Opportunities for Advanced Plasma and Materials Research in National Security

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Outline: Plasma and Materials Research in National Security

- National Security areas of interest
- Reports published
- Funding Opportunities
- Plasma-based research in national security
- Materials-based research in national security
- Research plans at Purdue

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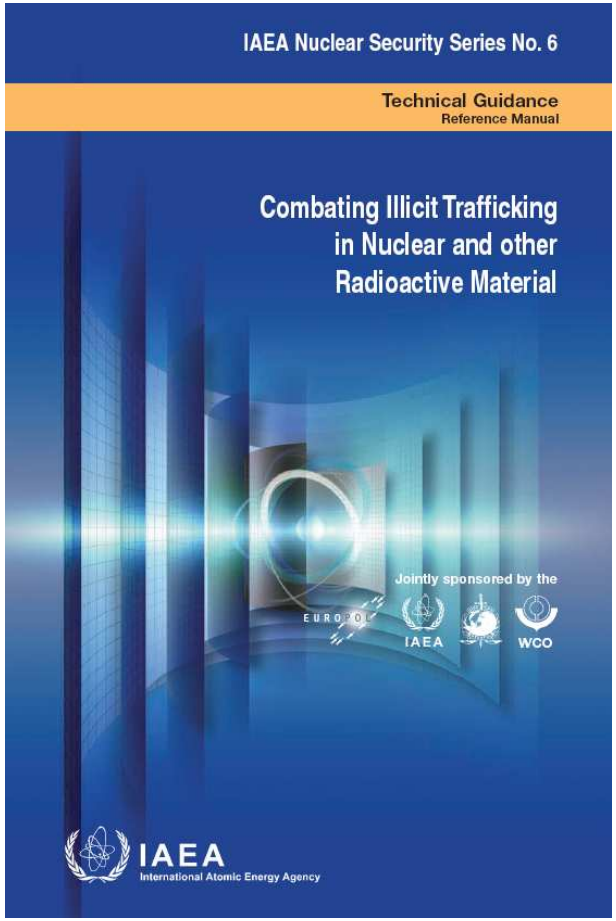
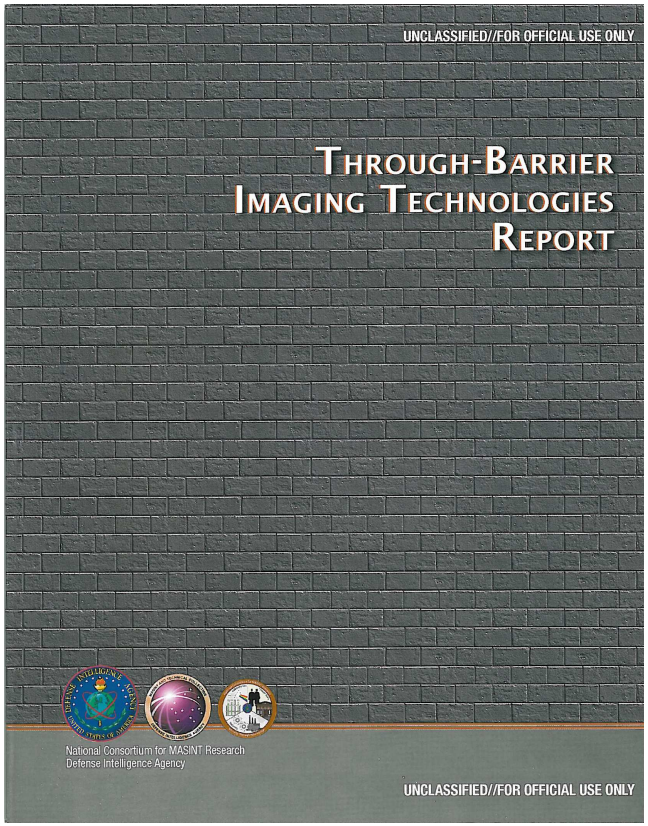
National Security areas of interest

- Through-barrier technologies
  - Passive, active, non-nuclear sensor technologies
- Special Nuclear Materials Detection
  - Shielded HEU (highly-enriched uranium)
- Explosives
- Chemical/Biological detection

National Security related recent reports published





- IAEA – Combating Illicit Trafficking in Nuclear and other Radioactive Material, December 2007
- Defense Intelligence Agency Report on Through-Barrier Imaging Technologies, if you need more info please email me: allain@purdue.edu

