MetalJet

New Key Module for Enhanced Metrology Capabilities

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Research project manager

SEMICON EUROPA MADEin4 excillum

Agenda

- Excillum – The source for X-ray innovation
- MADEin4 – MetalJet enabling high throughput metrology
- Outlook – Success is built on collaborative partnerships

Excillum AB

Swedish SME based in Stockholm

- Headquarter, development and production
- Presence in USA, UK, Switzerland

Founded in 2007

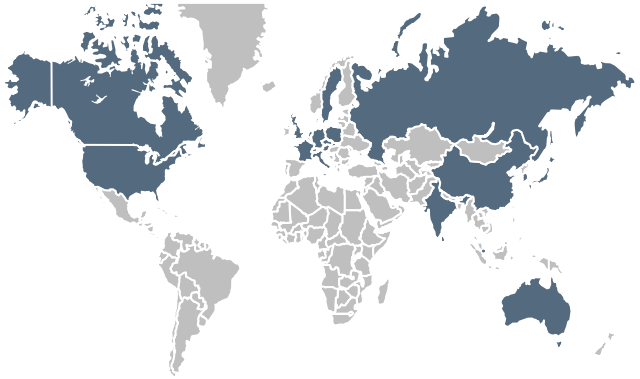
60+ employees: 50% in R&D

We make X-ray sources:

- Design, development and manufacturing

>100 X-ray sources installed:

- 20+ countries
- 10+ partners



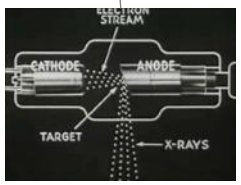
Member of AENEAS

Redefining the X-ray tube

1895

Discovery of X-rays

1913



Coolidge hot cathode tube

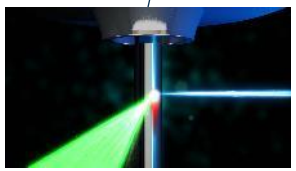
1929

First commercial rotating anode

1980s

3rd generation synchrotrons

1999



Liquid metal-jet anode technology invented (Excillum's founders)

