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Recent developments in X-ray imaging

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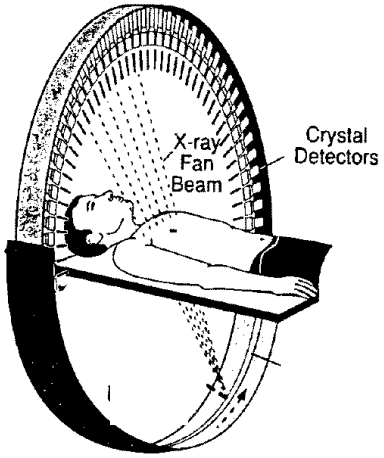
www.SCANCO.ch

SCANCO Medical

- Company
- Systems and components
- Applications
- Analysis/Quantification
- New Methods

SCANCO Medical AG

- Company founded in1988
- IBT (ETH/UNI Zürich) bone research using computed tomography to measure **bone density**
- Focus of presentation on CT scanning
- Systems for nondestructive testing of material in 3D



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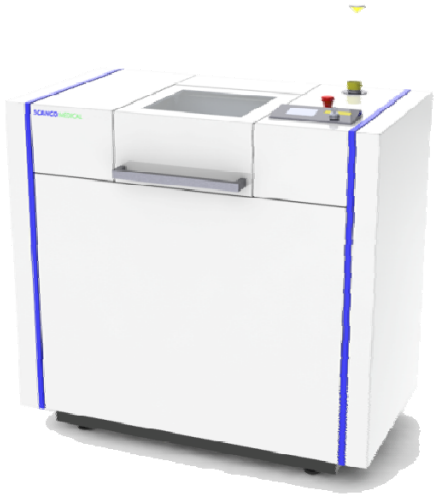
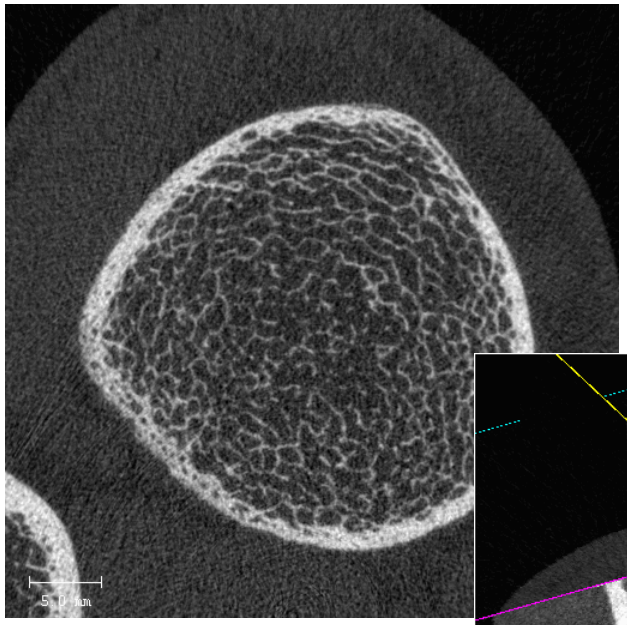
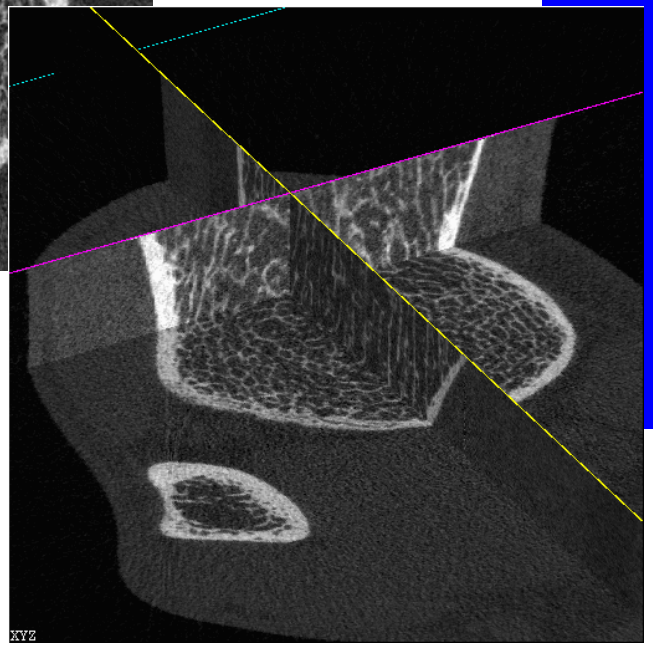
Systems

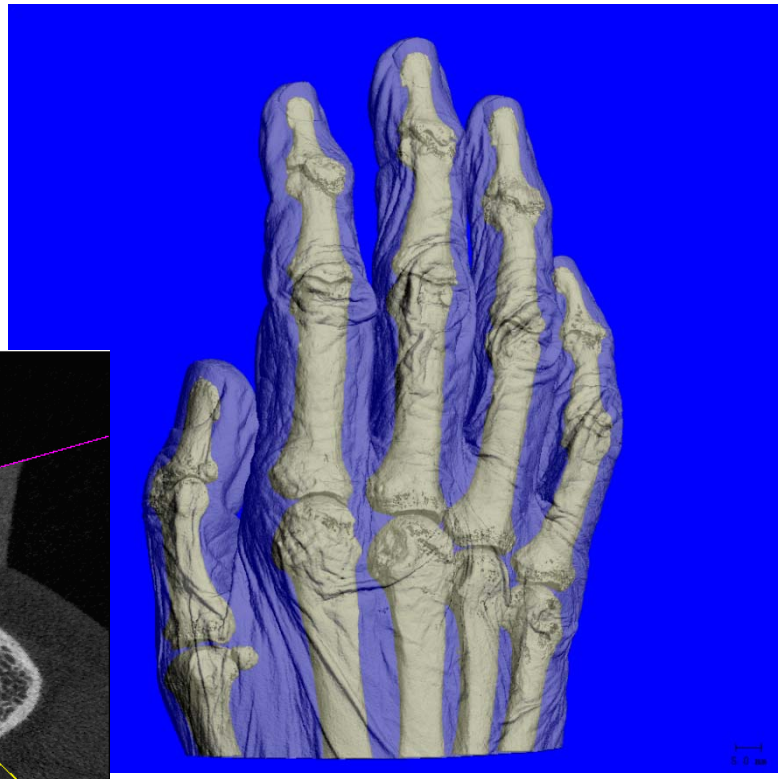
- Specimen scanners
- Animal systems
- Patient system



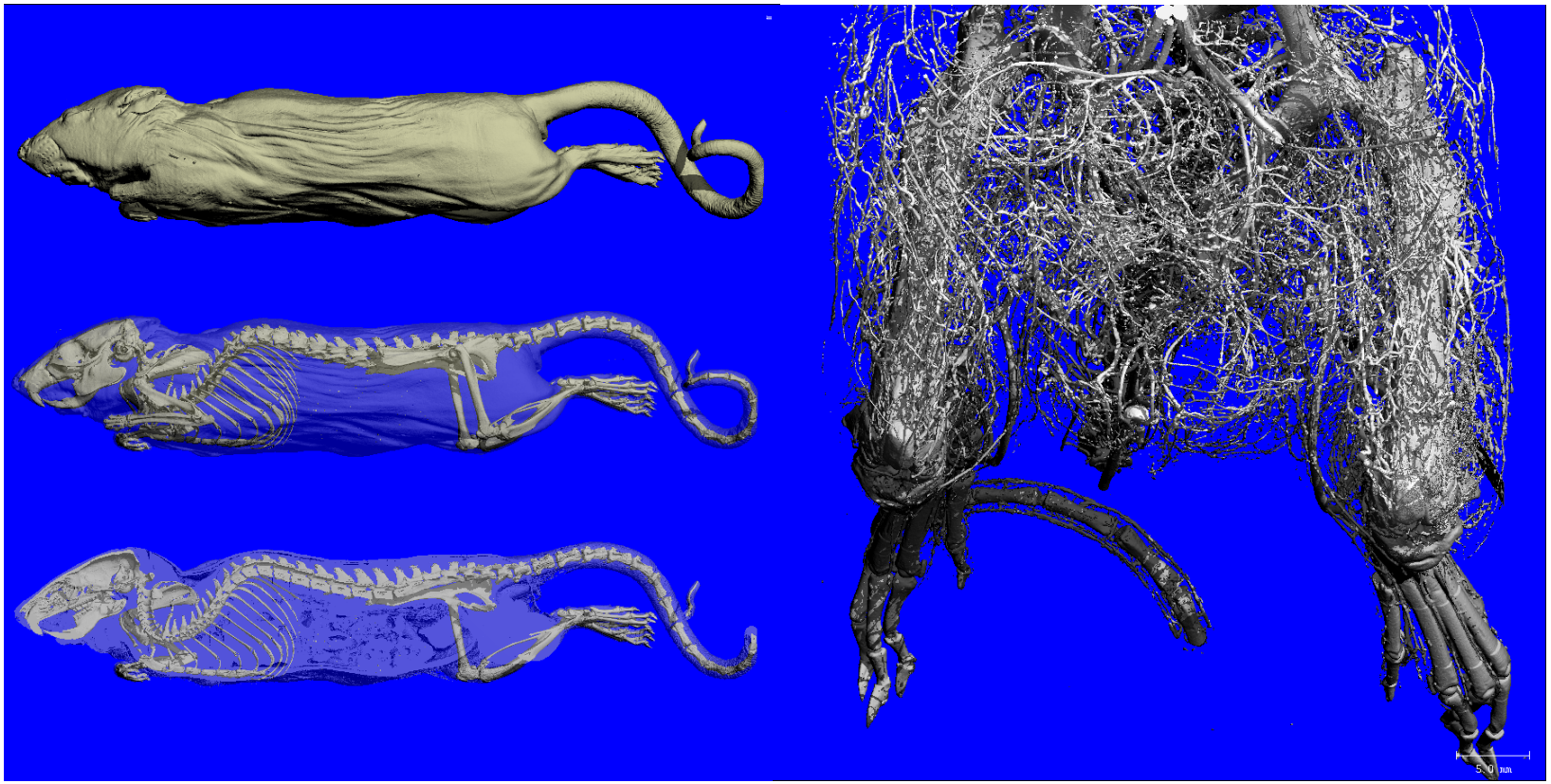
Patient (extremities) scanner (~60 µm)







Small Animal Systems (~10 µm)