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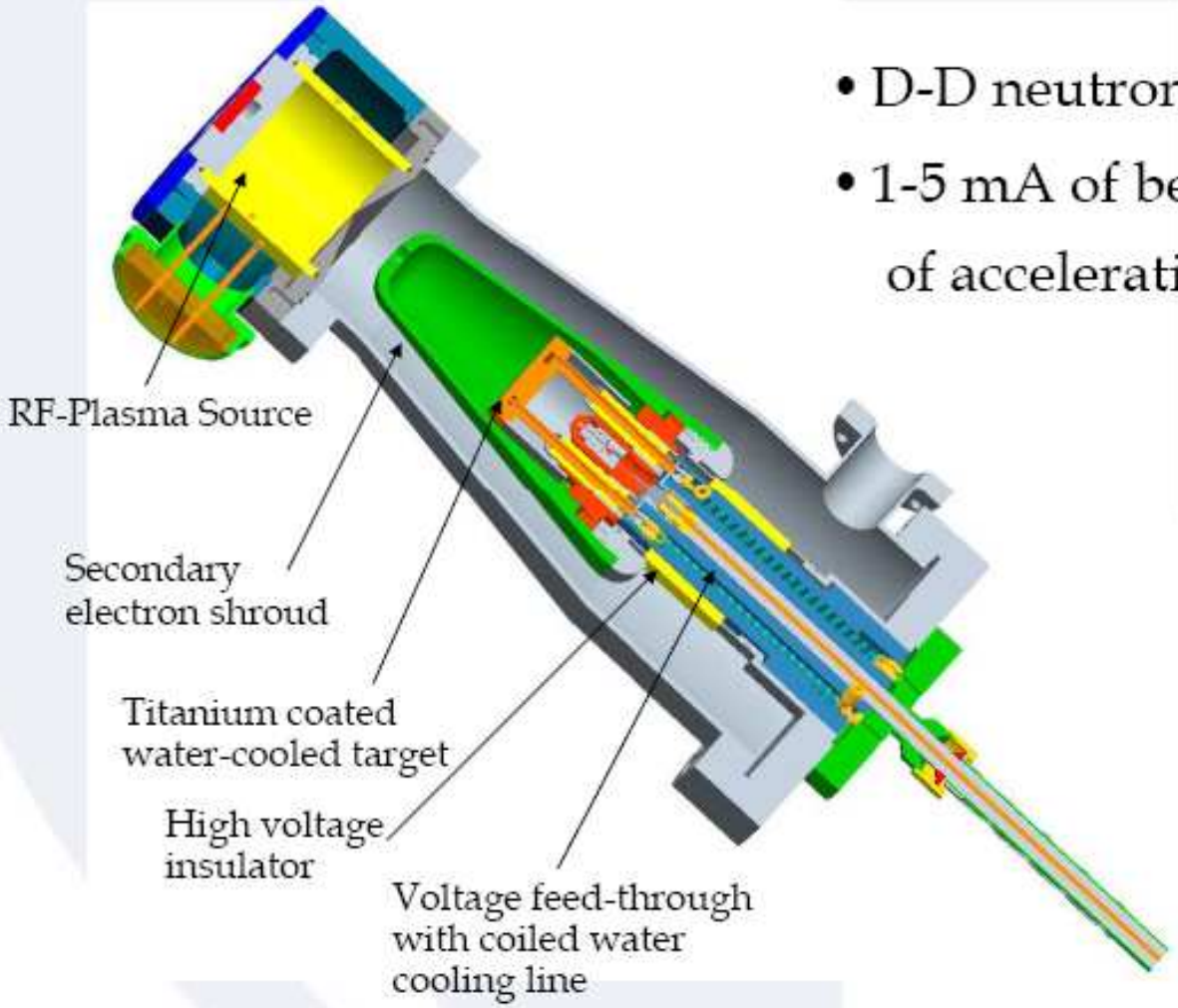
Funding Opportunities

- National Consortium for MASINT Research
  - Defense Intelligence Agency partnerships (non-NSF related funding)
  - NSF funding with “6.1” type research
- NA-42 Stabilization Program
- NA-22
  - Advanced Materials
  - SNM Detection
  - ^{235}U production detection
- Recent omnibus bill: $50 M for Megaports initiative and > $200 M for second line defense. This under “National Nuclear Materials Protection” section

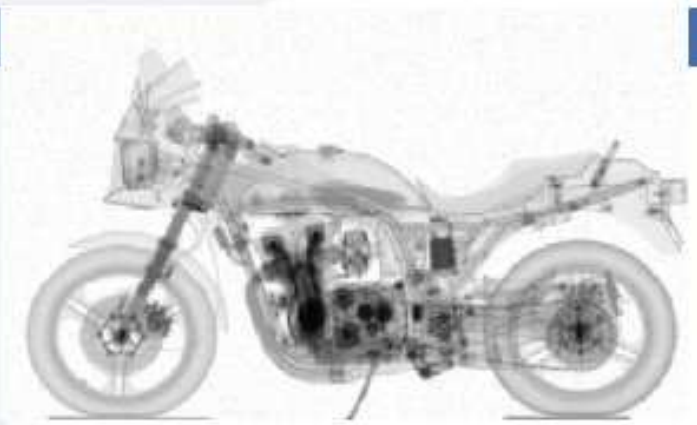
Adelphi: RF plasma neutron source



- D-D neutron yield of 10^8 n/sec
- 1-5 mA of beam current & 80 kV of acceleration voltage

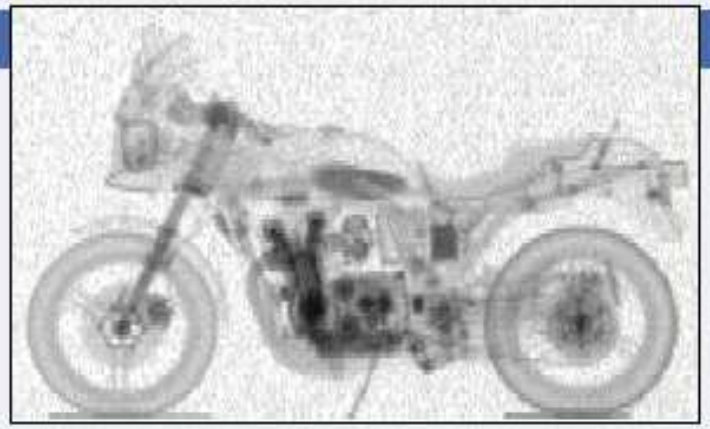
Courtesy: M. Fuller

CSIRO System



γ image

+



- Non-linear filters to reduce noise and increase definition
- Register γ and n images
- Correct for scattering and cosmic-ray background
- Determine R value for each pixel
- Map R to hue, gamma-ray attenuation to lightness