2007

Excillum founded MetalJet D1

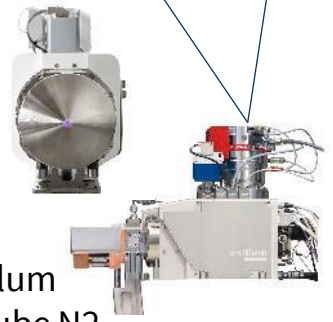
2011

Excillum MetalJet D2

2016

Excillum NanoTube N1

2020



Excillum NanoTube N2 MetalJet E1

2021

Excillum MetalJet E1+

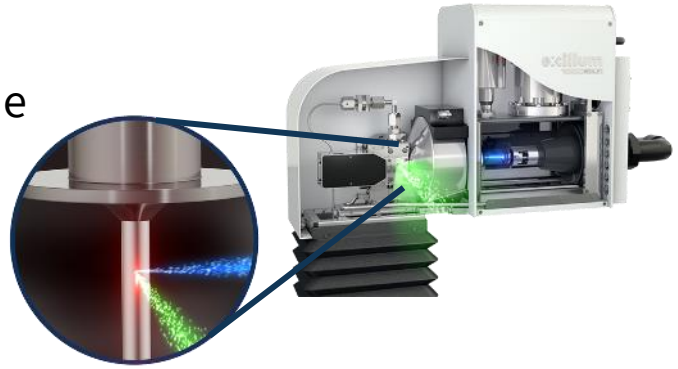

excillum
METAL JET

Our technology and product lines

MetalJet

World's brightest microfocus X-ray source

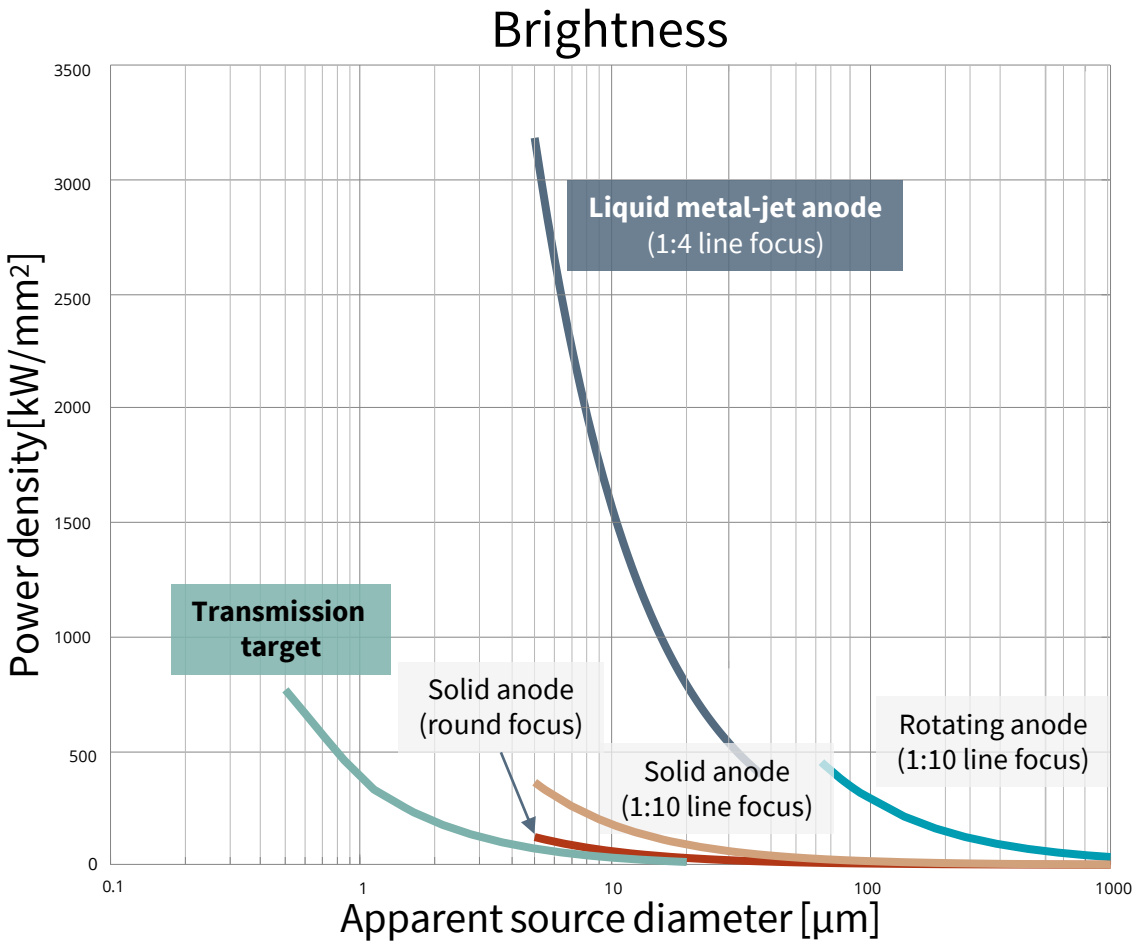
Liquid metal-jet anode technology



NanoTube

World's smallest X-ray nanospot

Advanced electron beam technology

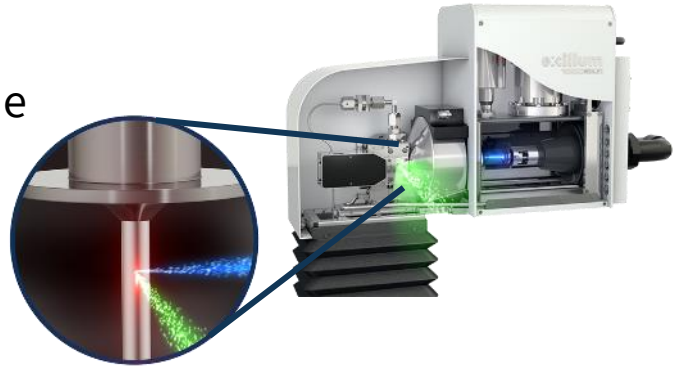


Our technology and product lines

MetalJet → faster measurements

World's brightest microfocus X-ray source

Liquid metal-jet anode technology

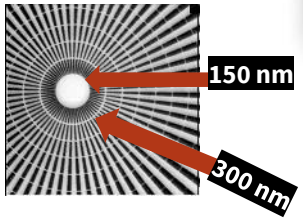


NanoTube → view much smaller details

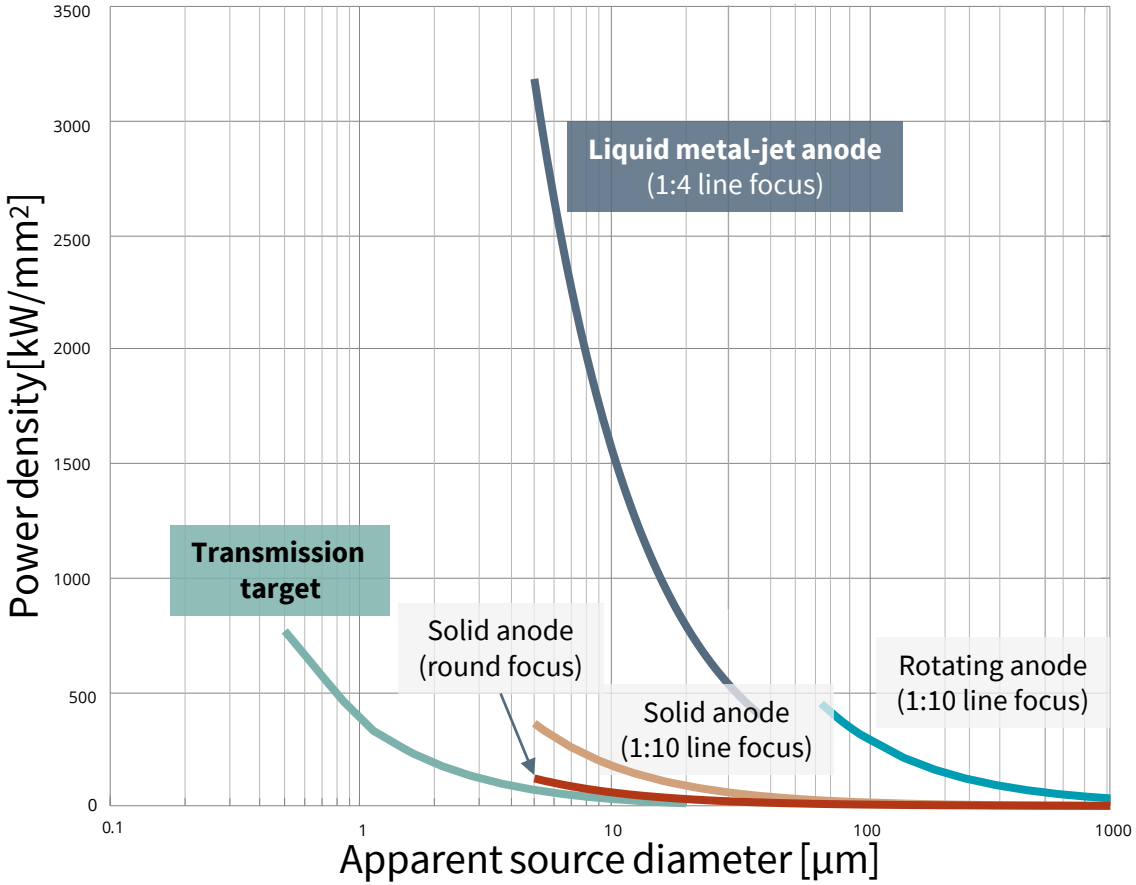
World's smallest X-ray nanospot

Advanced electron beam technology

Extreme Resolution

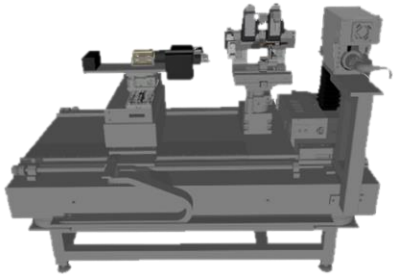


Brightness



X-ray techniques using Excillum's sources

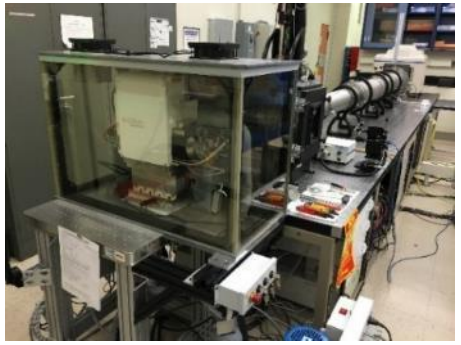
- Imaging
  - Attenuation-contrast imaging
  - Phase-contrast imaging
  - X-ray microscopy
- Spectroscopy/fluorescence
  - Hard X-ray Photoelectron Spectroscopy (HAXPES)
  - X-ray Emission Spectroscopy (XES)
  - X-ray fluorescence imaging (XRF)
- Scattering/diffraction
  - Small-Angle X-ray Scattering (SAXS)
  - Small molecule crystallography
  - Protein crystallography