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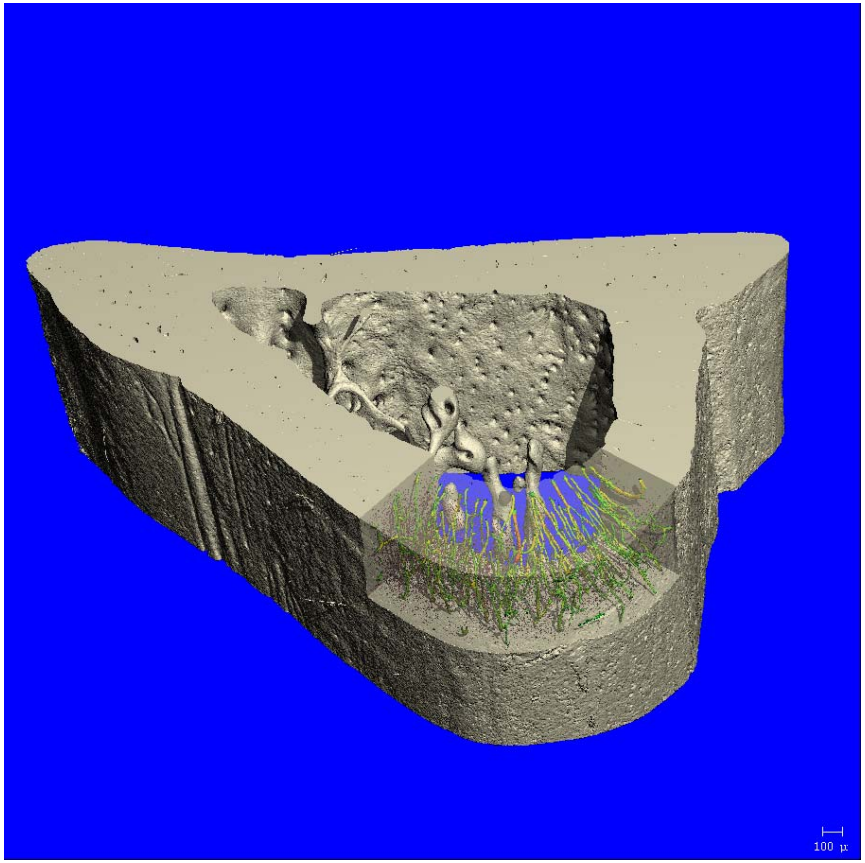
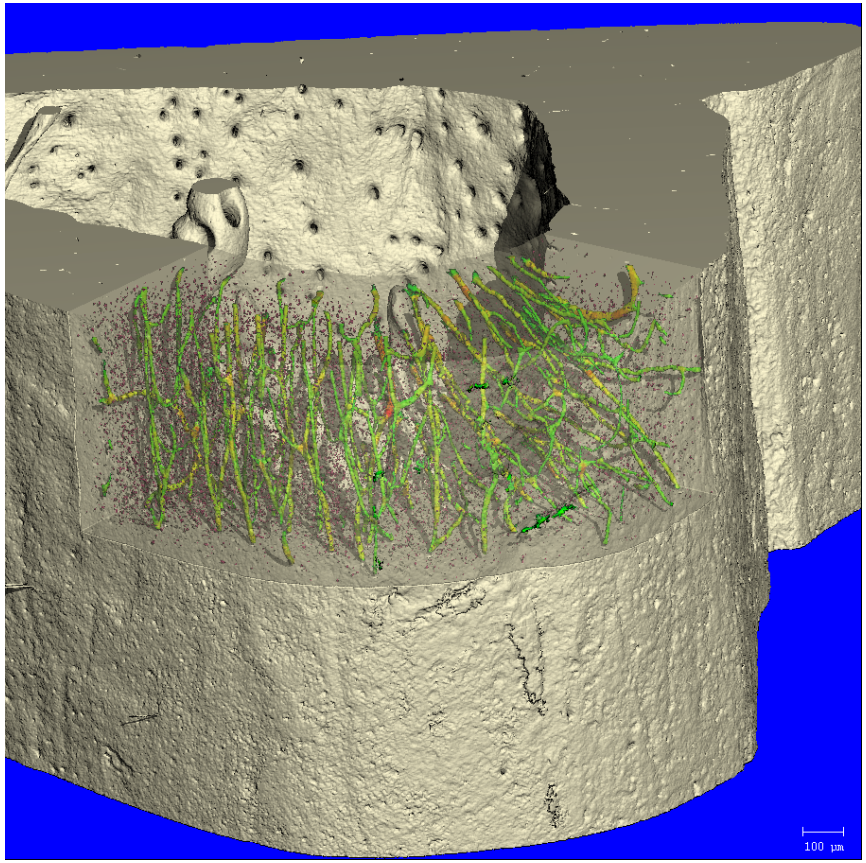
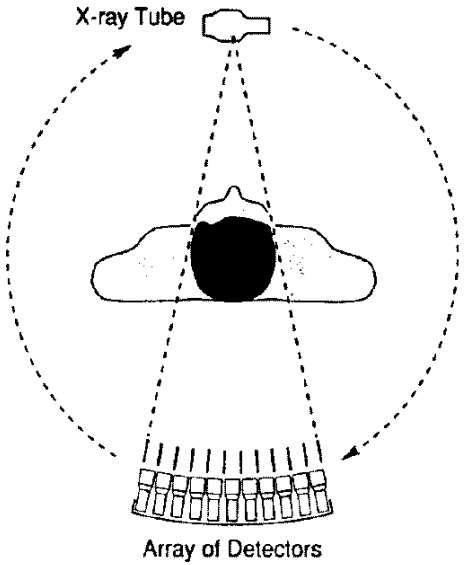
Specimen Scanners (~1 µm)



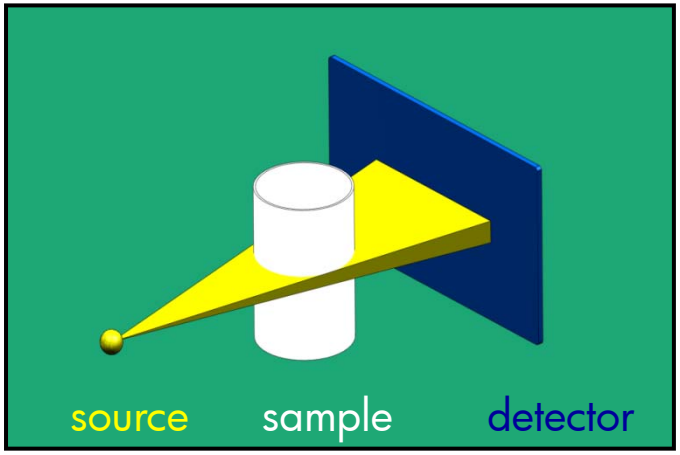


Components today

- Sealed Microfocus x-ray tube
- CCD Detector with fiber optic scintillator



Rotating gantry



Rotating specimen

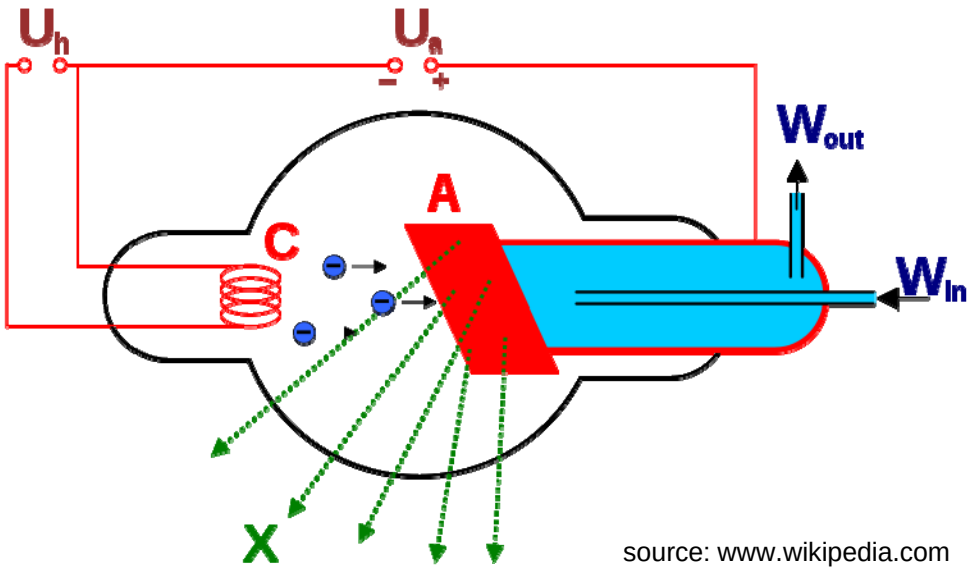
X-ray source

Synchrotron

- Very high flux
- Coherent radiation
- Monochromatic X-rays

X-ray source

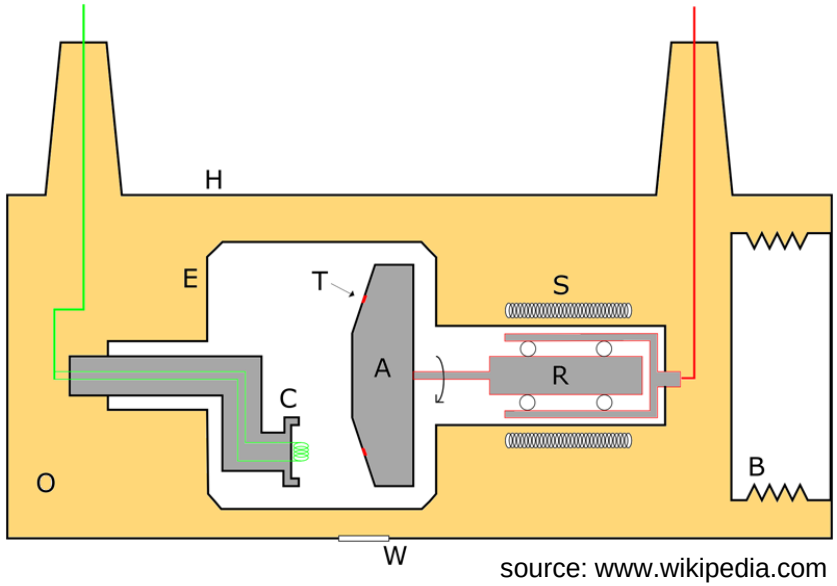
- X-ray tube
  - ✓ Sealed tube (still the same as what Conrad Röntgen used)
    - Microfocus: Dispenser Cathode, electrostatic focusing, 8µm /8W (<1% of electron beam energy is converted into x-rays!)
  - ✓ Open tube
    - <1µm
    - Higher magnification



source: www.wikipedia.com

X-ray source

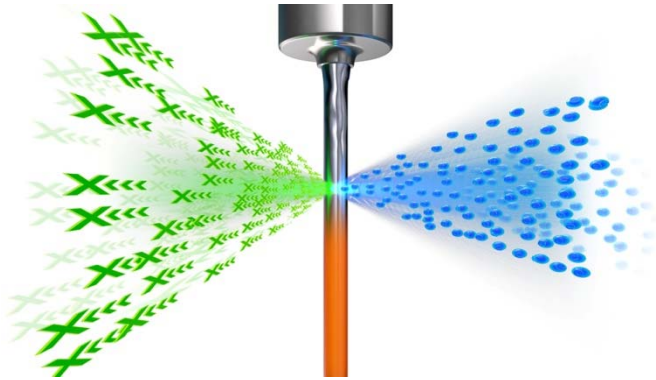
- Rotating Anode
  - ✓ 80kW for short time (Focus in mm range)
  - ✓ Down to ~100µm focus available