n images

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Courtesy: M. Fuller

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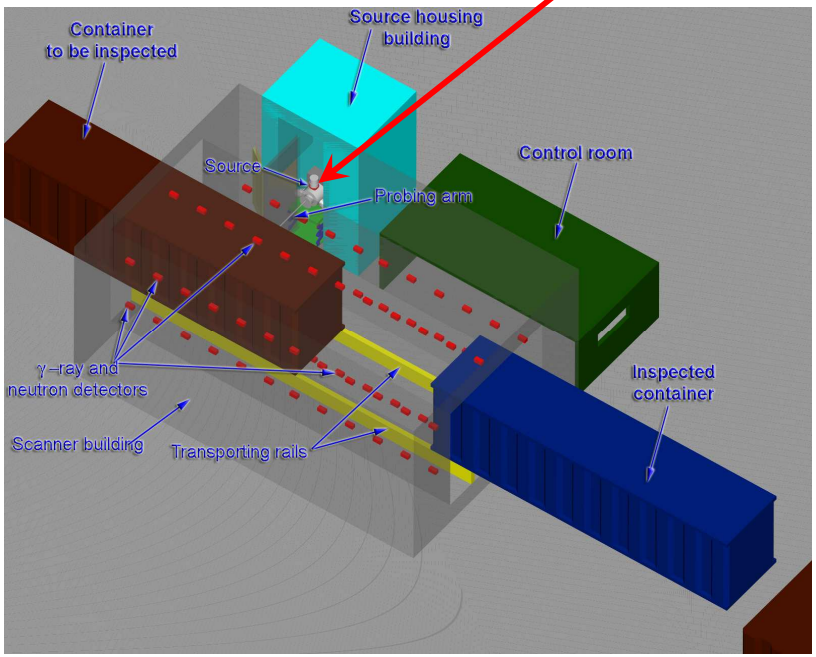
A novel hybrid detection system (HDS) for national security to counter seaborn container terrorism

- The HDS proposed will generate both a high flux of pulsed fast neutrons and high power EUV/VUV light from a compact 1-5 kHz Z-pinch device
- Neutrons can be used for bulk detection
  - Fluxes up to ~ 10^{12} to 10^{14} neutrons/sec at the source
- EUV/VUV light for trace detection
  - 10-50 mJ/pulse, 50-100 eV photons
- Unique detection capability allows for detection of:
  - Nuclear-graded materials
  - Explosives
  - Biological agents
  - Chemical agents



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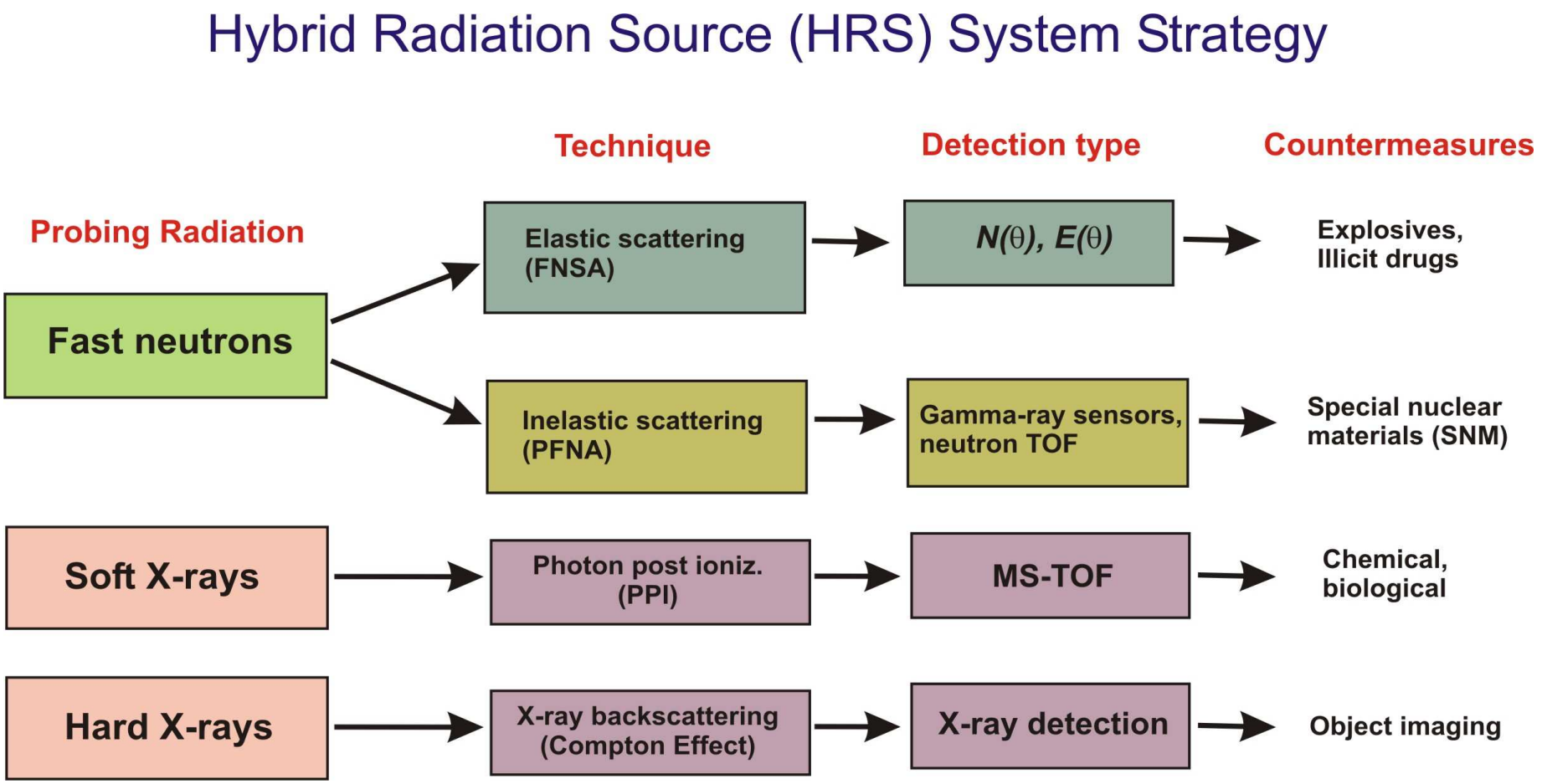
Combining experiments with computational simulation codes (A. Hassanein) for advanced plasma-source systems



