Smart*Light

X-ray imaging for science, art, industry and society

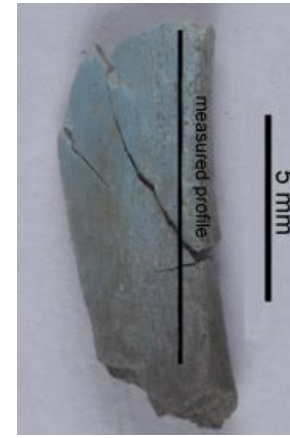
On behalf of
Jom Luiten & Joris Dik

by Jan Visser

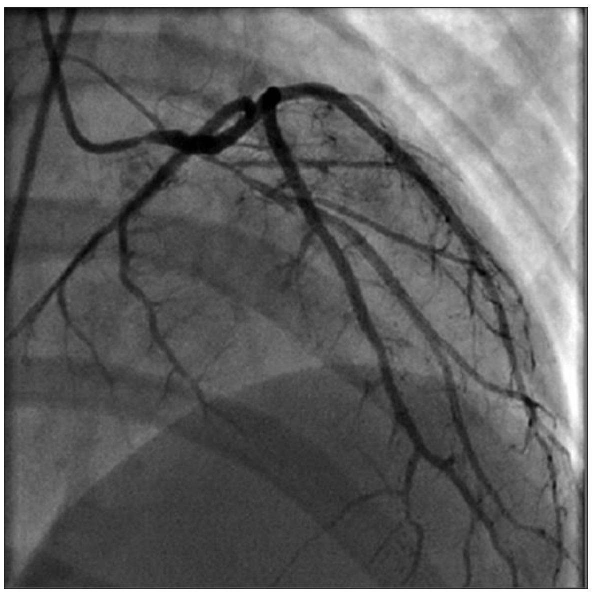
Revealing hidden paintings

Painting alterations

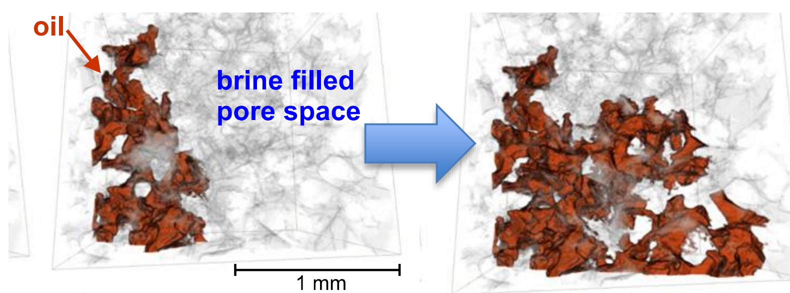
Bones



Varnishes on musical instruments



Dichromatic coronary angiography

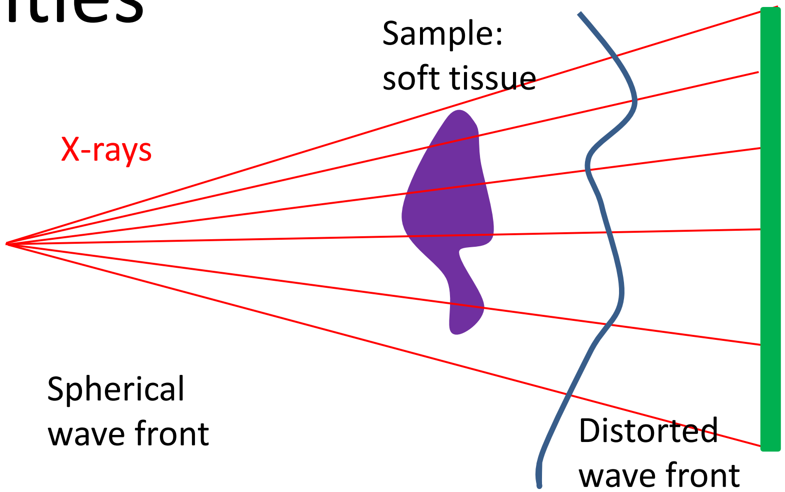


Oil transport in porous rocks

Desirable imaging capabilities

Phase contrast imaging (PCI):