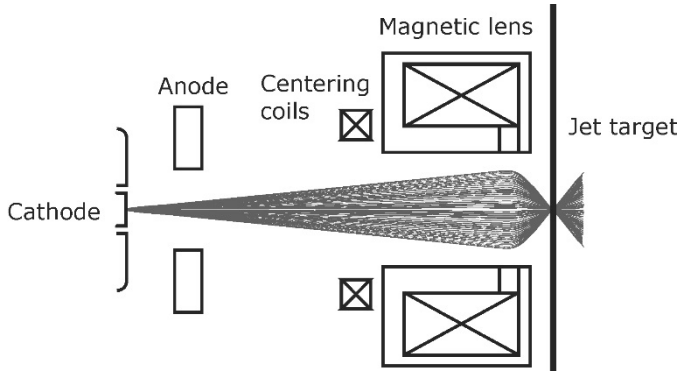
source: www.wikipedia.com

X-ray source

- Liquid jet (e.g. Ga/In/Sn)



source: www.excillium.com



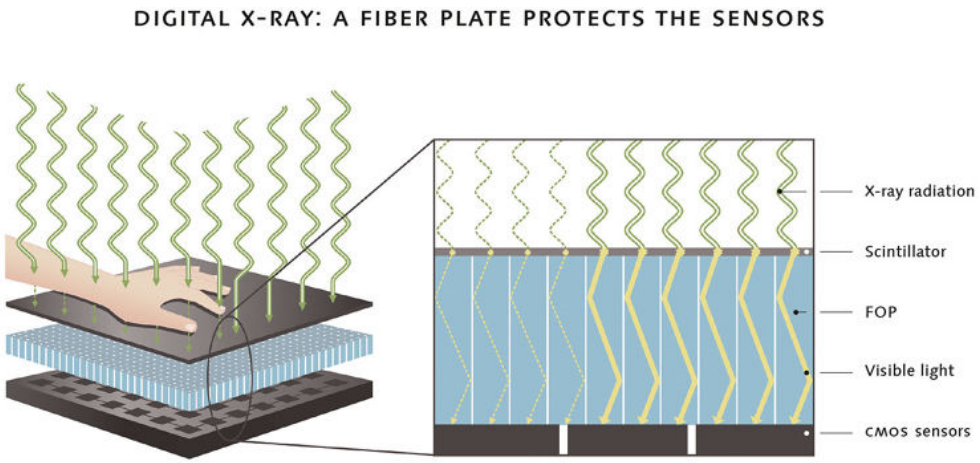
source: www.excillium.com

Up to ~30 x brighter than a sealed microfocus tube

X-ray Detector

- Indirect Detector

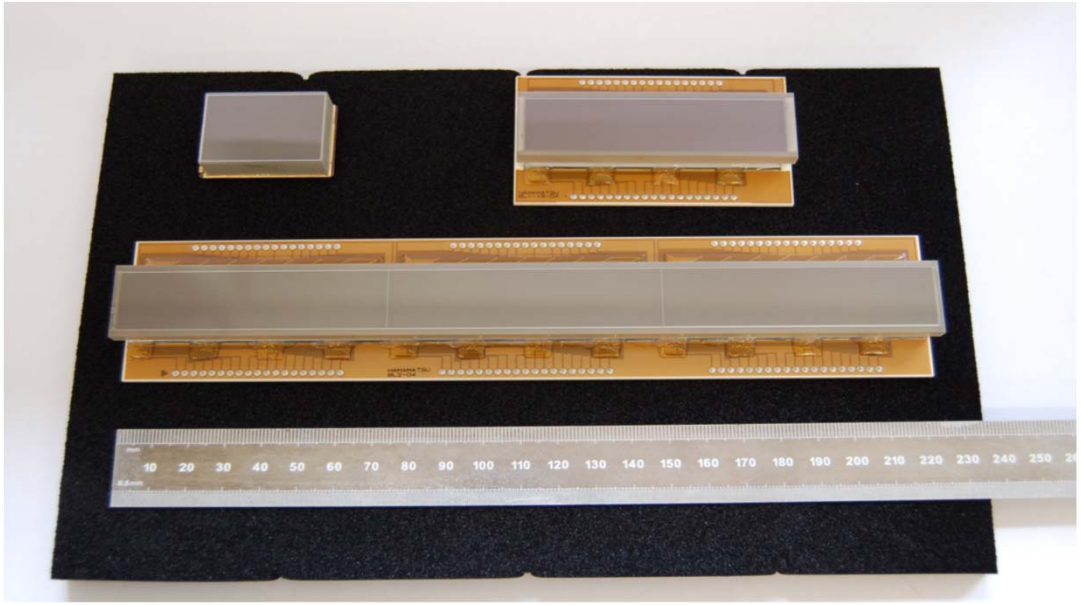
  - ✓ Scintillator (efficiency/resolution)
  - ✓ Fiber optic (geometric distortion)
  - ✓ Pixel array (size, efficiency, resolution, speed,…)



source: www.schott.com

X-ray Detector

- CCD, Full frame
  - ✓ ~100% fill factor, X-ray needs to be blocked during readout (~50ms)
  - ✓ 50µm pixel size, parallel outputs (4/segment)



X-ray Detector

- CMOS active pixel sensors ("DSLR-like")
  - ✓ Very low noise (few electrons)
  - ✓ Fast readout (>10 Frames/s, 200Mbyte/sec)
  - ✓ Rather small pixels (few microns ->Scintillator, Fiber optic)
  - ✓ Low fill factor (+/- 50% except back illuminated)
  - ✓ Limited area (standard up to 24 mm x 36 mm)
  - ✓ Additional functionality (windowing, rolling shutter, global shutter)

X-ray Detector

- CMOS x-ray flat panel
  - ✓ Pixel size from 24µm to 100µm
  - ✓ Low Nosie (~100 electrons)
  - ✓ Relative large area (up to 11cm x14cm single tile size, buttable for larger area)
  - ✓ Acceptable fill factor (~80%)

X-ray Detector

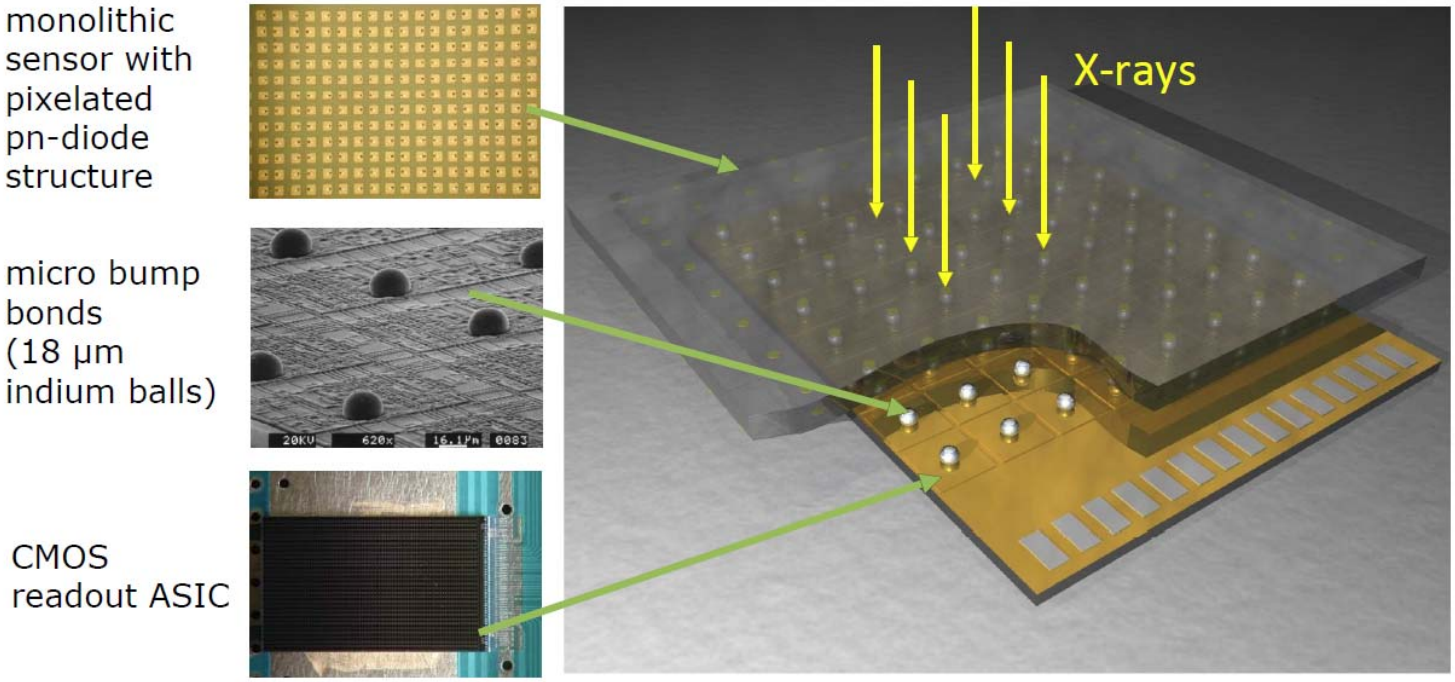
- Indirect detection with TFT Flat panel and scintillator
  - ✓ Large area (e.g.43cm x 43cm)
  - ✓ Larger pixels (75µm- 400µm)
  - ✓ Radiation tolerant (no fiber optic, suitable for high energy >200keV)

- Direct detection with TFT Flat panel

  amorphous Selenium, direct conversion of x-ray photons into electrons

X-ray Detector

- Hybrid, Photon counting, direct detection
  (CdTe, Cd(Zn)Te,Ge,GaAs)
- Allows energy selective photon counting



Source: www.dectris.com

Detector summary

- CMOS sensor (active pixel sensor, front illuminated/back illuminated)
- CMOS x-ray flat panel (as in Cone beam CT, Mammography systems, Digital x-ray)
- TFT flat panel (direct/indirect)
- Hybrid, photon counting detectors

New components allow

- Dedicated systems
  - ✓ Larger objects, still very high resolution (8kx8k images)
  - ✓ Big objects, low resolution, but ultrafast
  - ✓ Very small objects, extremely high resolution
  - ✓ …

Wider industrial fields I (LR, fast)

- Baggage inspection
- "and dual-energy 3-D imaging for large baggage"
- "at 1,000 bags per hour"

Source: Leidos, USA, www.leidos.com

Wider industrial fields II (LR, fast)