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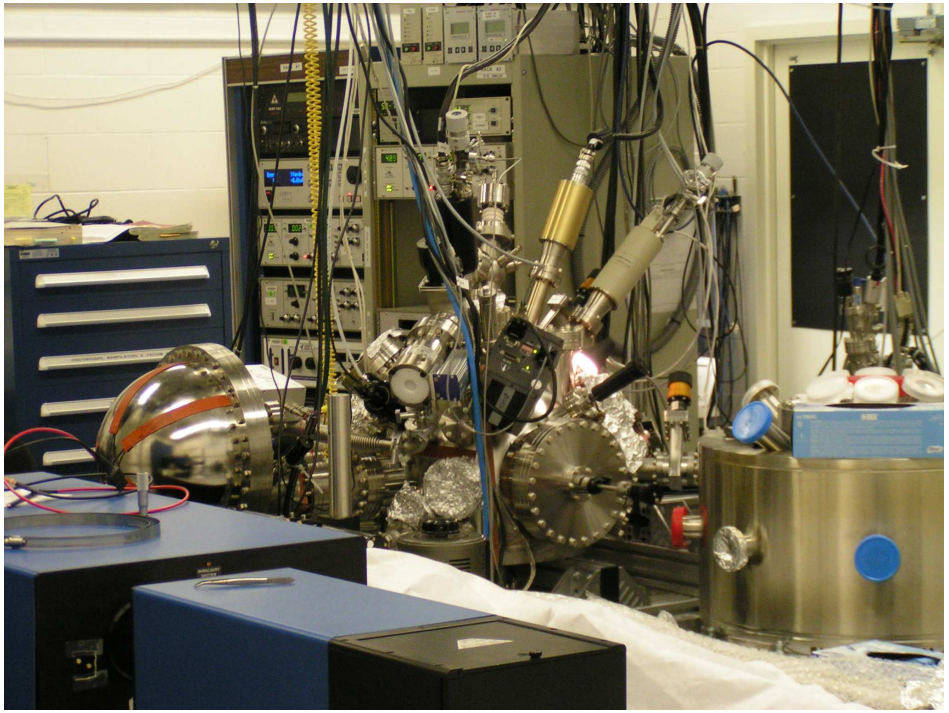
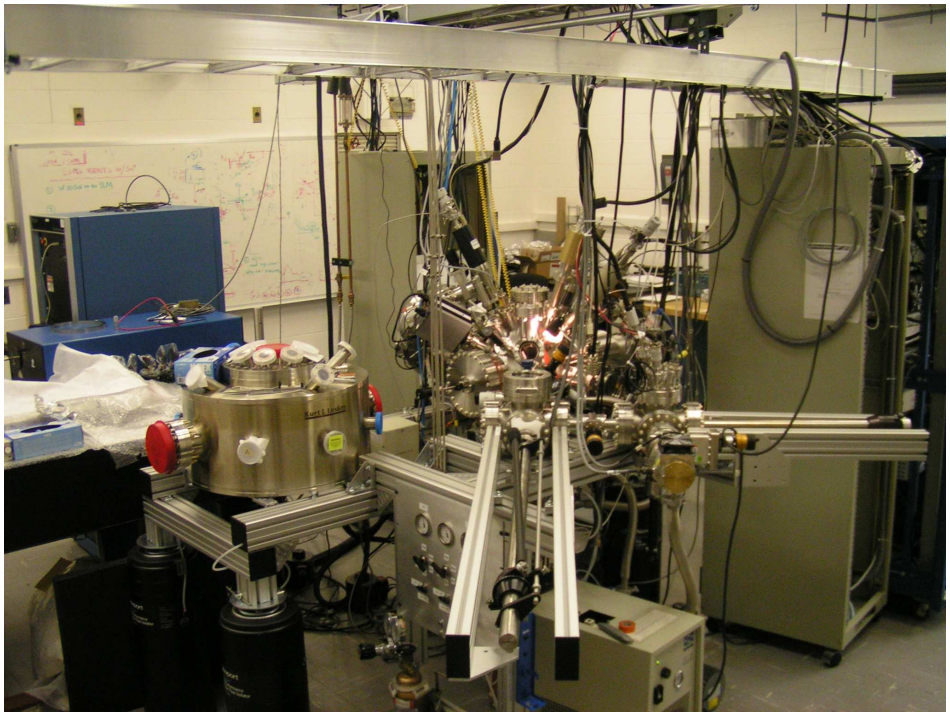
IMPACT: Interaction of Materials with Particles and Components Testing with Prof. A. Hassanein





- The IMPACT experiment is designed to study multi-functional and multi-component surfaces and interfaces under far-from equilibrium irradiation conditions.
- At Purdue our group will design and build the next generation IMPACT system: PRIHSM (Particle Radiation Interaction with Hard and Soft Matter):
  - Study ultrafast interactions of radiation and matter (metals, biomaterials)
  - Couple surface *structure* techniques with surface *composition*

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J.P. Allain et al. Rev. Sci. Instrum., 78 (2007) 113105