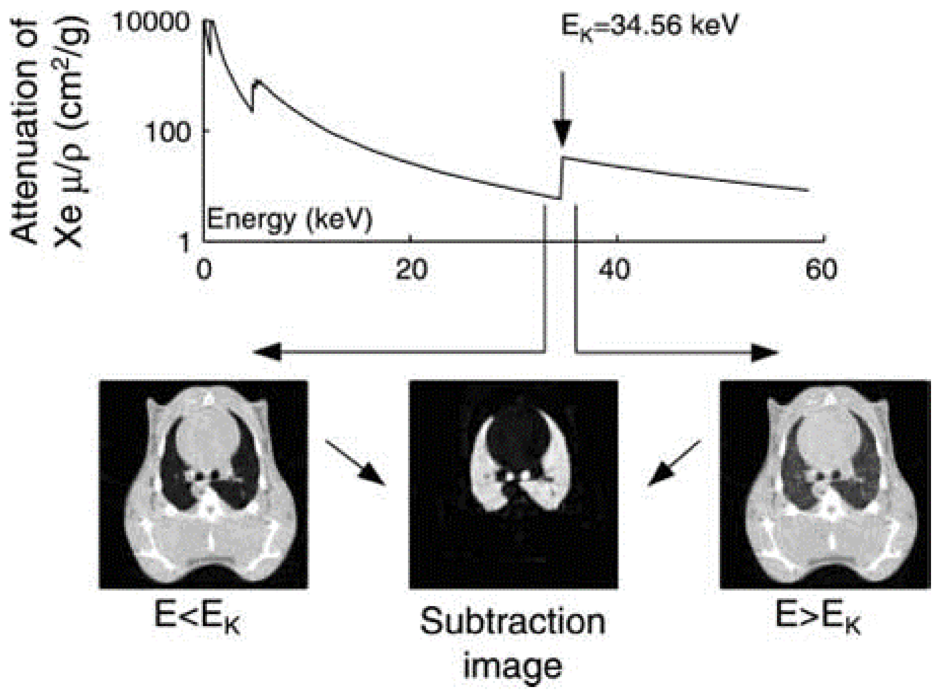
- Higher contrast at lower dose in soft tissue
- 20-100 keV X-rays
- ≥1µm ***coherence*** length @ sample

