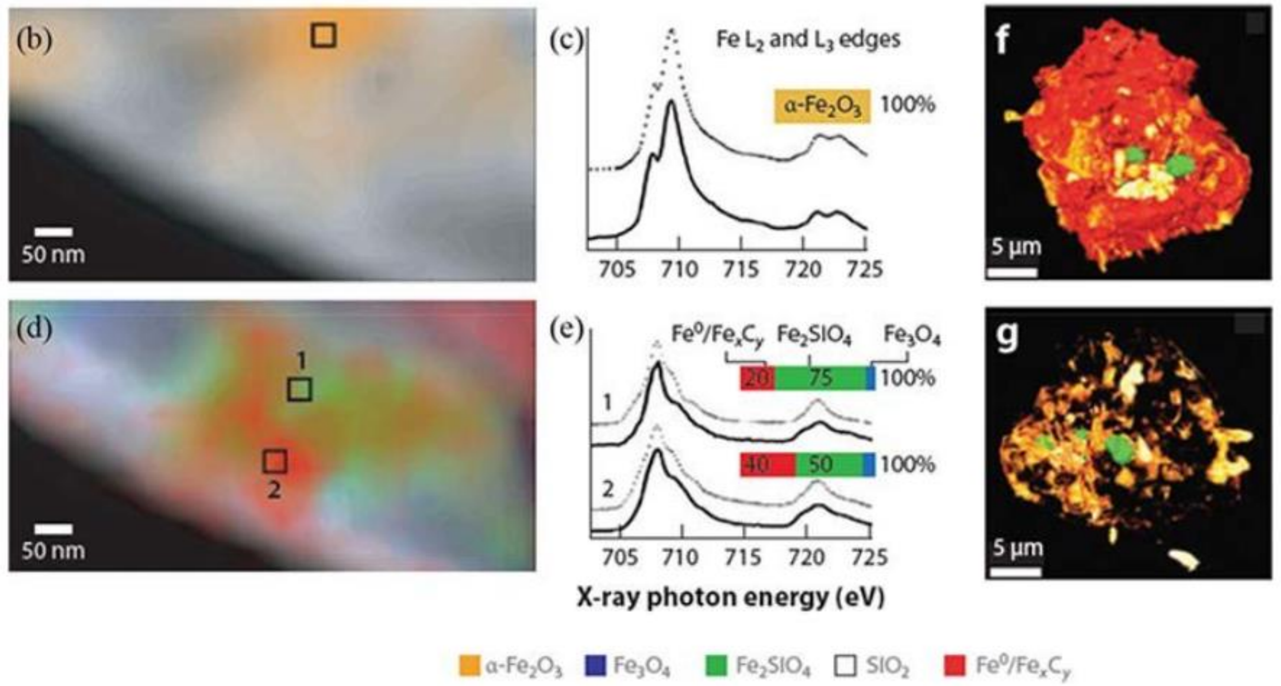
SPECTRAL IMAGING

Tune X-ray photons



- Image a sample with different absorption edges

- Spectral/hyperspectral imaging - Detector level, create bins to separate interacted photons

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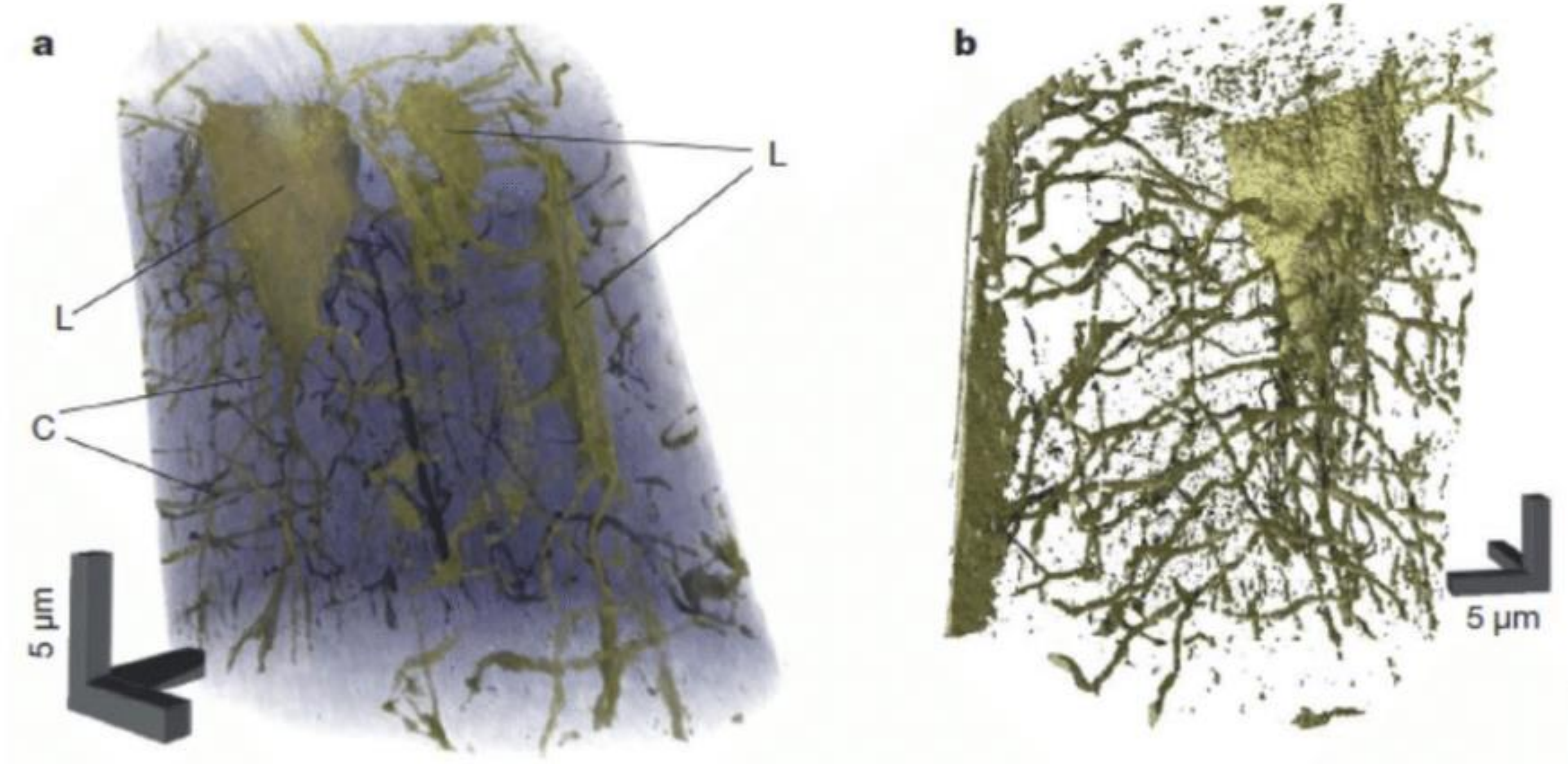
NANOTOMOGRAPHY