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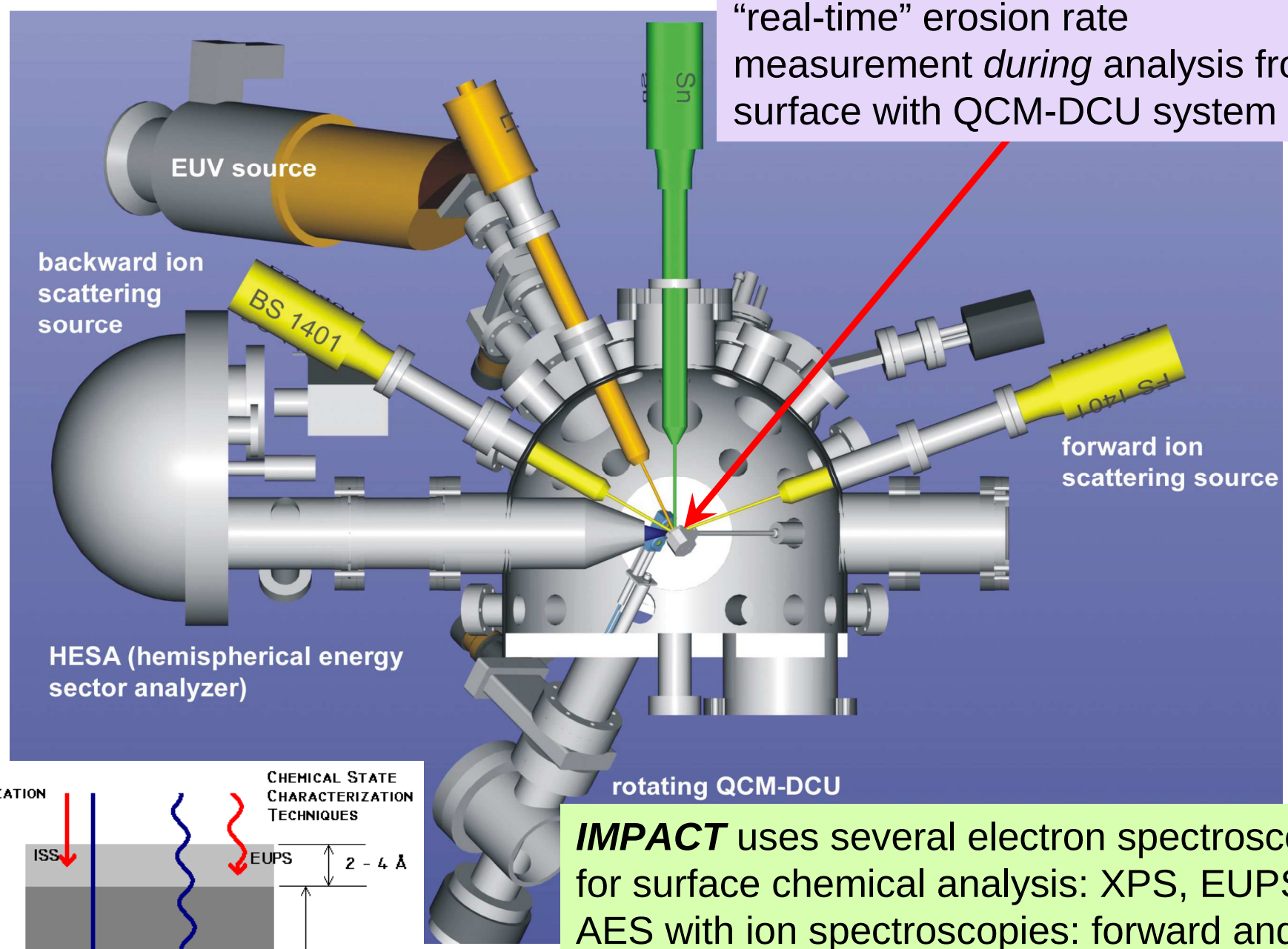
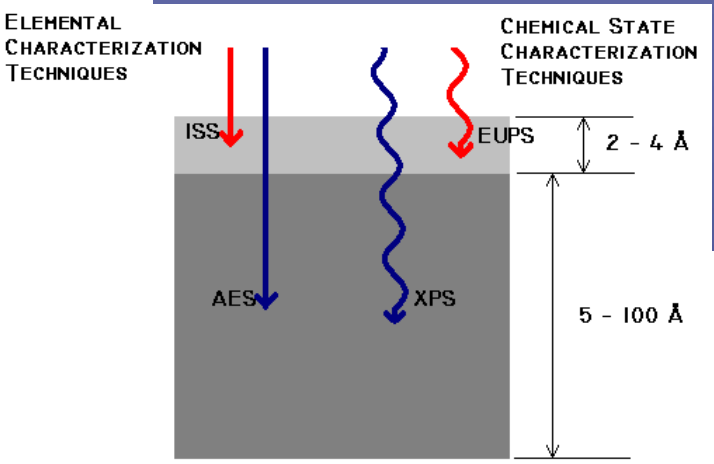
“real-time” erosion rate measurement *during* analysis from surface with QCM-DCU system





IMPACT uses several electron spectroscopies for surface chemical analysis: XPS, EUPS and AES with ion spectroscopies: forward and backward scattering modes