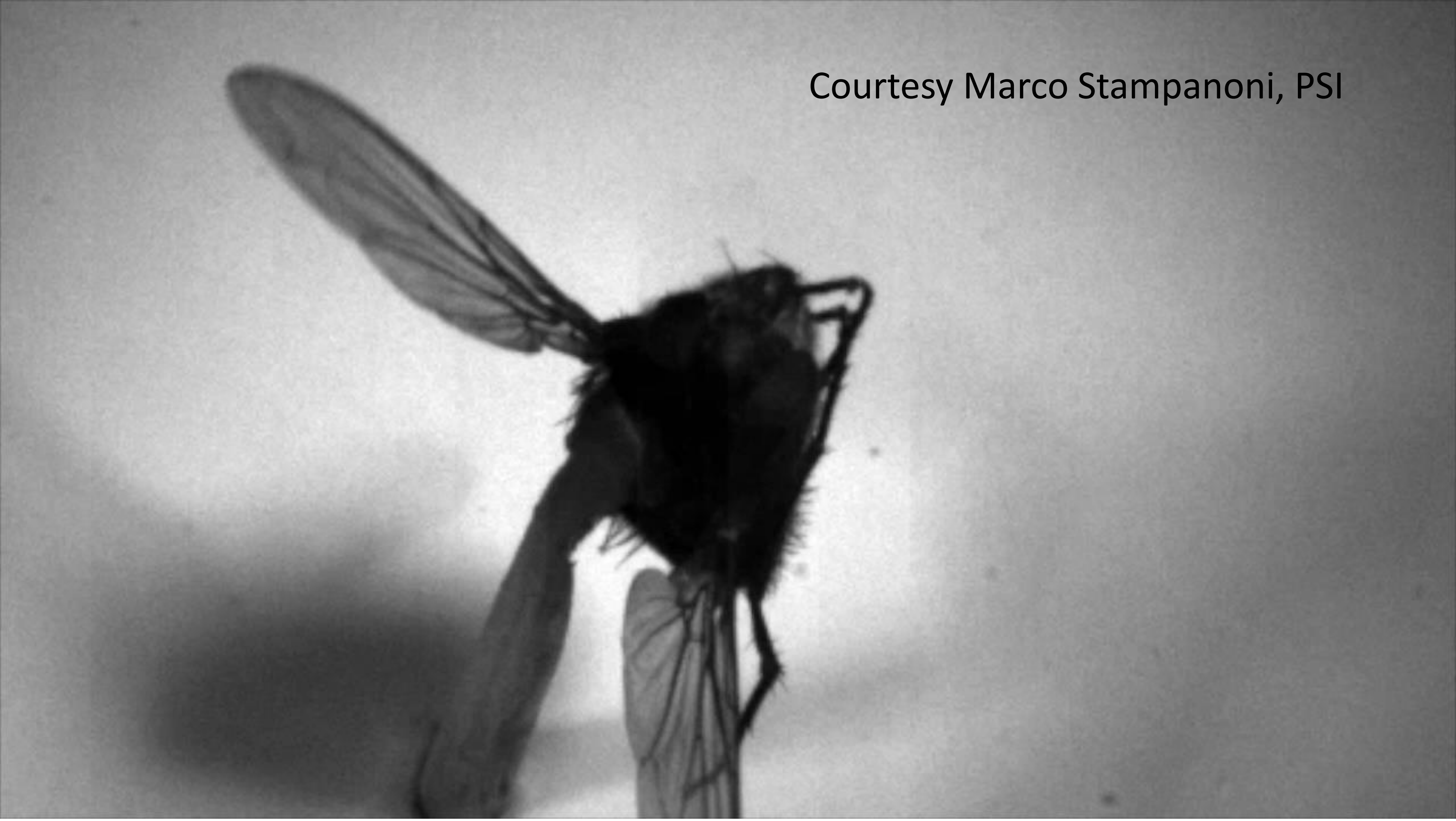


K-edge subtraction imaging:

- 20-60 keV X-rays
- ***Monochromatic & tunable*** X-ray energies

Lung filled with Xenon:





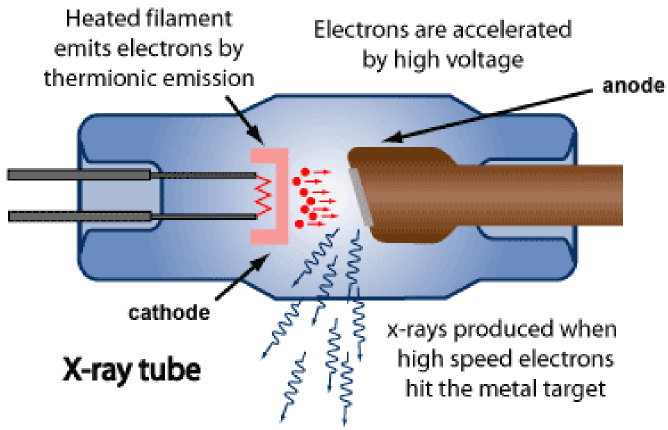
PCI microtomography:
The Fly...

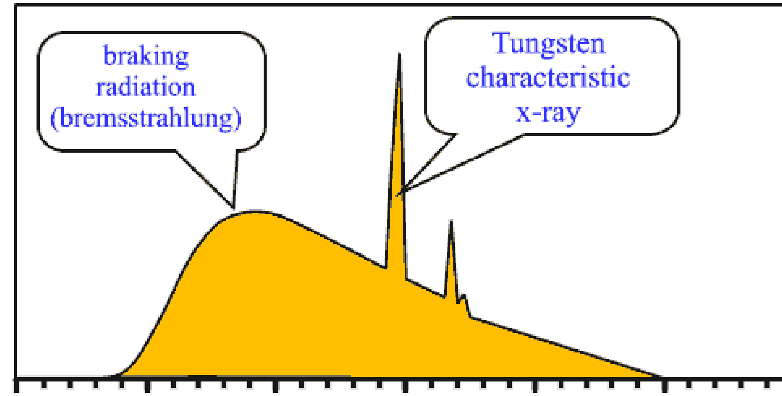

Synchrotrons...
• High energy X-rays
• High brilliance
• Coherent
• Variable energy
BUT: • Accessibility
• Beam time
• Available space
➢ Elemental, molecular & structural characterization
➢ Imaging with sub-micron resolution
➢ The most powerful non-destructive diagnostic tool

Current lab X-ray sources

X-ray tubes:

- Broadband with few characteristic lines
- Reasonable photon flux but limited brilliance