- Can be achieved in lab-based setup e.g. HECTOR
- Synchrotron at the detector level
- Newer approach → Ptychography or Ptychotomography
- Based on Coherent diffraction imaging can reach resolution below 10 nm



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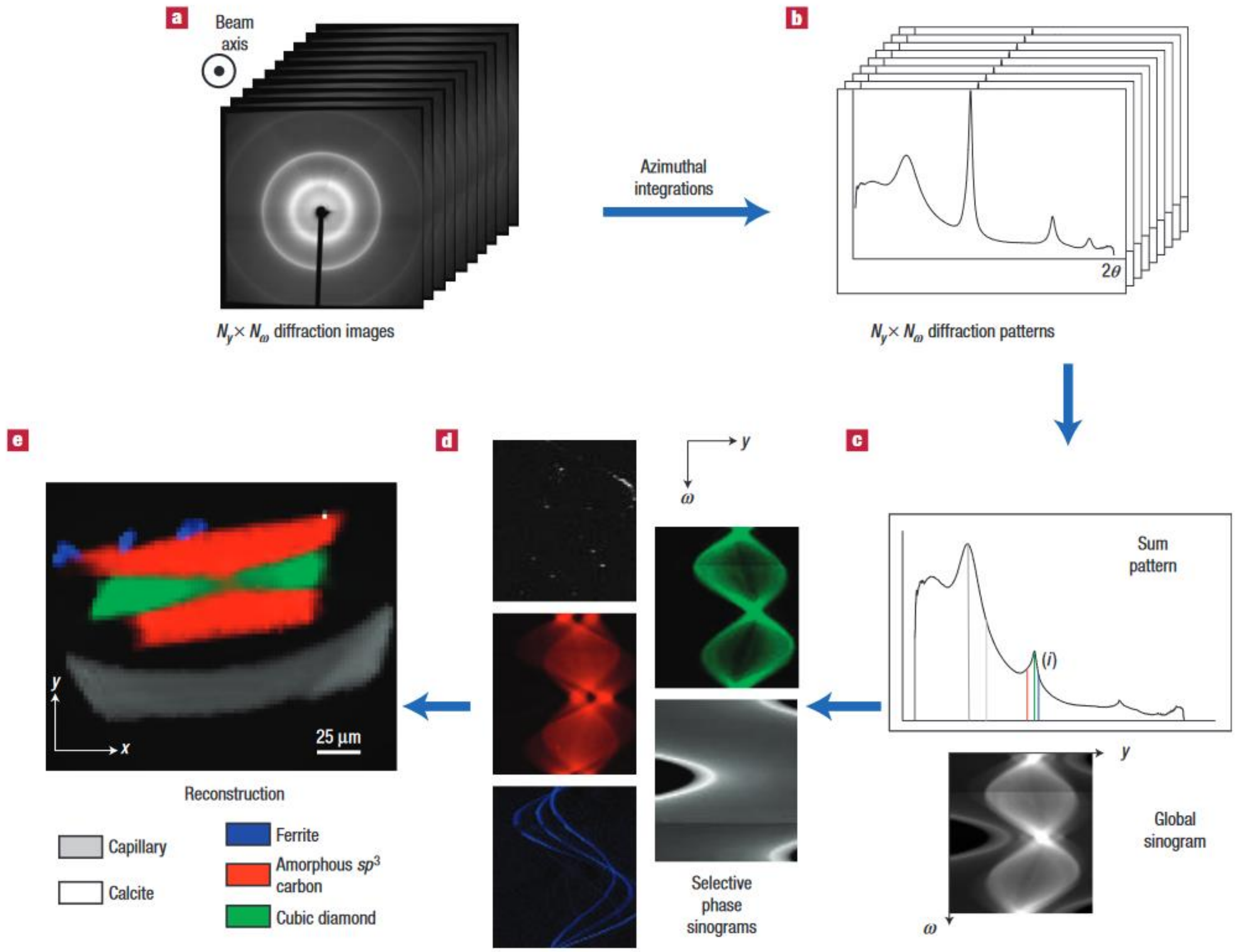
DIFFRACTION CONTRAST TOMOGRAPHY