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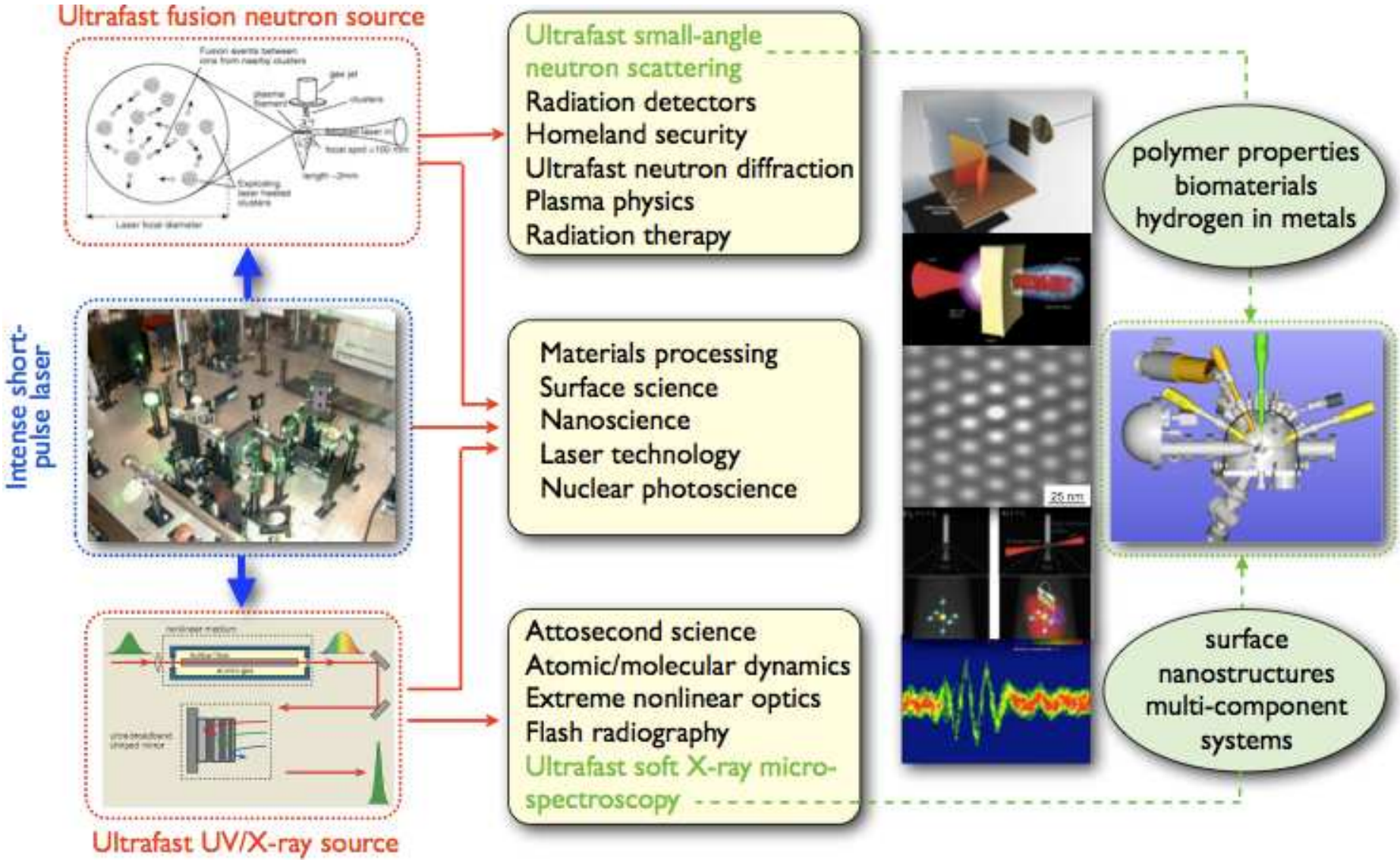
Use of intense laser-based ultrafast radiation (X-rays, neutrons) sources for characterization



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Collaboration with Prof. Jovanovic, NUCL

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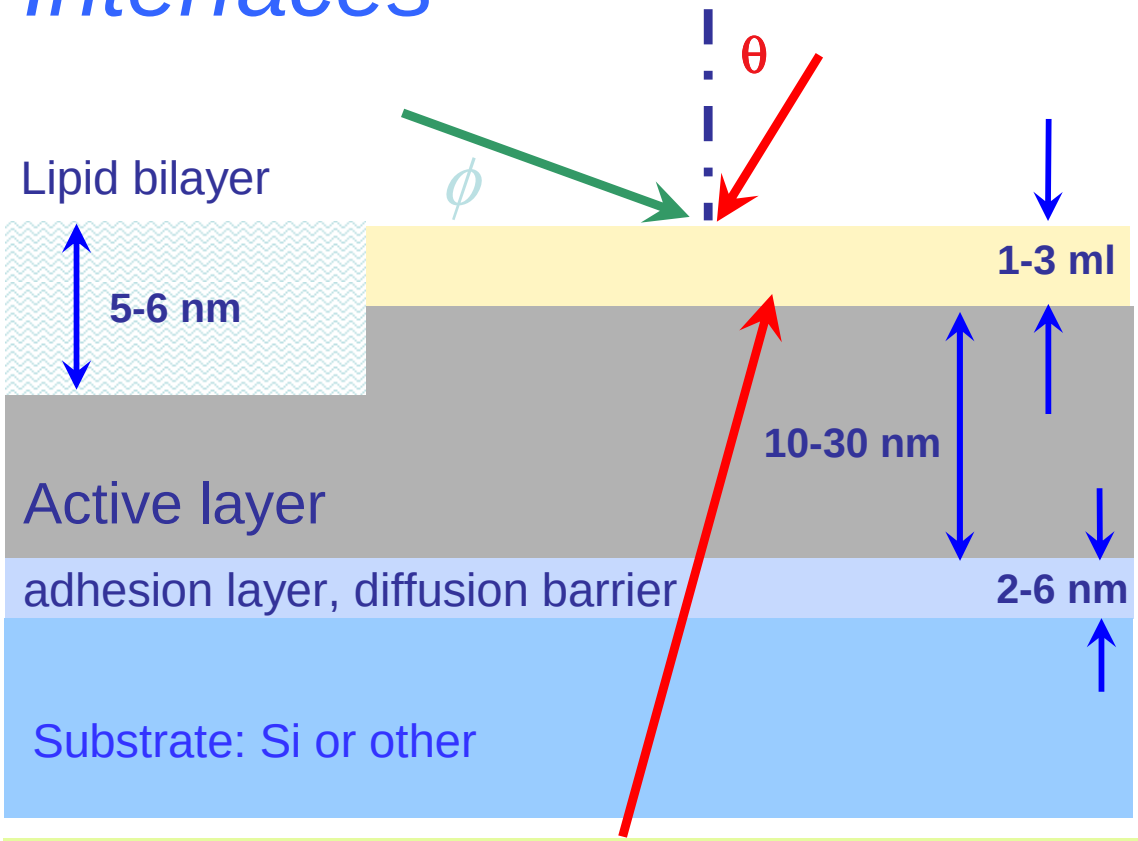
Model Nanoscale Systems: Surfaces and Interfaces