- "Scan speed down to 15 sec. for a cylinder head" (GE)

Sources: Rayscan, www.rayscan.com
GE/Phoenix X-ray, www.phoenix-xray.com

Wider industrial fields III (BIG, fast)

- Wood
- up to 180 m/min

Source: Microtec Italy, www.microtec.eu

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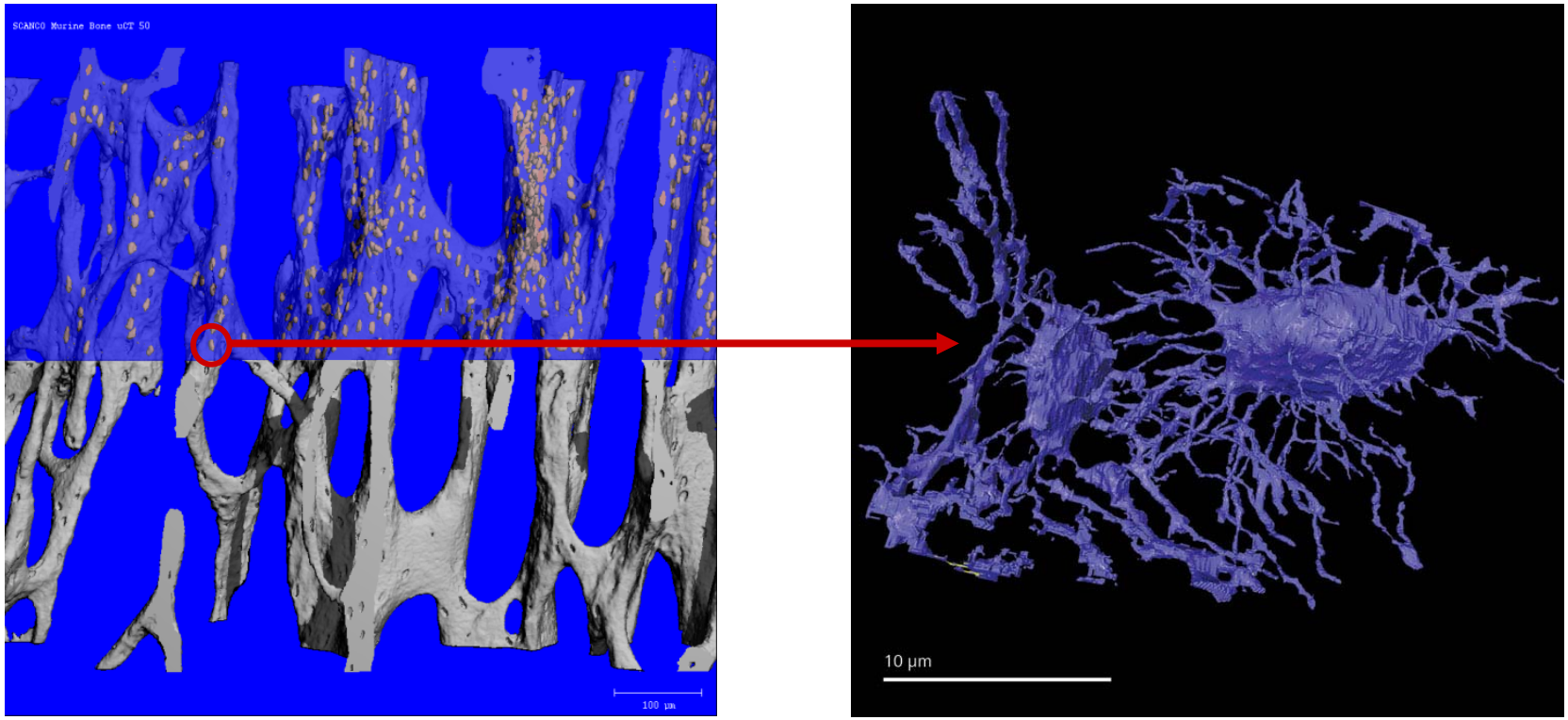
Wider industrial fields IV (ultra HR)

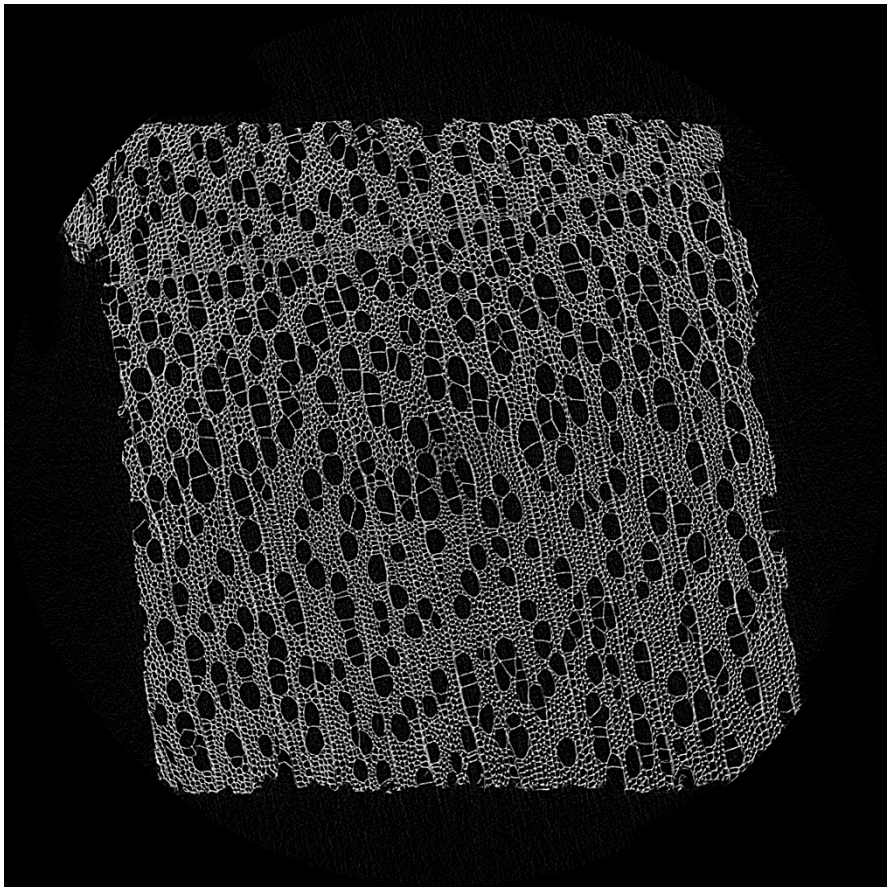


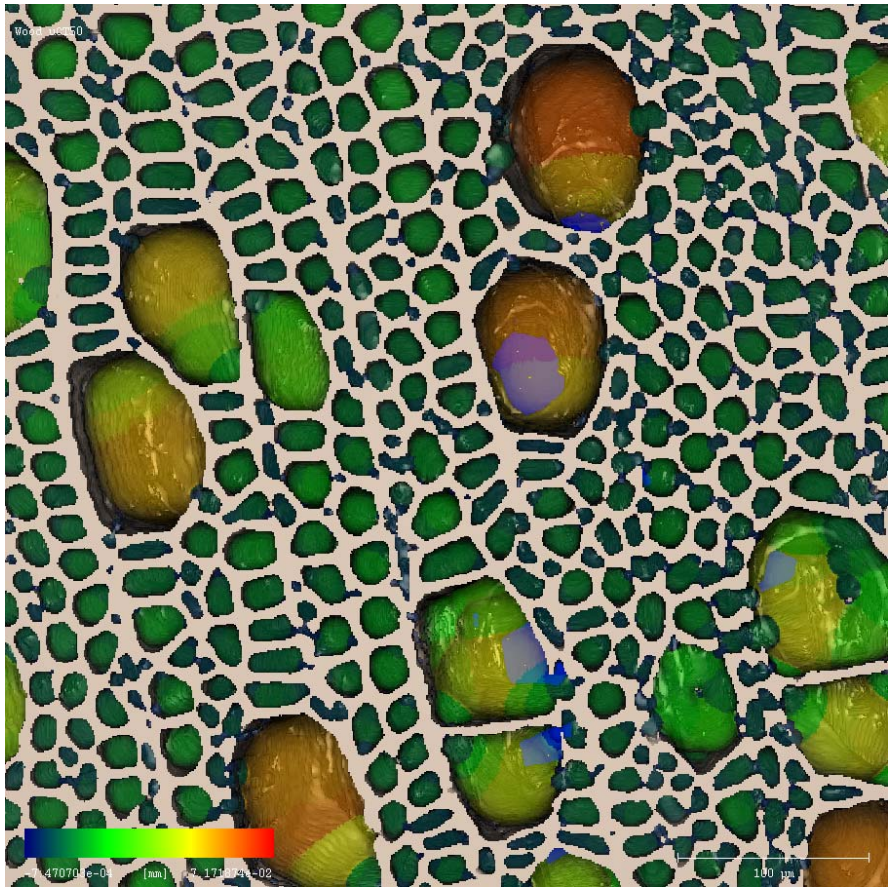
Sources: SCANCO Medical AG, www.scanco.ch
Zeiss AG, www.zeiss.com

Applications

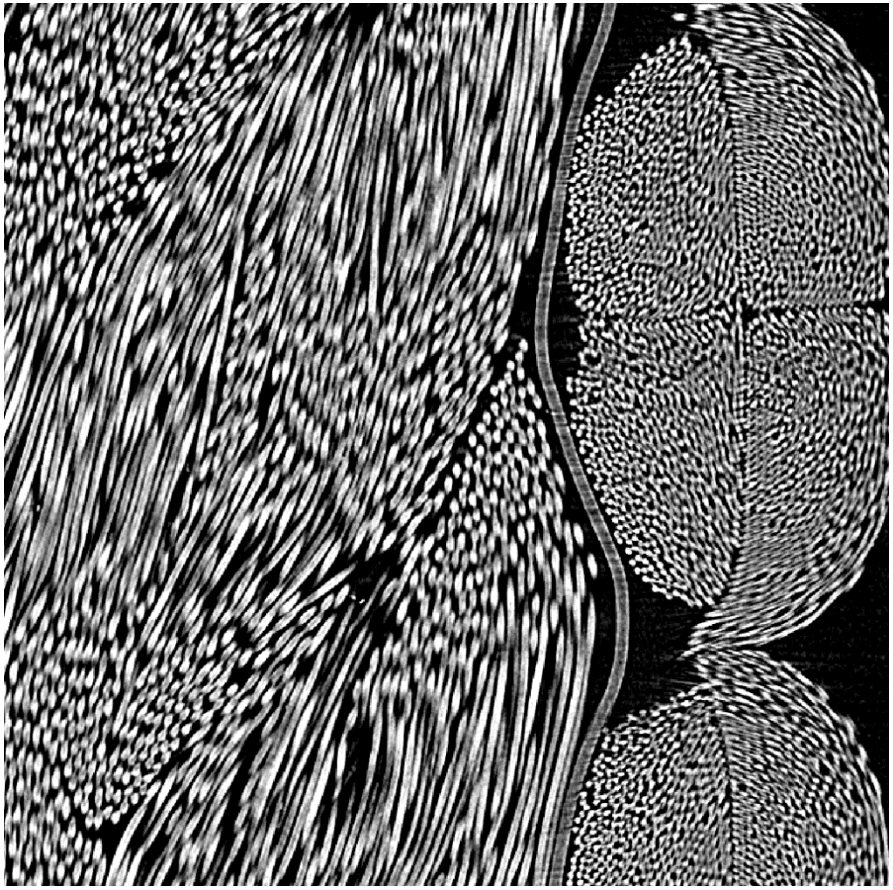
- Porous structures
- Fibers
- Paleontology
- Thin layers / Wall thickness
- Hidden Features
- Electronics
- Food
- …