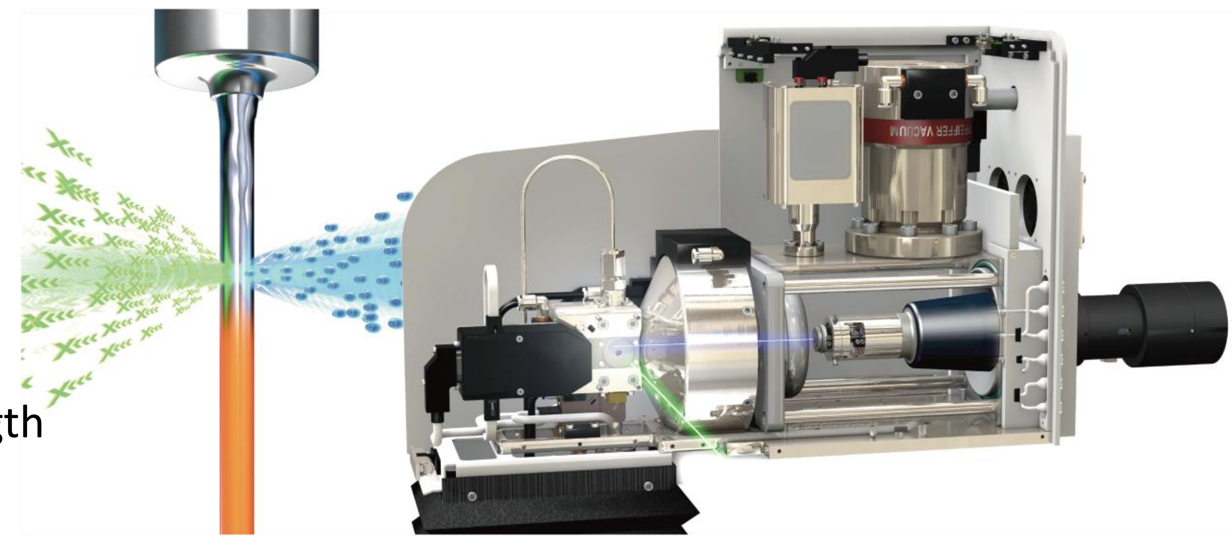




Exciting development:

Liquid Ga source:

- 9.2 keV line (Ga K_{α})
- Very good brilliance
  2.6×10^{10} γ s^{-1} mm^{-2} $mrad^{-2}$
- Unfortunately no wavelength tunability