  - Powder X-ray Diffraction (pXRD)



Multi-modal microscope
Würzburg University / Fraunhofer Institute
Germany

Phase-contrast imaging system
by Proto
Johns Hopkins university, USA

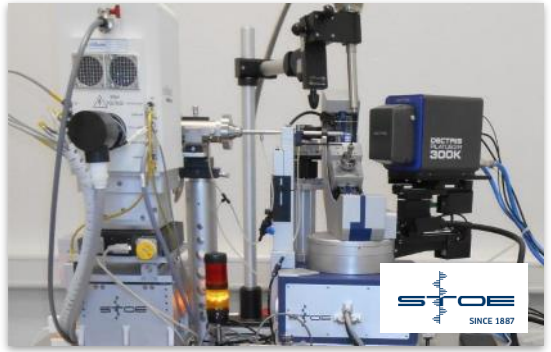
X-ray emission spectroscopy
system, Max Planck Institute,
Germany

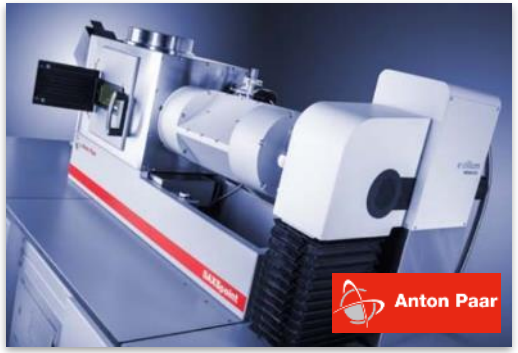


SAXS system
National Institute of Standards
(NIST) USA

Analytical X-ray OEM partners - our main business since 2011

X-ray sources for our partners' state-of-the art analytical systems typically using SCD, SAXS or HAXPES methods in biology, chemistry & material sciences, and high-tech manufacturing quality assurance.





X-ray imaging OEM partners
- a growing business since 2020

X-ray sources for our partners' state-of-the art **computer tomography (CT) or phase-contrast imaging** systems for use in research and manufacturing quality assurance (e.g. electronics, batteries, additive).

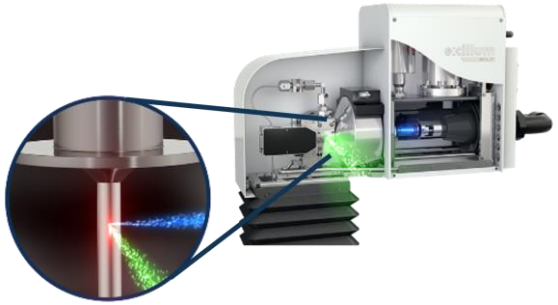
Agenda

- Excillum – The source for X-ray innovation
- MADEin4 – MetalJet enabling high throughput metrology
- Outlook – Success is built on collaborative partnerships

Excillum in MADEin4

WP3: Metrology platforms developments for **enhanced productivity**

Task 3.1.2: Metrology for front and back-end process characterization



Why Excillum's MetalJet?

- The metrology need:

  → **X-ray methods for 5nm nodes and below**

- The fundamental problem of X-ray methods:

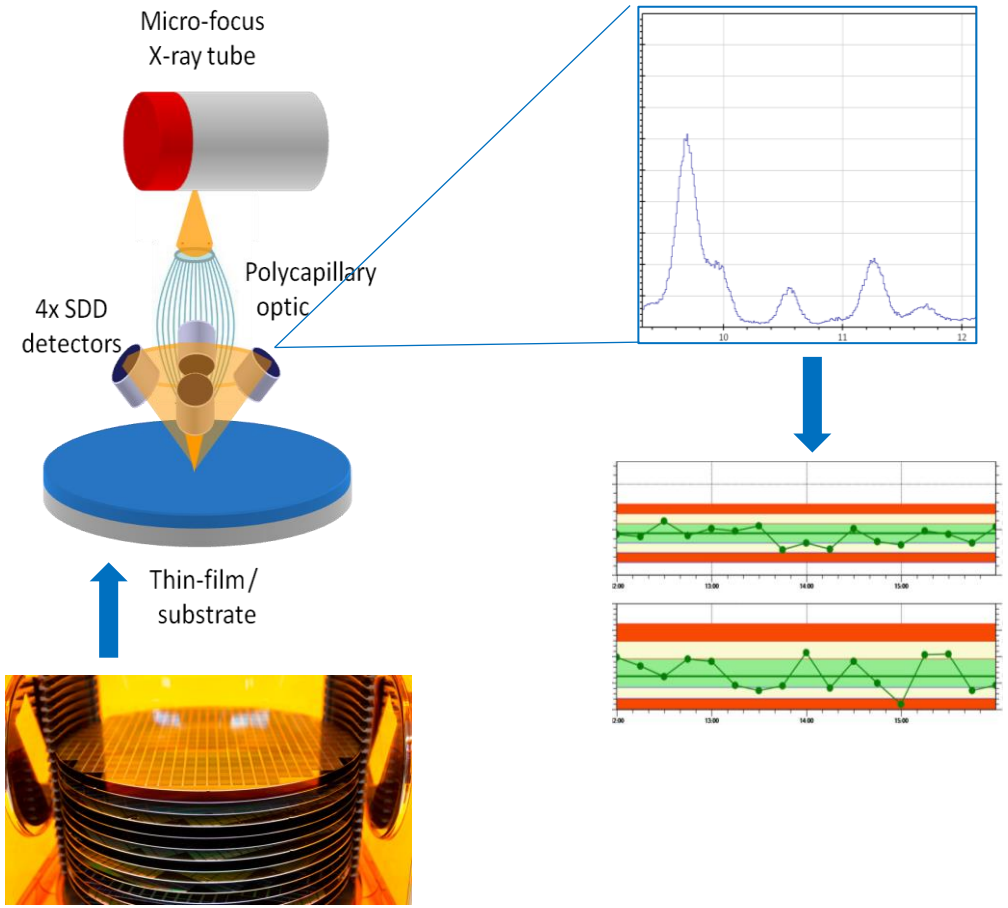
  → **the X-ray source is too weak** to enable enough throughput or precision for high volume manufacturing

- The solution:

  → **MetalJet** offers the possibility for **significantly higher power loading resulting in faster measurement**

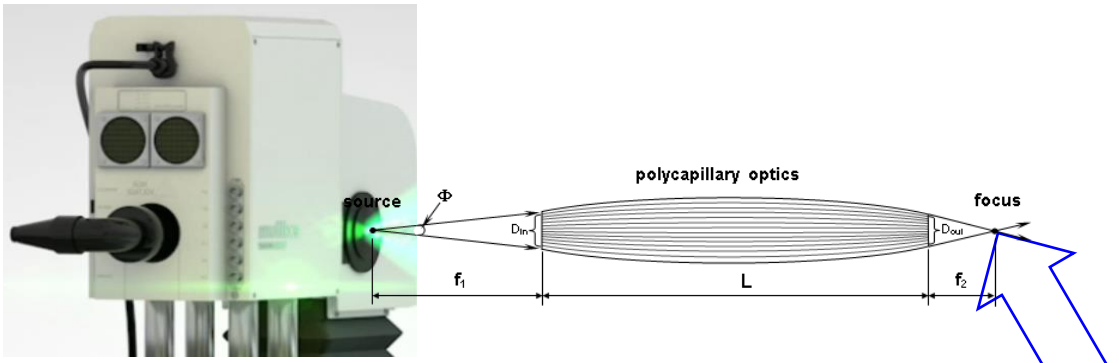
Excillum in MADEin4

Collaboration with Bruker: µXRF metrology for inline process monitoring



To enhanced µXRF capability:

- Increased brightness of source
- Improved (source + optics) efficiency



Objective:
10x performance gain

BRUKER MADEin4

Developments enabling enhanced productivity

Increased macroscopic thermal capacity of MetalJet X-ray source

MetalJet D2+ 250 W

Technical specifications	
Target material[1]	Ga or In rich metal alloy
Target type	Liquid jet
Voltage	21–160 kV
Power[2]	0-250 W
Max current	4.3 mA

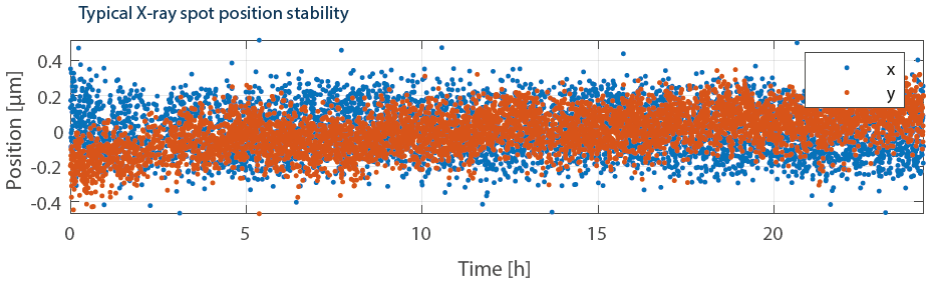
MetalJet E1+ 1000 W

250W → 1000W

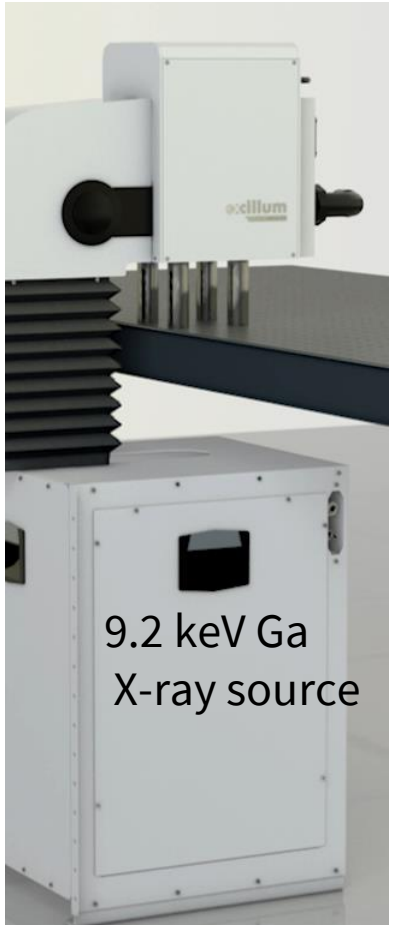
Increased brightness

E-beam power [W]	Radiant flux [photons/(s mrad2)]
1000	3.7E+07
700	3.1E+07
250	1.1E+07