- To measure crystallinity
- Are of two types – DCT/XDT
- Computationally intense
- Lab based – not good resolution
- Better at Synchrotrons



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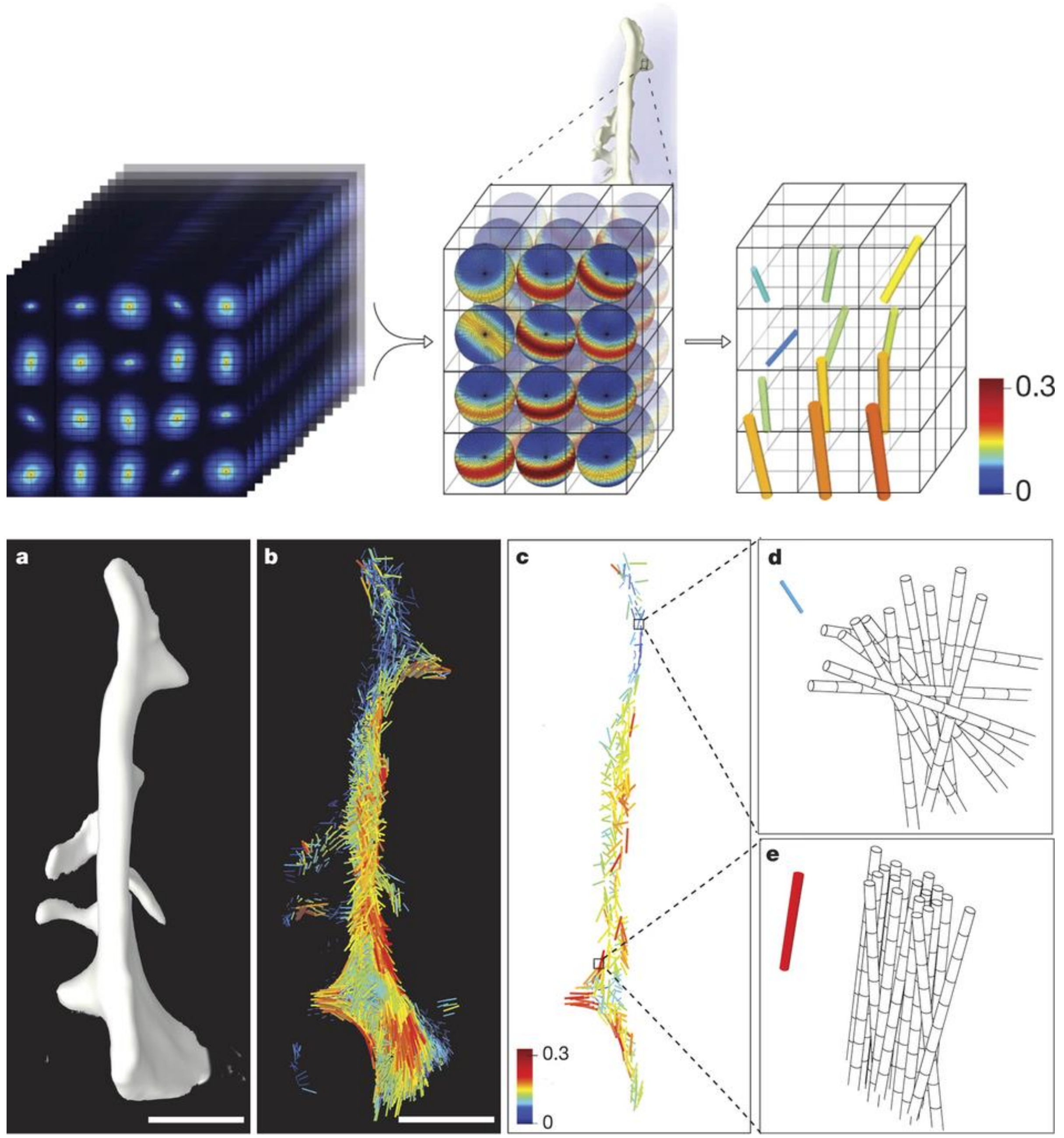
SAXS TENSOR TOMOGRAPHY

– Absorption – Scalar quantity

– 3D X-ray scattering – Tensor quantity



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