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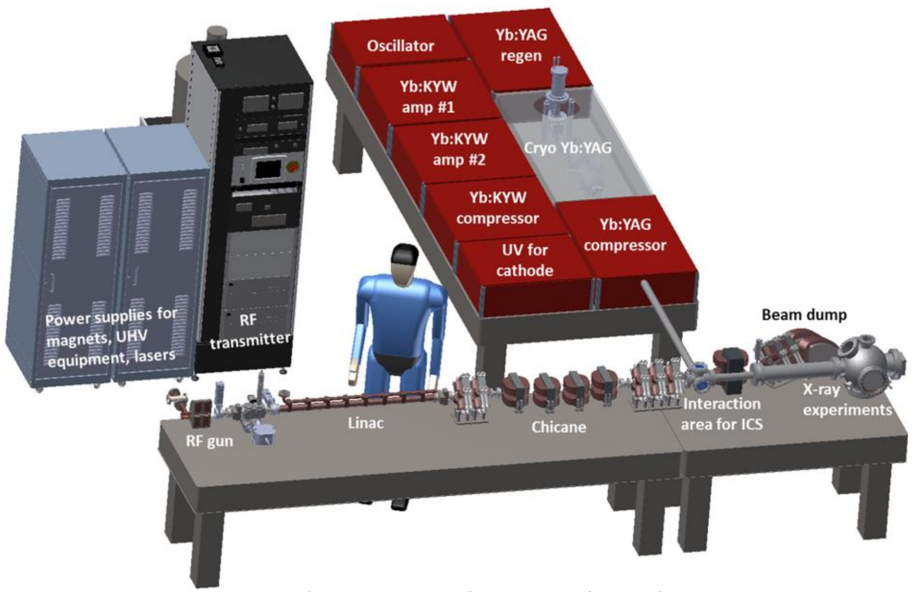
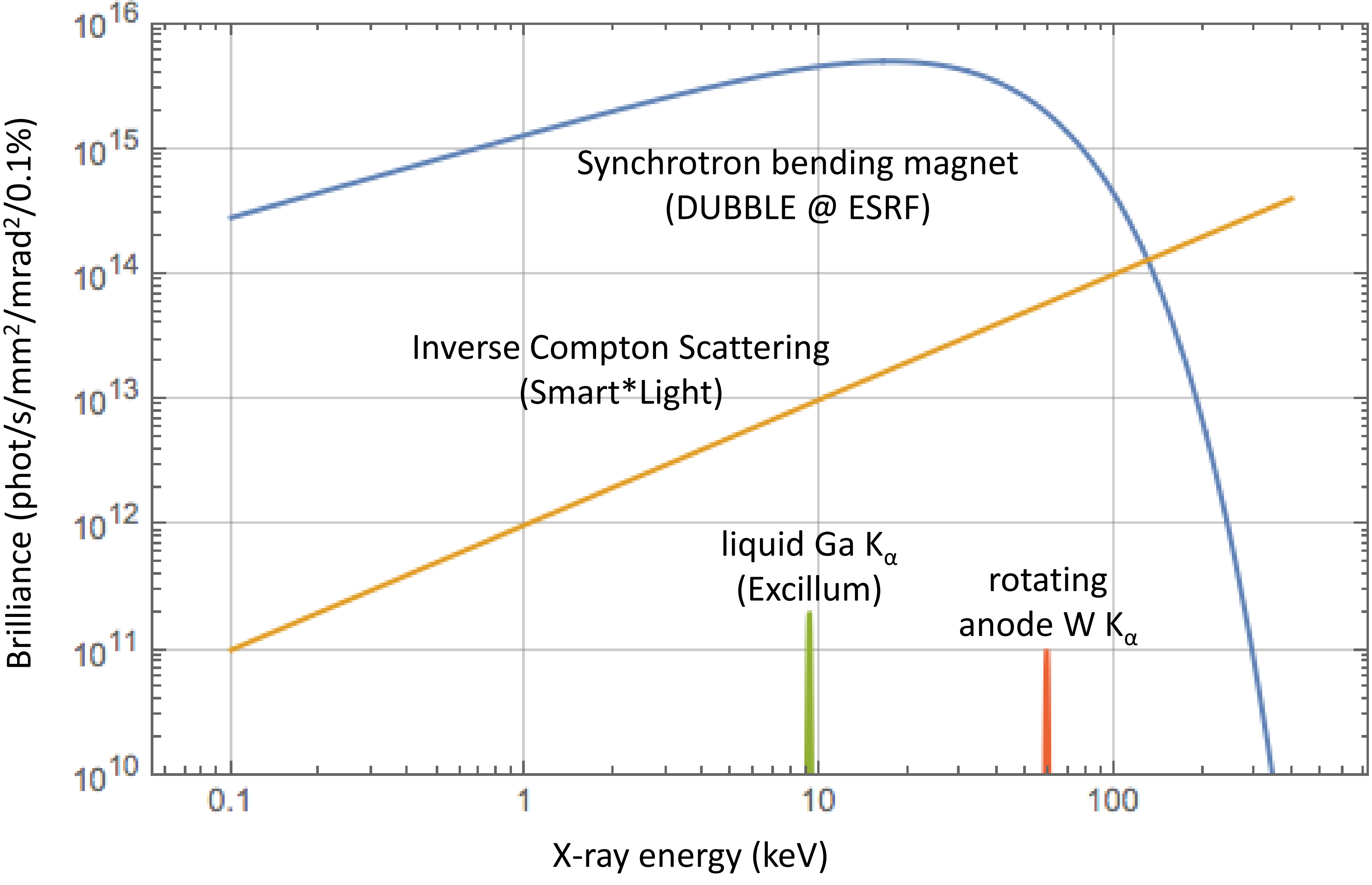
REDEFINING THE X-RAY TUBE