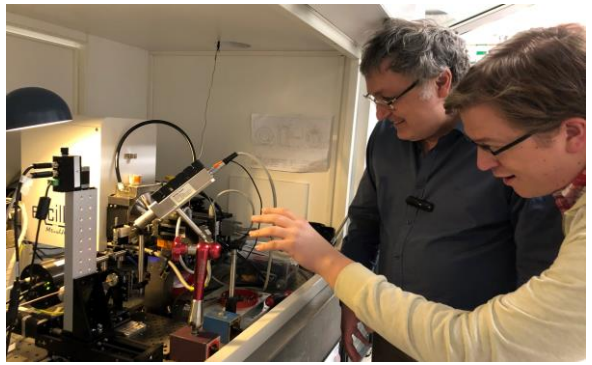
KW microfocus performance with submicron stability



High throughput µXRF enabled by MetalJet



Excillum-Bruker µXRF tests



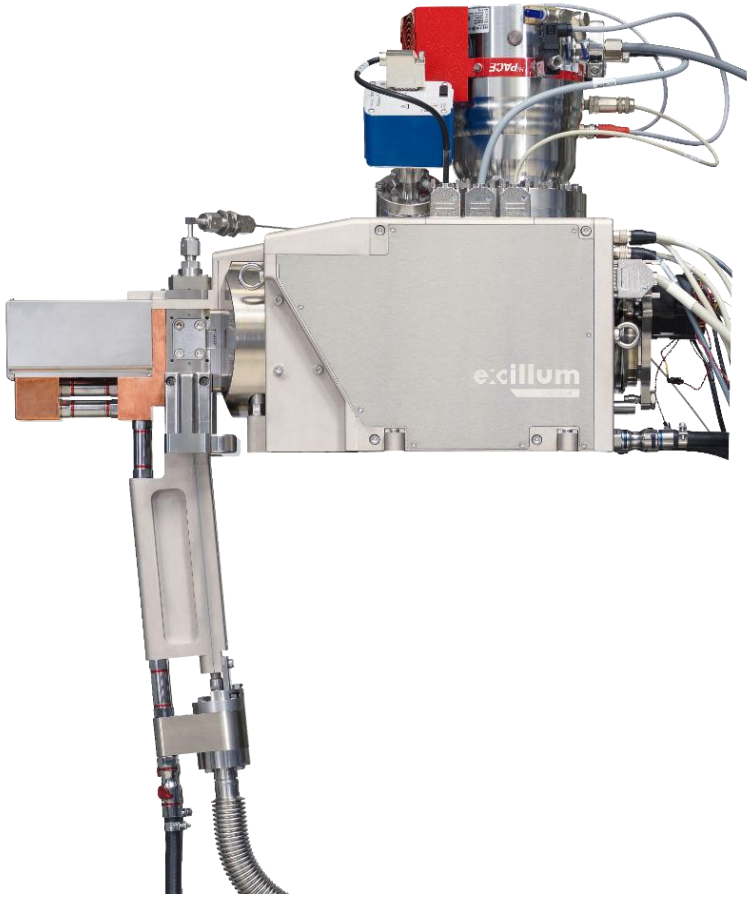
Layer	Projected improvement*
TiN 100Å (DRAM)	5-10X
W 2000Å (W plug)	>10X

*in acquisition time, **compared with SOTA**, maintaining 3σ<1%

End User Advantage

- **Increased throughput** of µXRF metrology for nanoelectronics process control
- **Enhanced productivity** for **at-line and in-line** µXRF metrology

Excillum in MADEin4



MetalJet is a Key Module for Enhanced Metrology Capabilities

Agenda

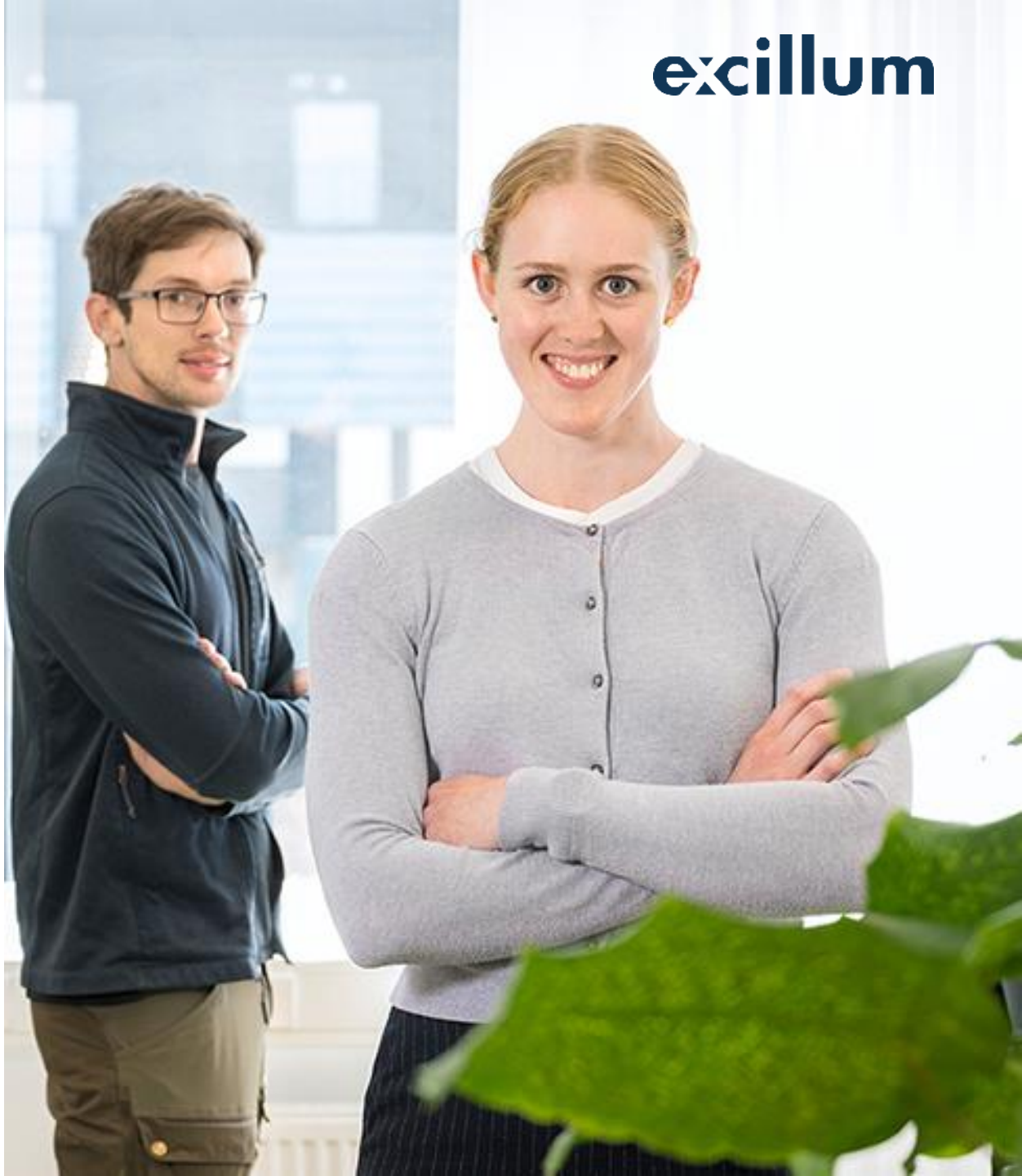
- Excillum – The source for X-ray innovation
- MADEin4 – MetalJet enabling high throughput metrology
- Outlook – Success is built on collaborative partnerships