- Top functionalized layer to protect active thin-film
- Ultrashallow implants can modify region of 1-2 nm from the air/film interface
- Optical techniques can probe down 10-50 nm (or more) into the particular nanoscale system
- Ion and electron-based spectroscopies probe closer to air-film interface

- Control, function and probing at various scales at the surface or in the ultra thin-film
- Test particle-surface and interface interactions
- Use surface-sensitive techniques to study growth and synthesis *in situ* aiding in design and function of systems at the nanoscale

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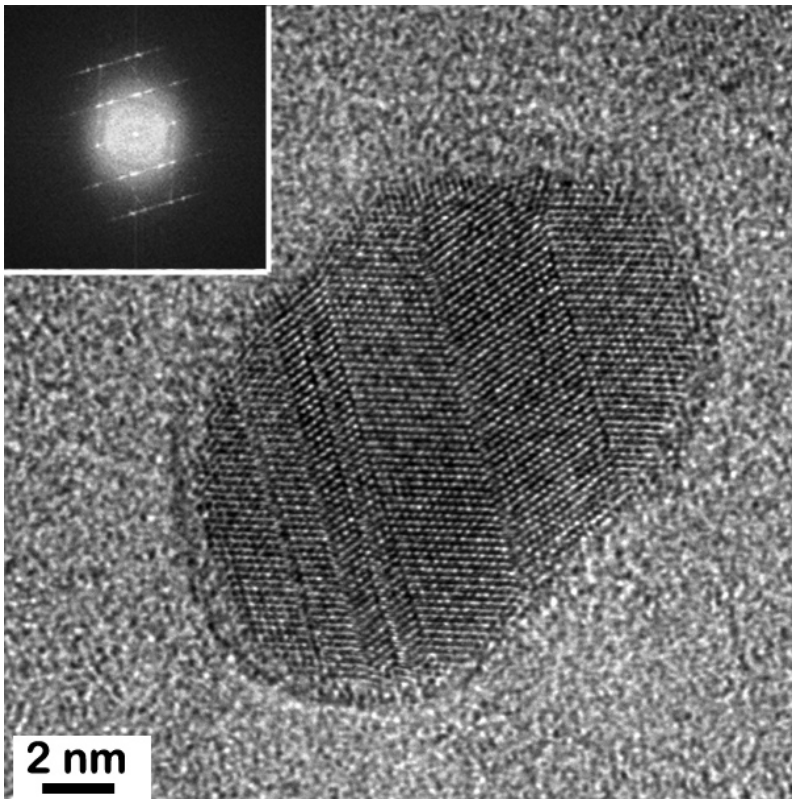
Transmission Electron Microscopy (TEM)

This machine is the first of a new generation of field-emission Environmental Cell Transmission Electron Microscopes / Scanning Transmission Electron Microscopes (E-TEM/STEM) from the FEI Corporation. It utilizes a new column design to allow ultra-high image resolution (1.0Å information limit, and 2.0 Å point-to-point resolution in TEM). Facility run by Eric Stach's group at Purdue.