Inverse Compton Scattering (soft) X-ray source



Courtesy W. Graves, ASU, USA

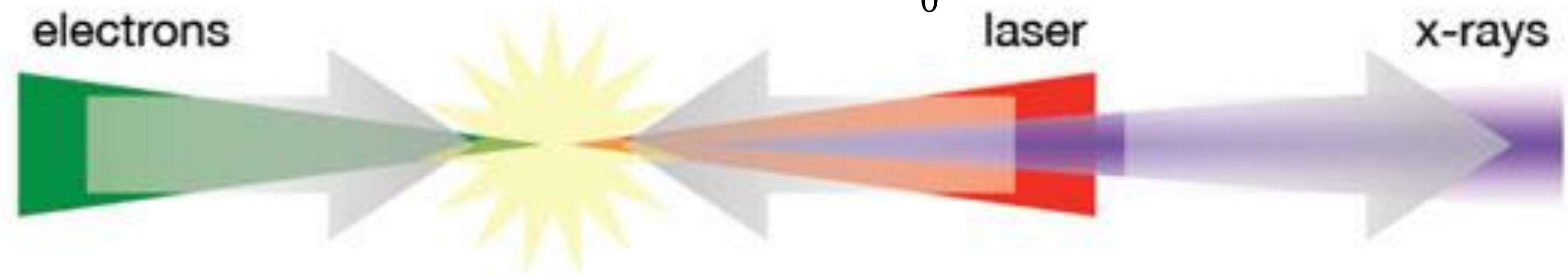
Brilliance



Brilliance (phot/s/mm²/mrad²/0.1%)
10^16
10^15
10^14
10^13
10^12
10^11
10^10
0.1
1
10
100
X-ray energy (keV)
Synchrotron bending magnet
(DUBBLE @ ESRF)
Inverse Compton Scattering
(Smart*Light)
liquid Ga Kα
(Excillum)
rotating
anode W Kα

Inverse Compton Scattering (ICS)

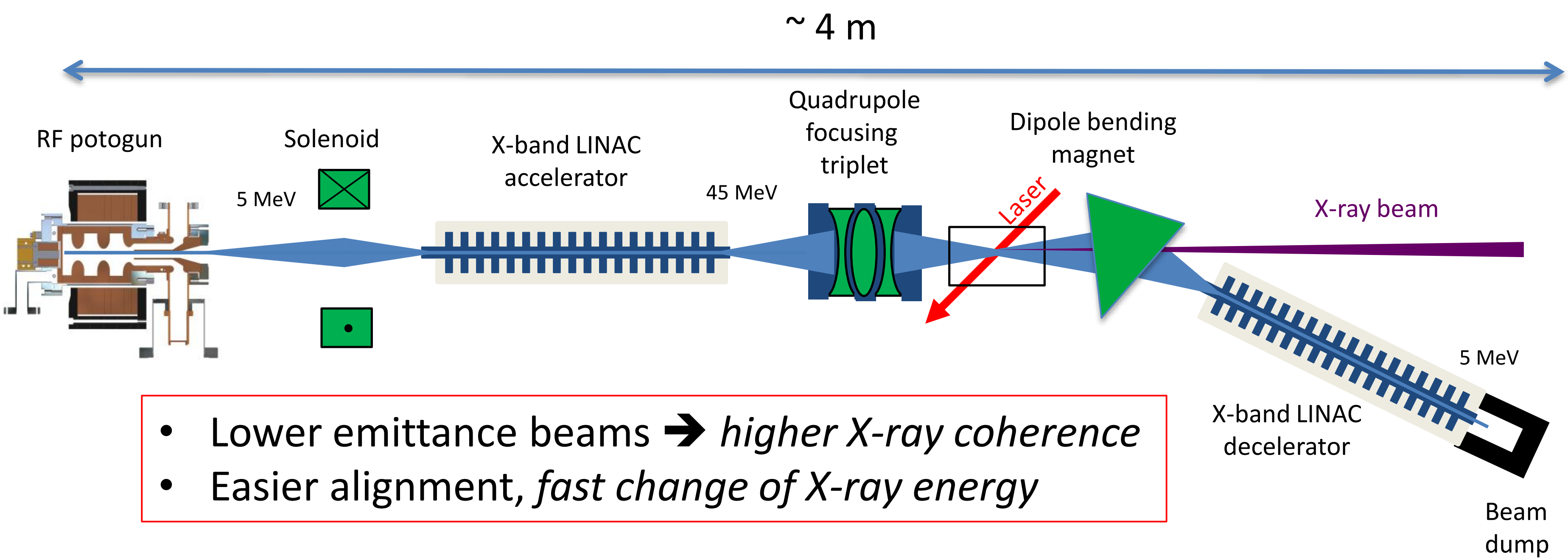
$l_0 = 400\ \text{nm}$



- X-rays emitted in narrow cone, half angle γ^{-1}
- X-ray energy dependent on emission angle
- 1% energy spread if $\theta < 0.1\ \gamma^{-1}$

Electron energy	Lorentz factor γ	X-ray wavelength	X-ray energy	Emission angle $0.1\ \gamma^{-1}$
5 MeV	11	8.6 Å	1.4 keV	9 mrad
15 MeV	30	1.1 Å	11 keV	3 mrad
30 MeV	60	0.28 Å	44 keV	1.7 mrad
45 MeV	89	0.13 Å	98 keV	1.1 mrad

LINAC-based ICS sources: why?