Our mission

is to **enable** new science, **improve** medicine and **enhance** manufacturing by redefining the X-ray tube.

Our vision

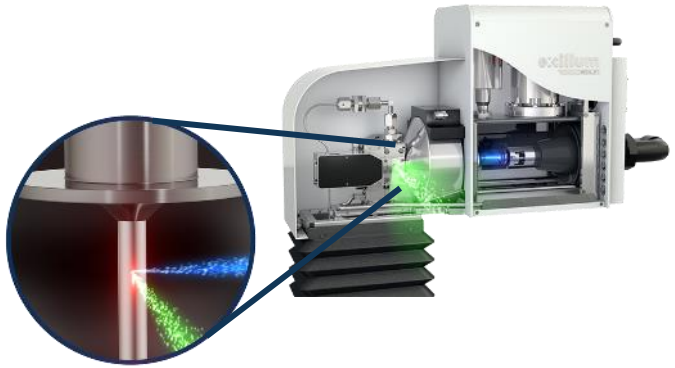
is to be the world’s **leading innovator and supplier** of premium X-ray sources.



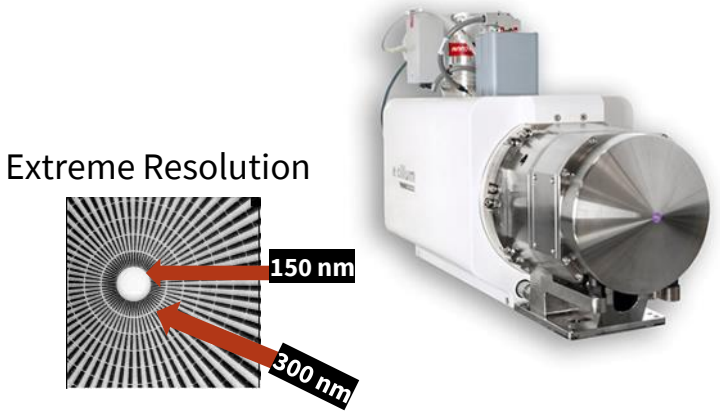
Excillume will continue to push the limits of the X-ray source to enable tomorrow's breakthroughs in both:

- Analytical X-ray
- X-ray Imaging

→ faster measurements



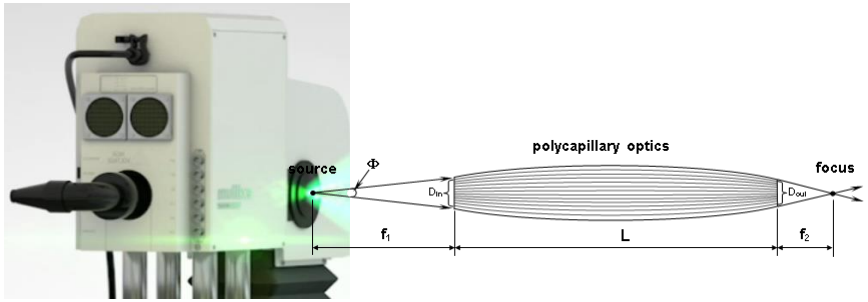
→ view much smaller details



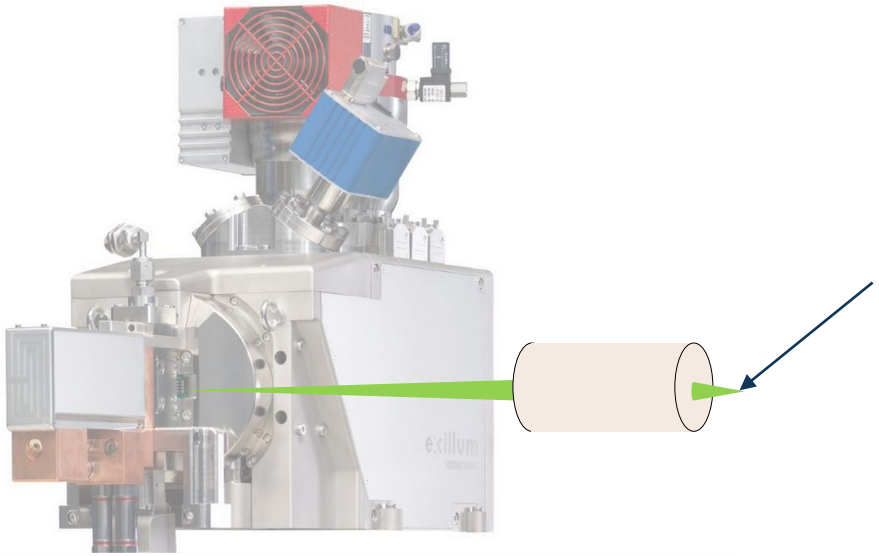
Success is built on collaborative partnerships!