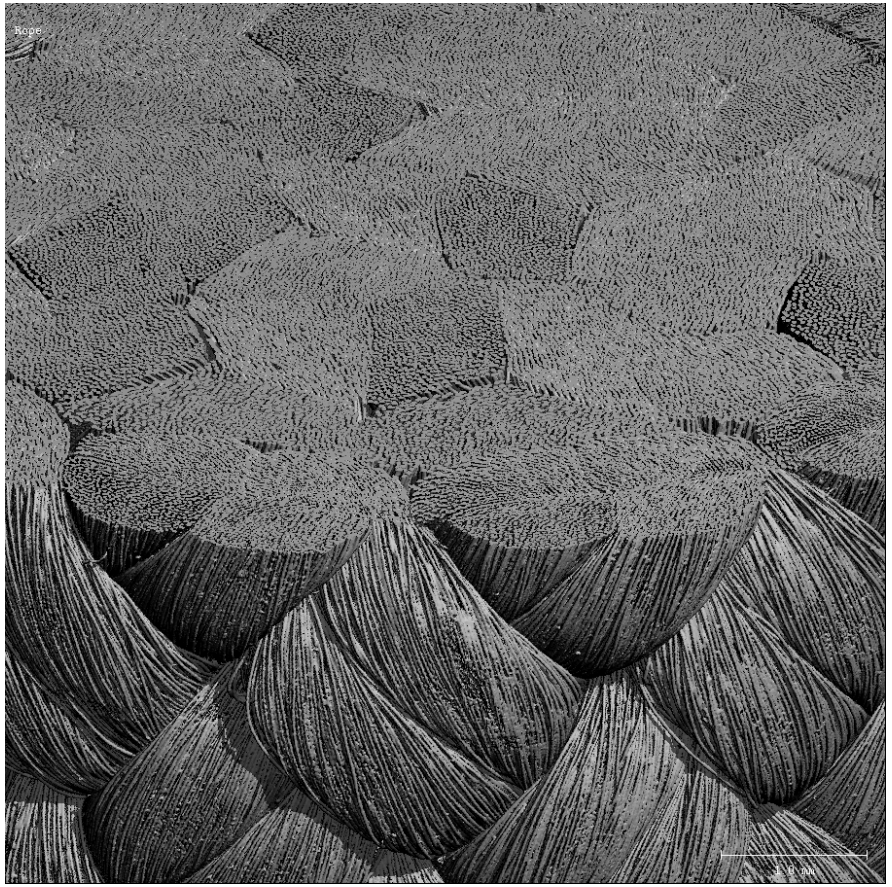
Porous Structures / Wood (match)





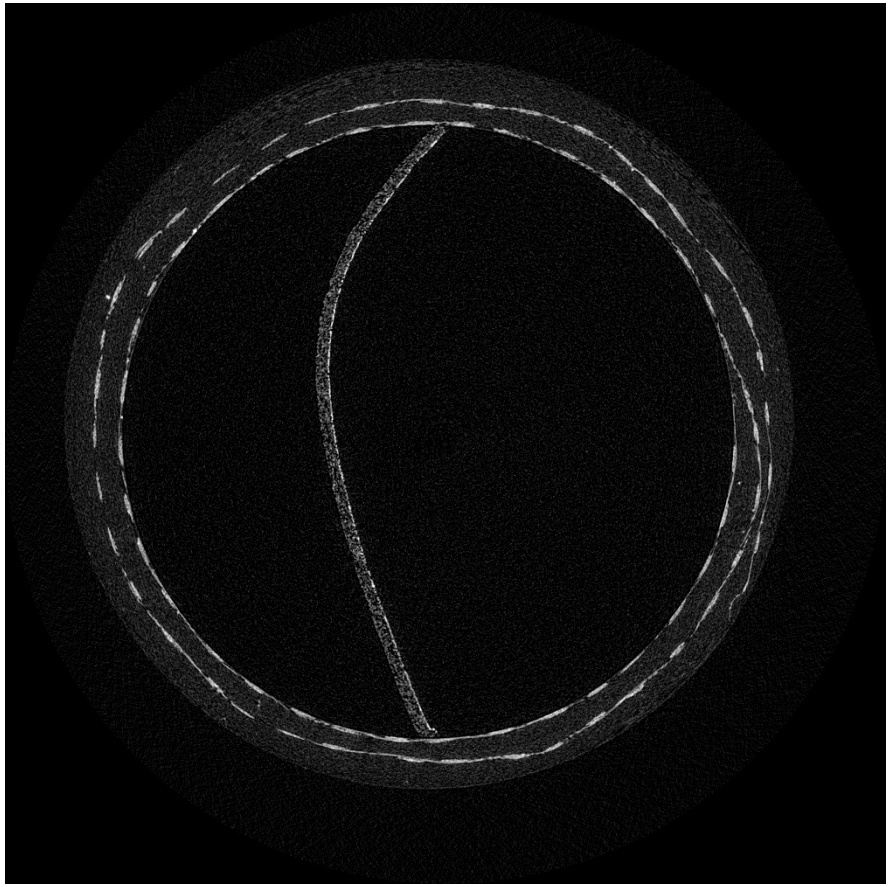
Fibers / Climbing Rope





Paleontology / Falcon Mummy

Thin Layers / Laserprinted 'A'



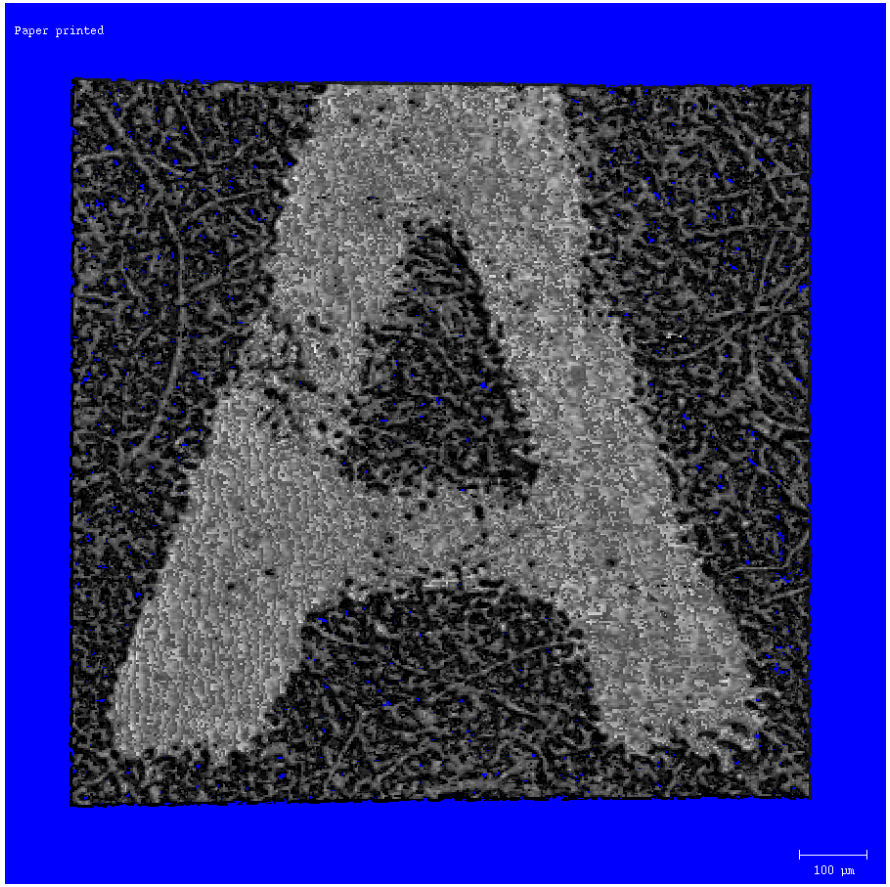
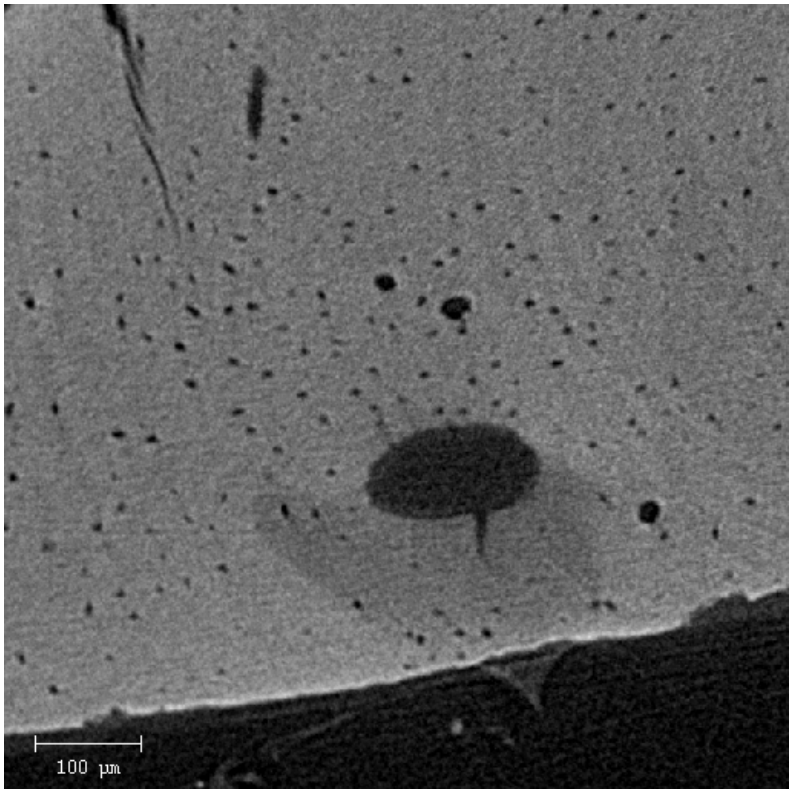
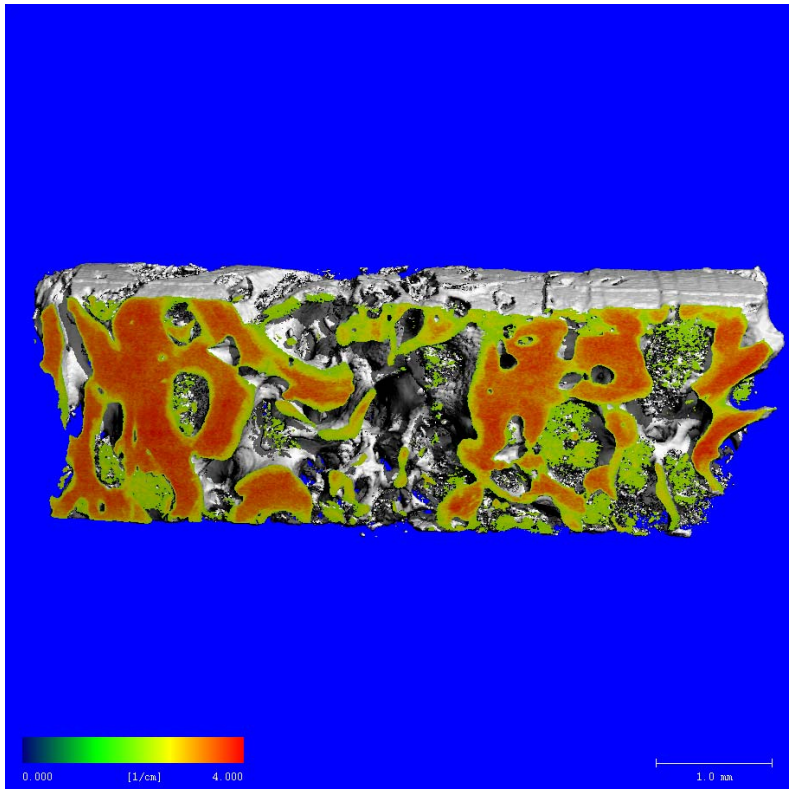