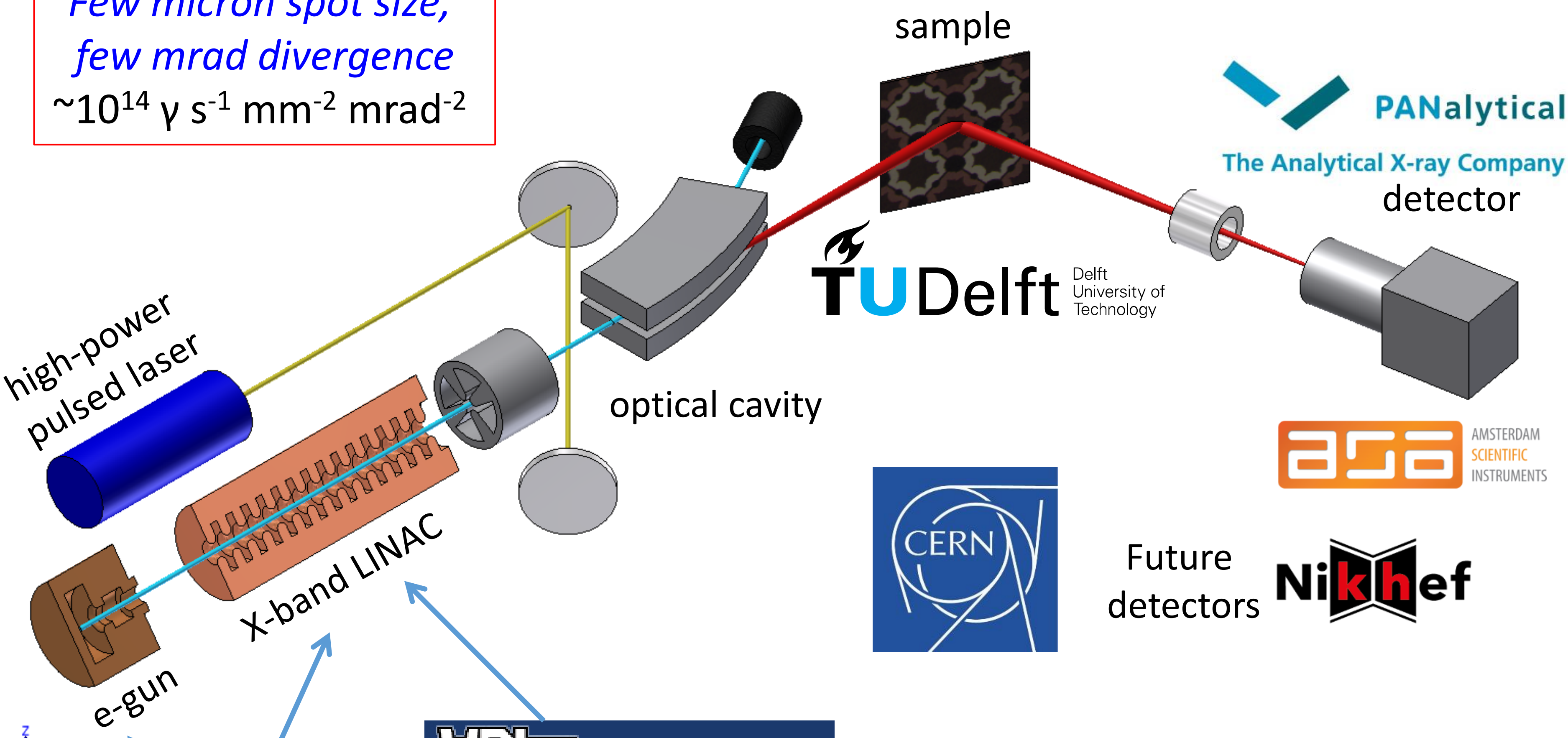


- Lower emittance beams ➔ *higher X-ray coherence*
- Easier alignment, *fast change of X-ray energy*

- Deceleration option: strongly *reduced shielding requirements*
- *Will fit into sea container*