Monochromatic microbeam generation

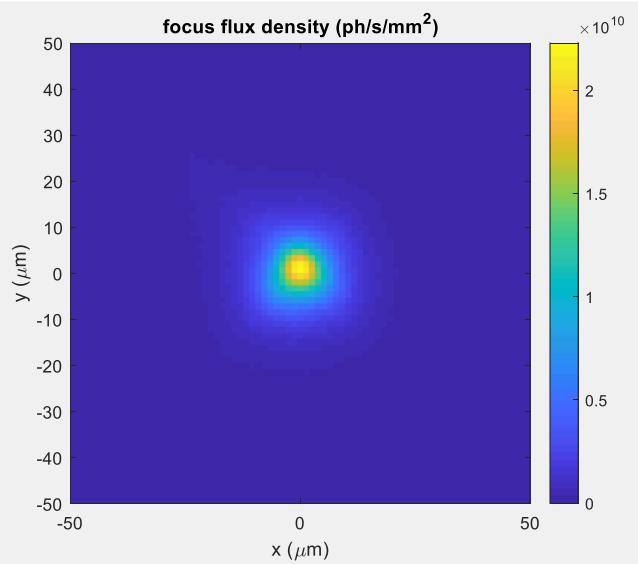
The MADEin4 focus was to generate **polychromatic microbeams** using polycapillary optics…



… but we have recently also demonstrated **monochromatic microbeams** using multilayer optics (out of MADEin4 scope).

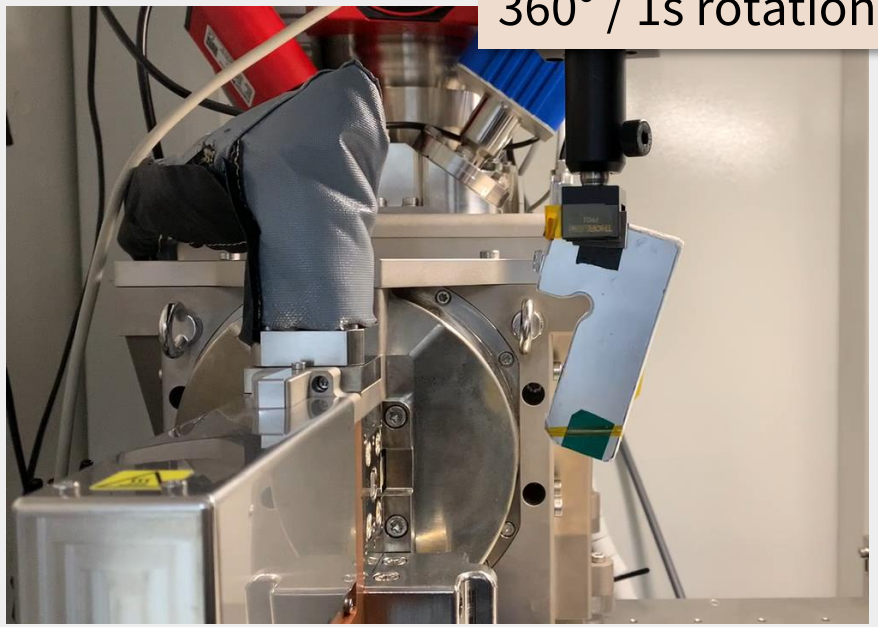


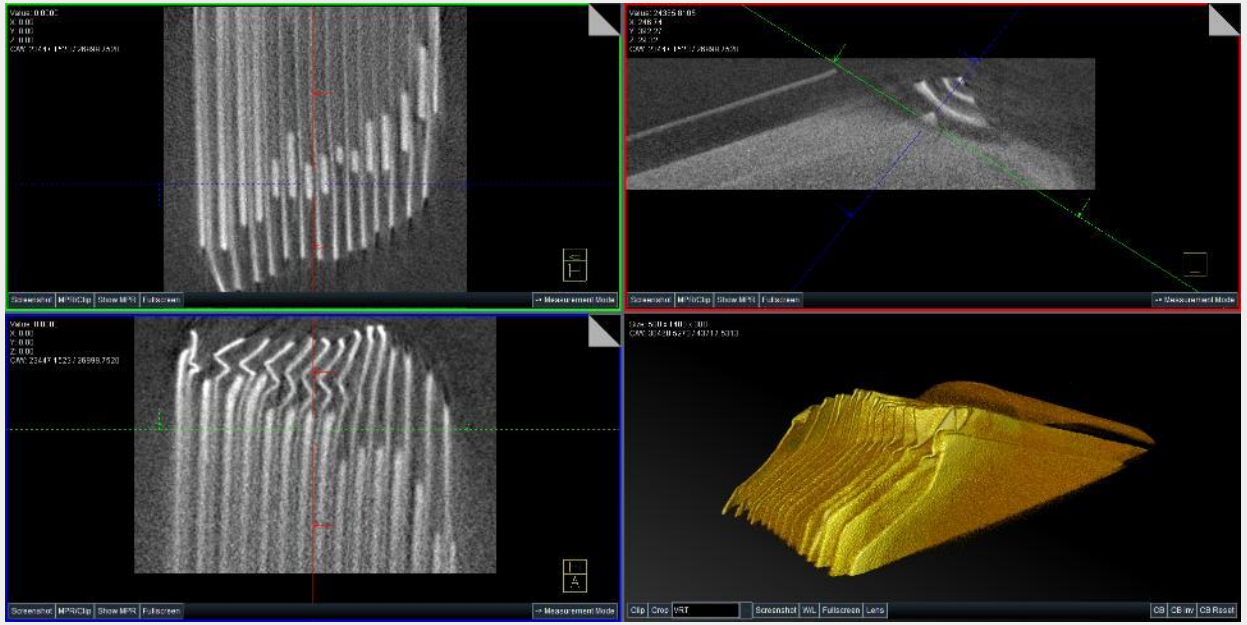
~1e7 photons/s of **24 keV** indium k-α radiation focused into a **~10 µm spot**