FEI Titan 80/300 Environmental TEM
at the Birck Nanotechnology Center



Multiply twinned Sn nanoparticles

Courtesy of: Eric Stach

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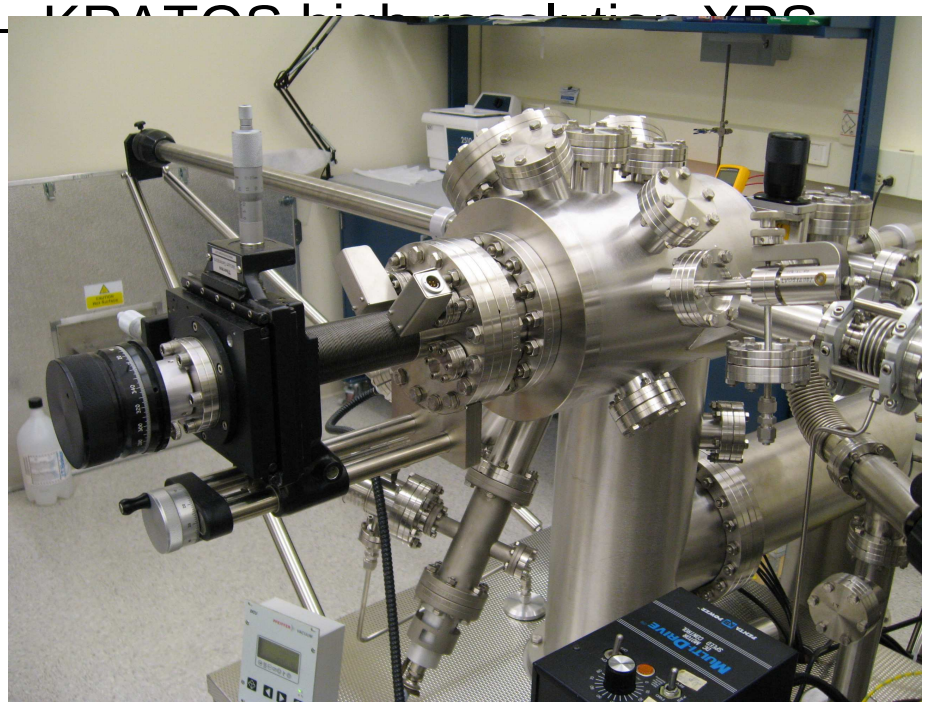
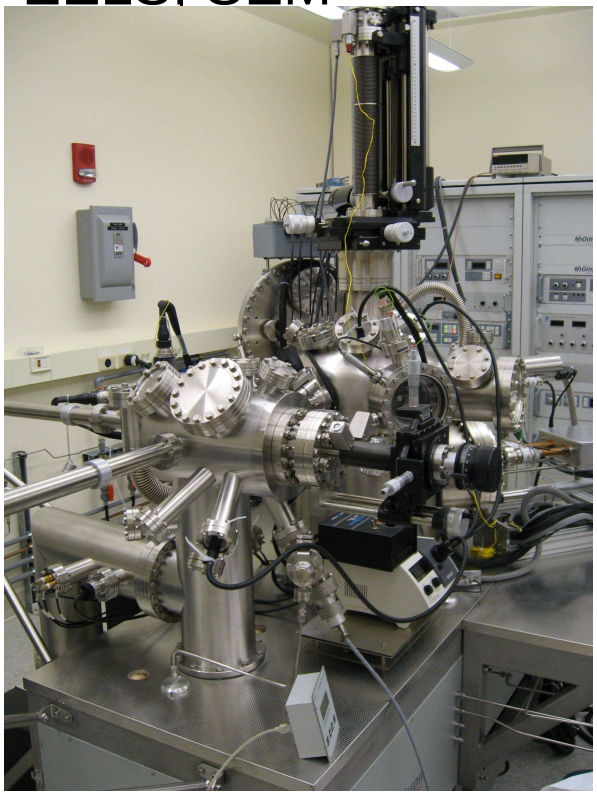
Surface Analysis Cluster at Birck

- Collaboration with Dr. D. Zemlyanov, two systems:
  - Omicron cluster system with: XPS, HR-EELS, SEM
  - KRATOS high resolution XPS





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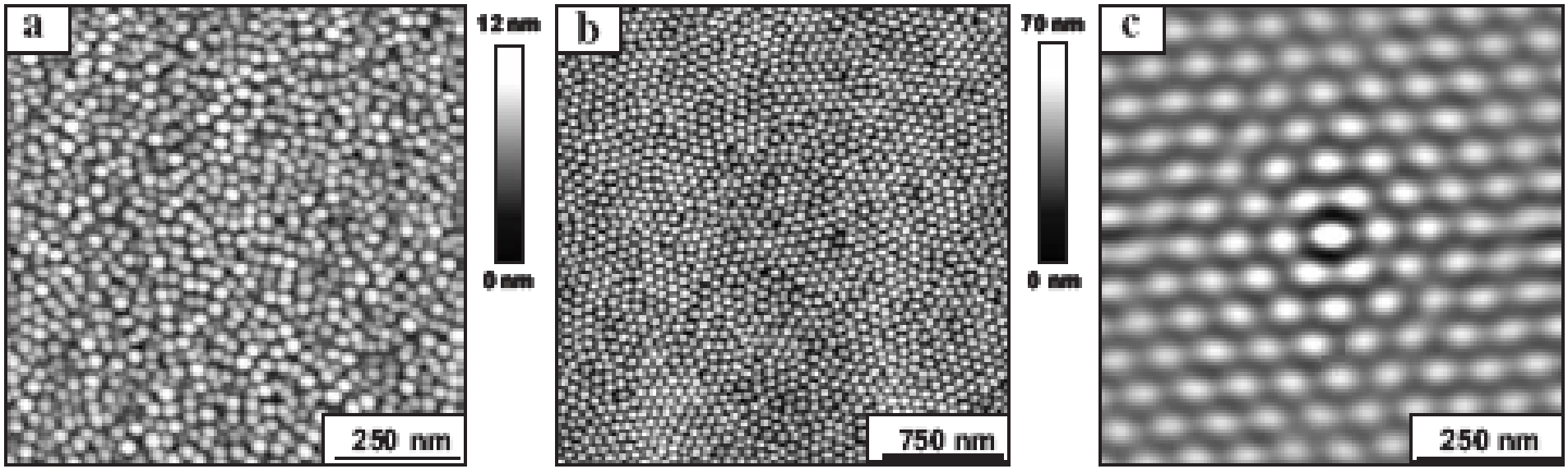
Functionalizing Surface and Interface Properties with Energetic Particles



Fluence = 5×10^{16} cm^{-2}

Fluence = 5×10^{17} cm^{-2}

- Ion-induced morphology on semiconductor surfaces evolves and depends on irradiation fluence (dose)
- 500 eV Ar sputtering with 400 μA/cm^2 ion incidence at 40 degree-incidence on InP
- Ion sculpting can be used for surface templating or quantum dot fabrication

F. Frost and B. Rauschenbach, Appl Phys A 77, 1-9 (2003)

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