LINAC-based ICS sources: Smart*Light

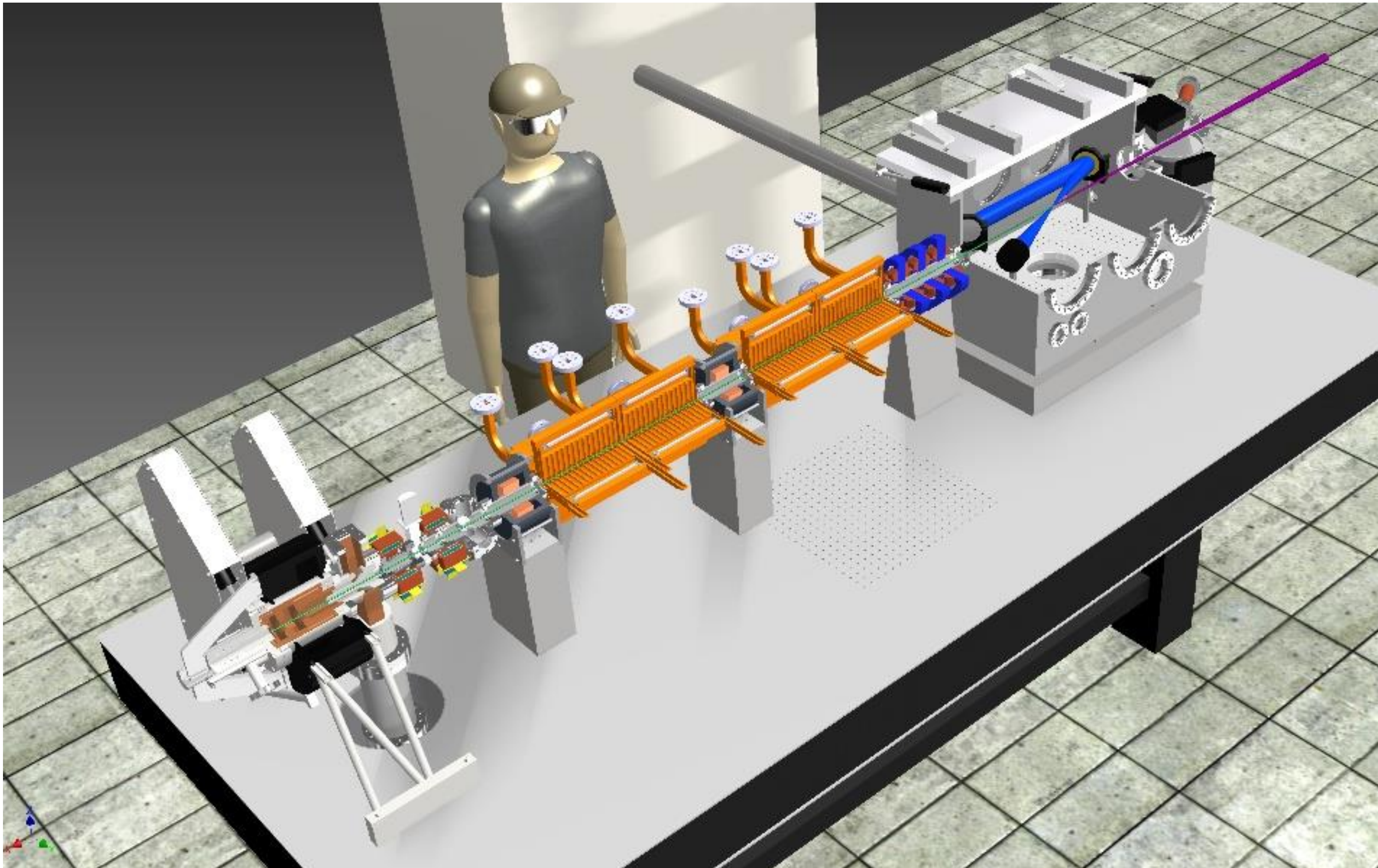
Few micron spot size,
few mrad divergence
~10^{14} γ s^{-1} mm^{-2} $mrad^{-2}$



VDL Enabling Technologies Group

Technische Universiteit **Eindhoven** University of Technology

LINAC-based ICS sources: Smart*Light



Summary

- X-ray imaging with hard X-rays and brilliance comparable to synchrotron conditions are achievable at the lab scale.

- Inverse Compton Scattering Source for tunable, monochromatic and highly coherent X-ray beams in a compact setup

- Achievable brilliance several orders of magnitude higher than current lab sources in hard X-ray region

- **Smart*Light combines advances in detector and accelerator technologies into a potentially movable lab-scale facility**

TU Delft Delft University of Technology

TU/e Technische Universiteit Eindhoven University of Technology