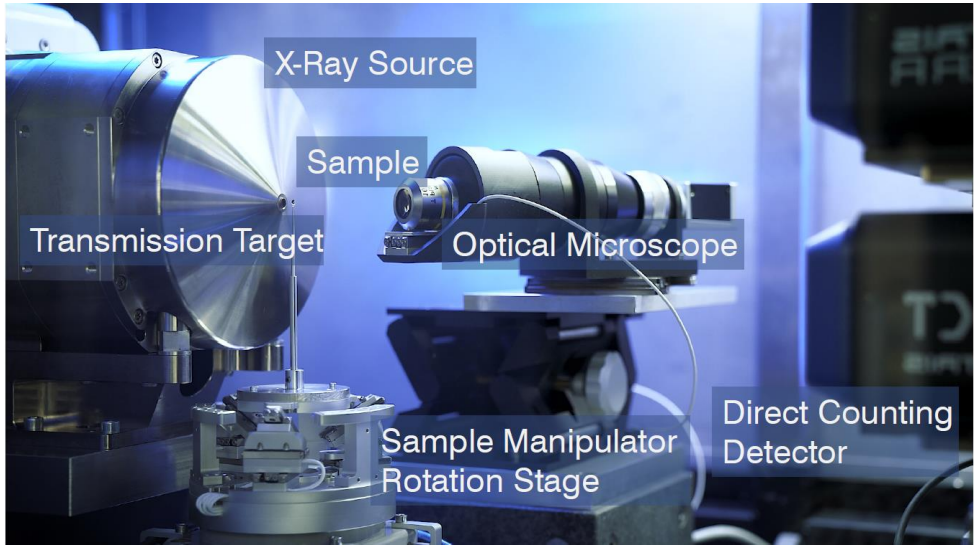
MetalJet - Enabler beyond MADEin4
- the battery example

360° / 1s rotation



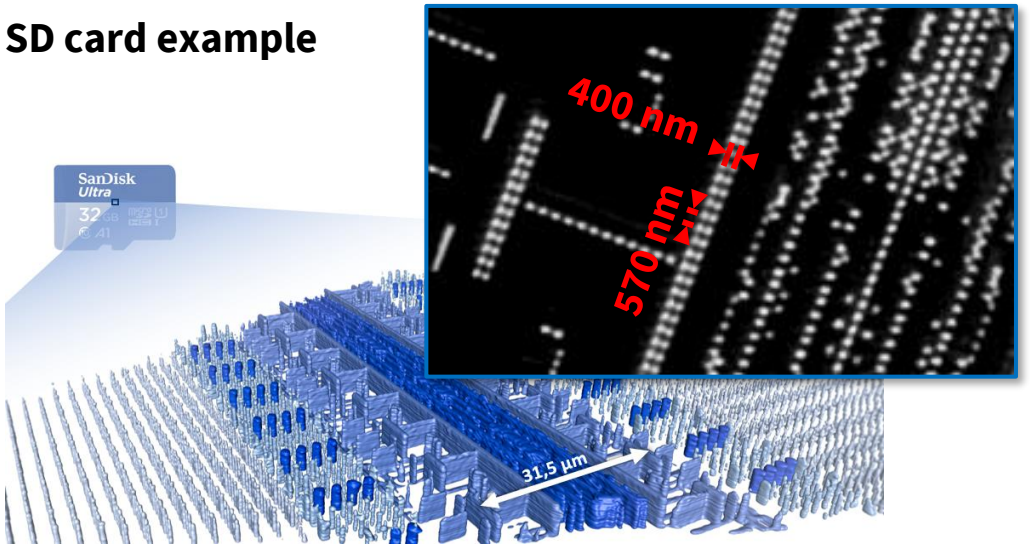


Nanotube – Pushing the limits

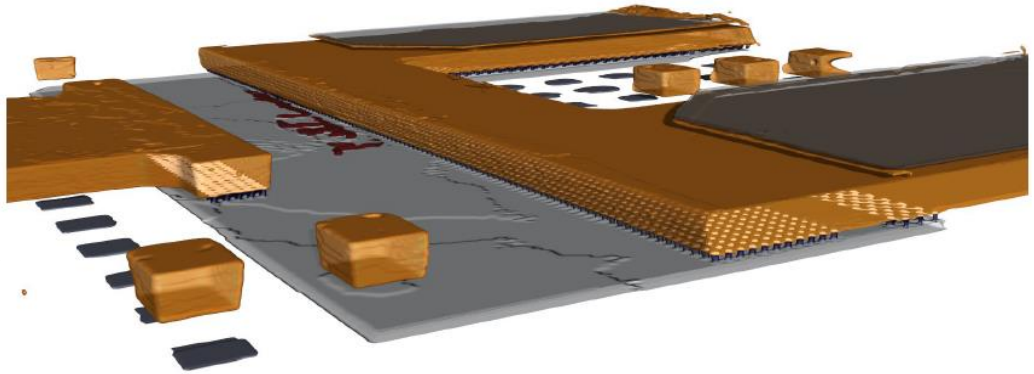


nano-CT imaging system

SD card example



Power devices:
3D measurements
for metallization
damage evolution



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