Image Analysis and Quantification

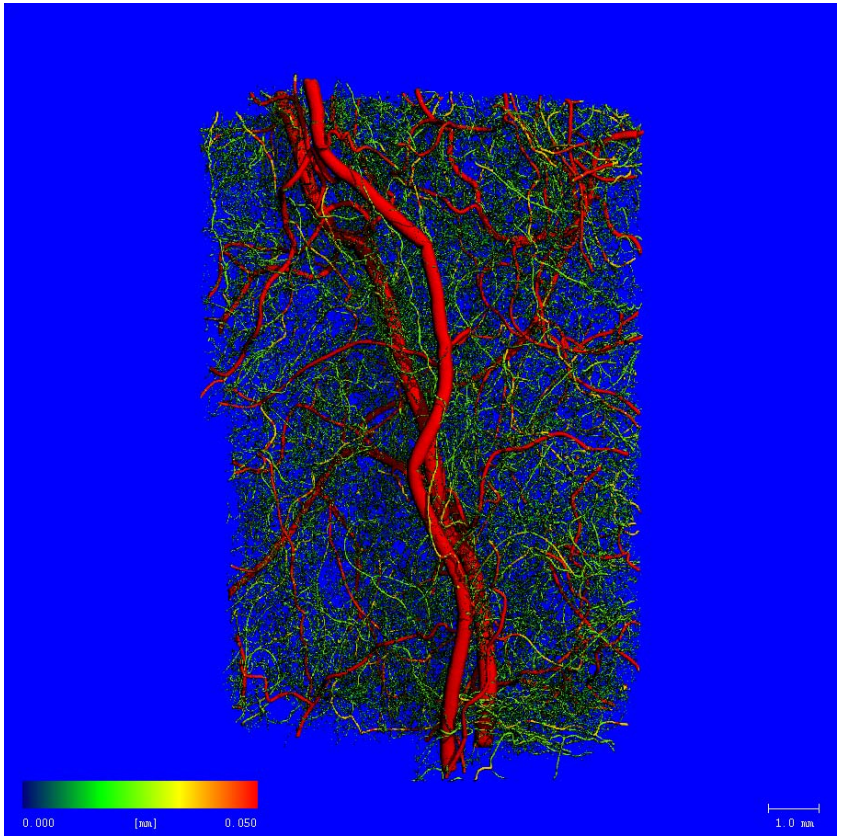
- Densitometry
- Morphometry
- Metrology
- Rapid Prototyping
- FEA
- …

Densitometry/Human Bone

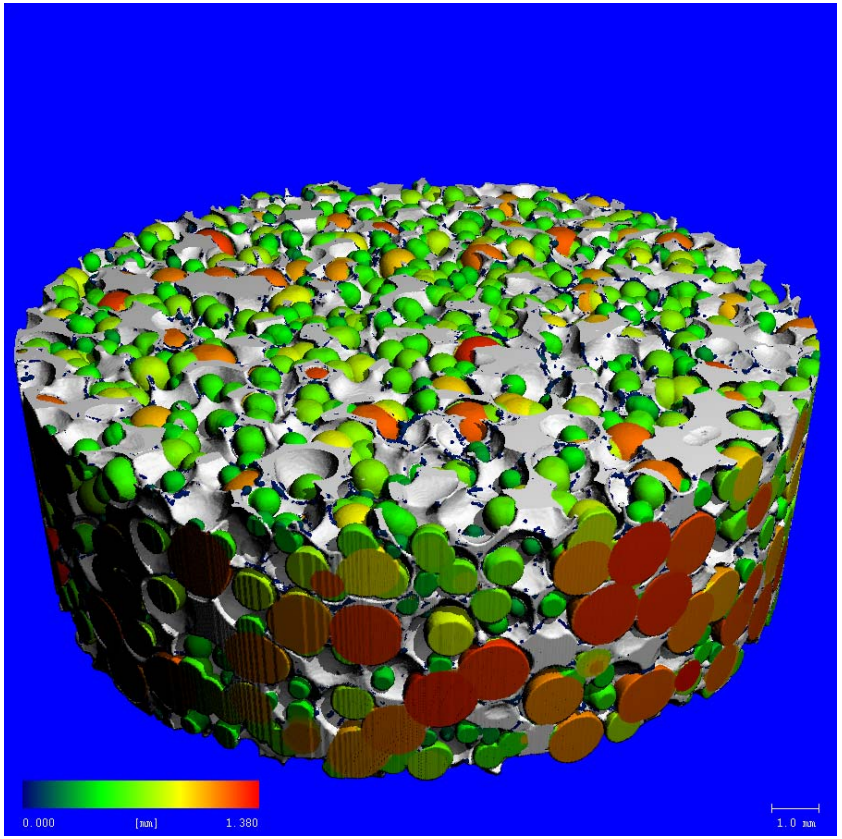




Morhpometry



Skin/Blood Vessels



Pore thickness

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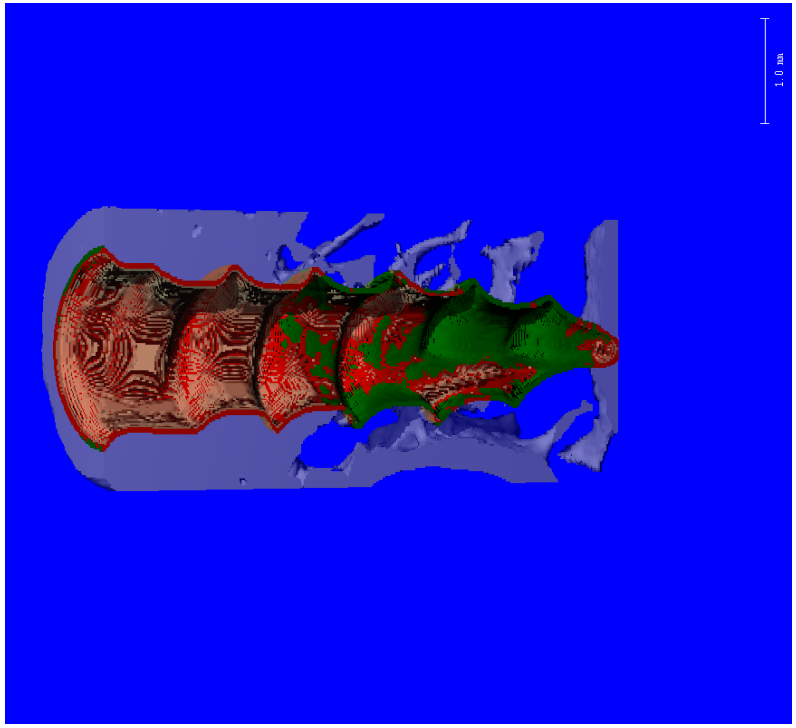
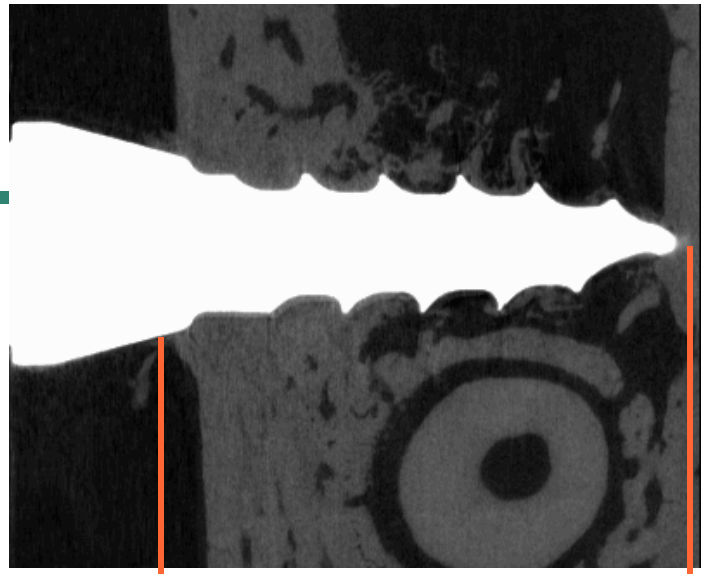
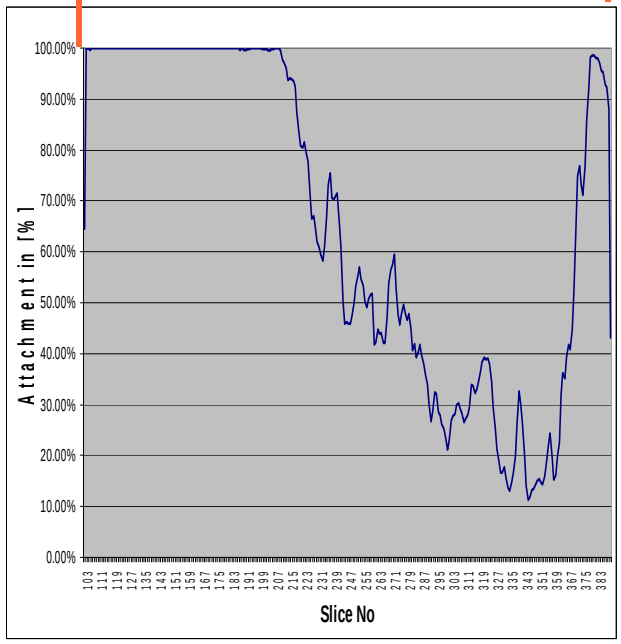
Attachment Analysis

- Is the implant attached to bone? expressed in % of the (local) implant diameter







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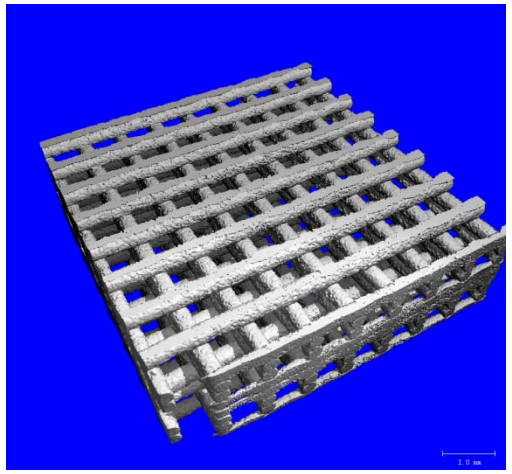
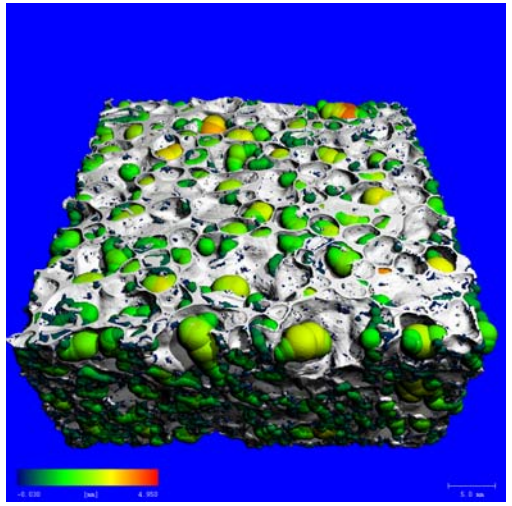
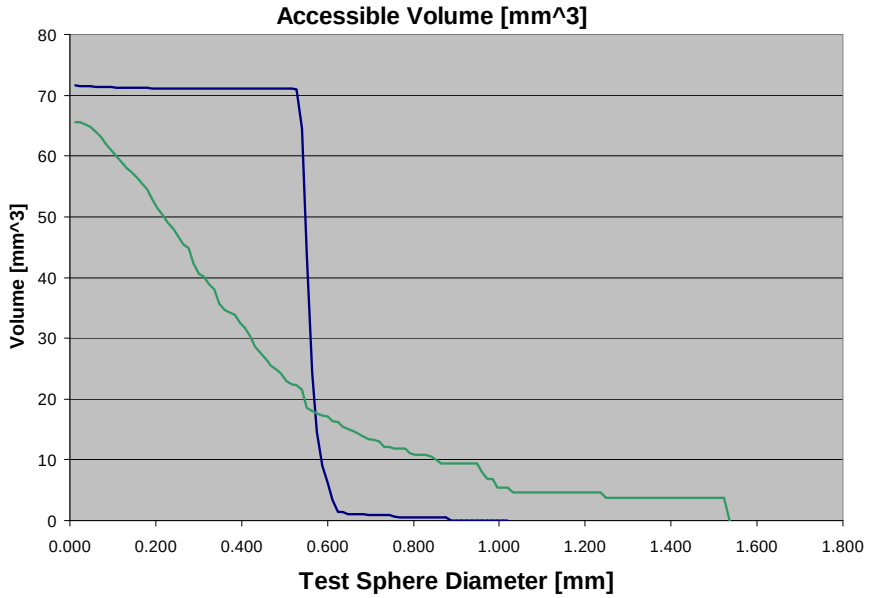
Accessible Pore Volume

- Permeability can be simulated: Accessible Pore Volume for a given ‘cell size’ (mercury intrusion)
- Virtual spheres with increasing diameter
- Accessible volume decreases







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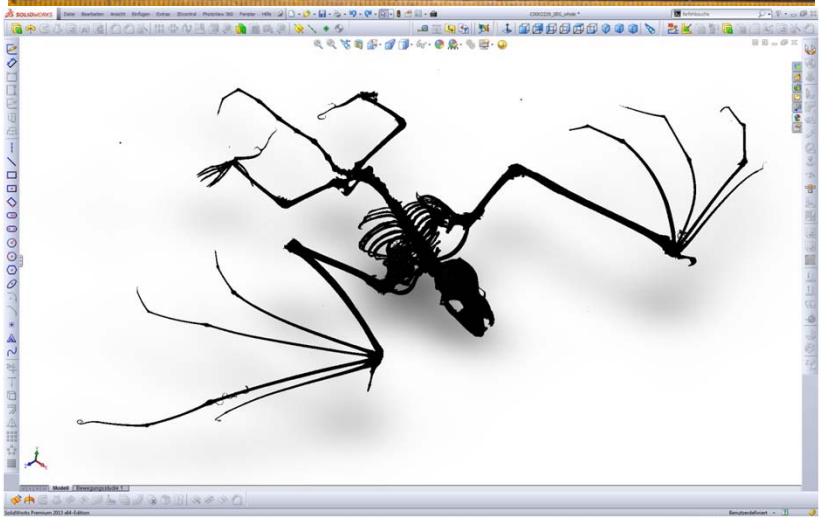
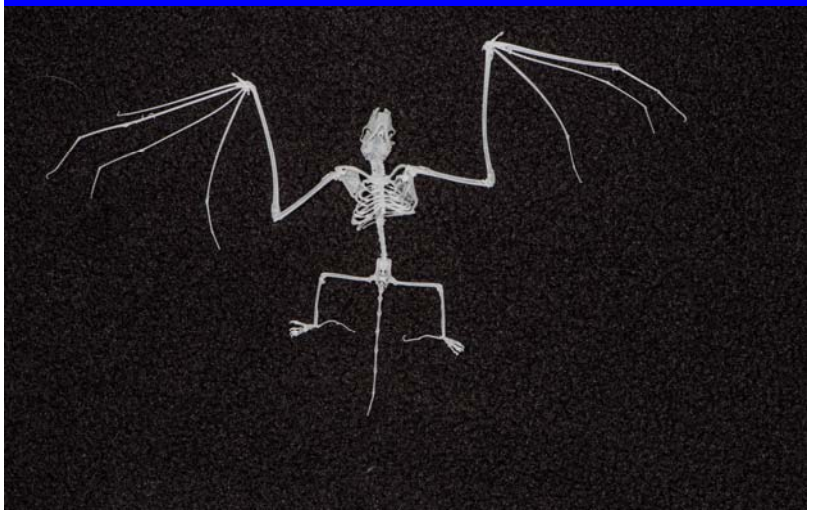
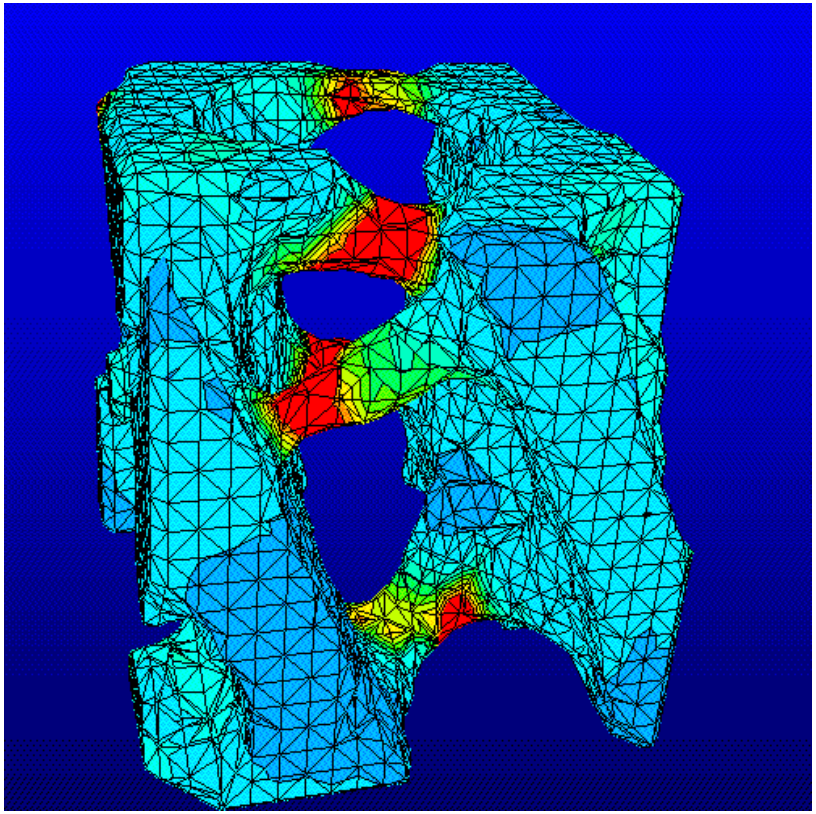
Reverse Engineering + Rapid Prototyping

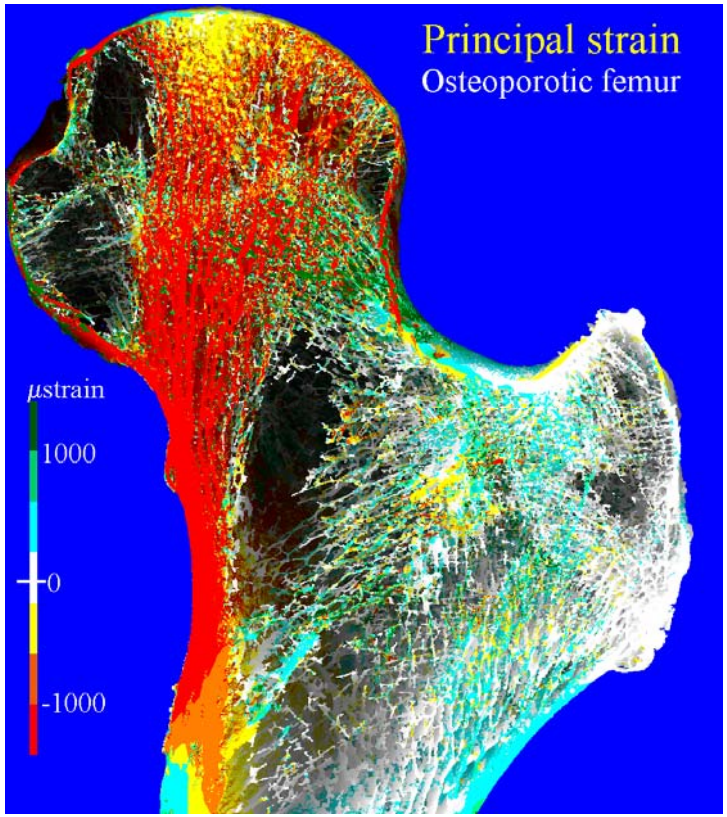




Finite Element Analysis



Trabecular Bone



Human Femur

New methods

- Phase contrast imaging with laboratory x-ray source
  - ✓ free-space propagation
  - ✓ grating interferometer-based techniques.
  - ✓ Speckle-Based
- Dual (multi) energy CT (energy resolving detector)
  - ✓ Low concentration of contrast agent
  - ✓ Reduction of metal artefacts
- Time lapsed CT
  - ✓ Motion Analysis
- Multi-modality imaging (CT, PET, SPECT combined with MRI and optical methods)

Phase contrast

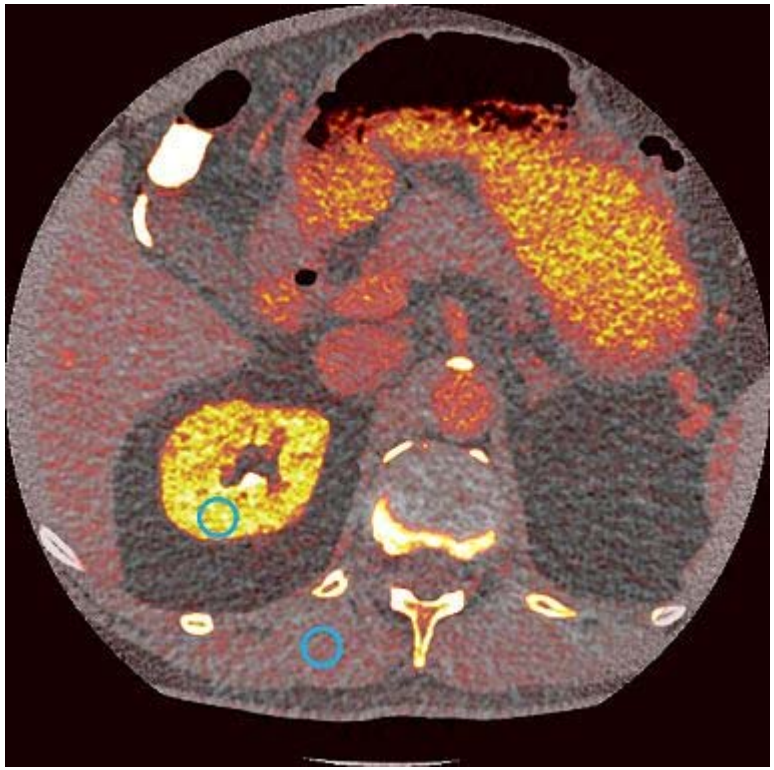
Absorption Differential Phase Dark Field

For this slice please follow the following link:

http://www.nature.com/articles/srep03209

Source: In-vivo dark-field and phase-contrast x-ray imaging, M. Bech, A. Tapfer, A. Velroyen, A. Yaroshenko, B. Pauwels, J. Hostens, P. Bruyndonckx, A. Sasov & F. Pfeiffer, *Scientific Reports* 3, Article number: 3209 (2013)

Dual Energy CT

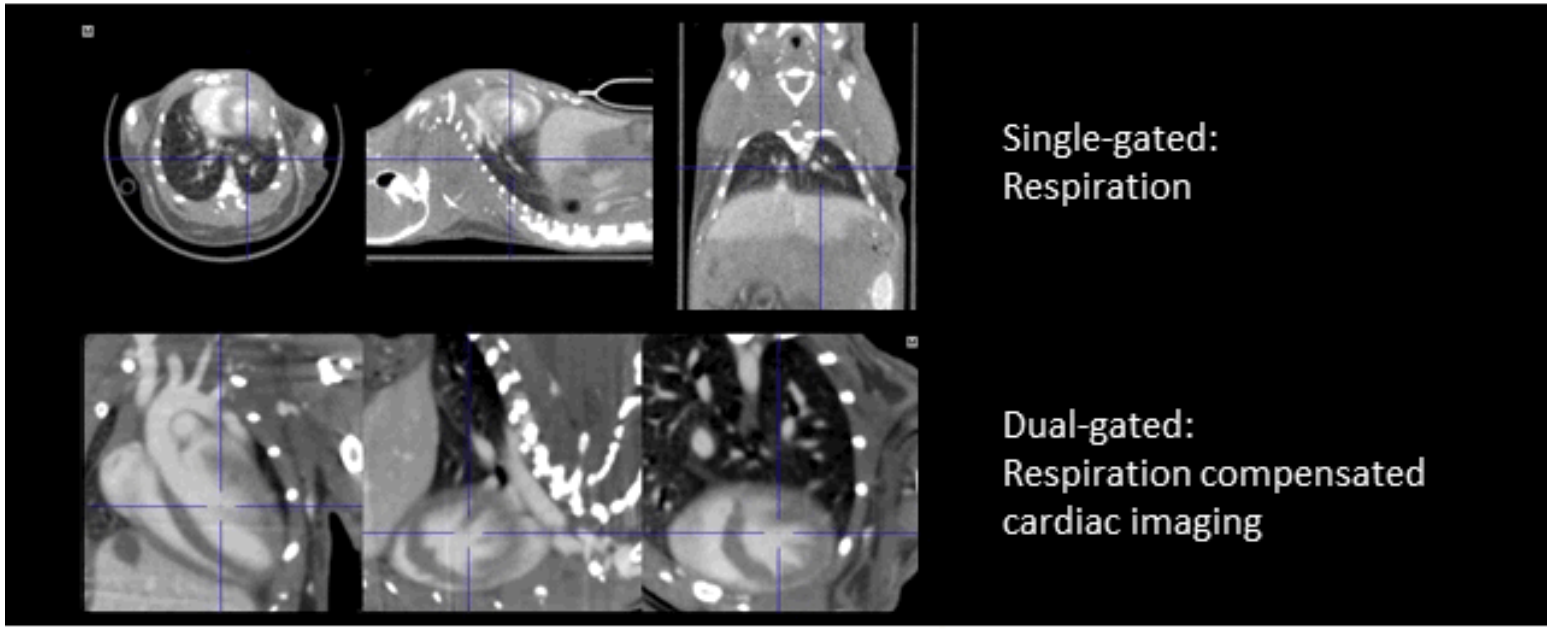


Source: NIH, www.nih.gov

Time lapsed CT

U-CT: Fast CT acquisitions

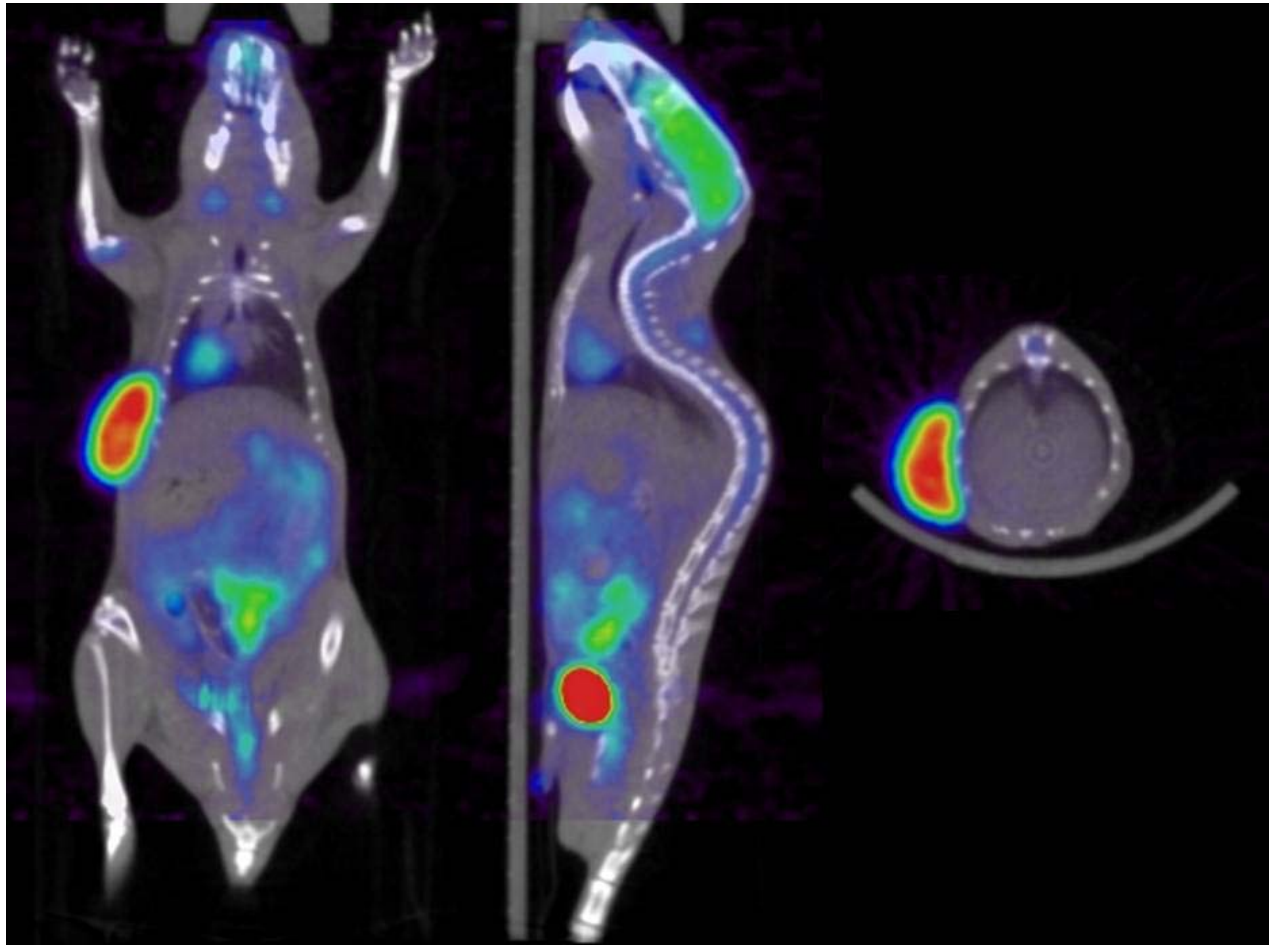
MILabs



Enabling cardiac- and respiratory-gated images

Source: MILabs, www.milabs.com

Multimodal Imaging (PET-CT)



Source: HUG, pinlab.hcuge.ch

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Thank you

Questions?