

# Improvements to Existing Infrastructure

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University of Missouri Research Reactor

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- Surface x-ray scattering for studies of the nanoscale
- Support of smaller Neutron Sources

# Crucial Points:

- Nanostructures are usually grown and supported on a substrate
  - surface/interfaces can dominate energetics of small crystal
  - internal structure
- x-ray scattering is a crucial and unique tool:  
“see” surface and subsurface together
- *In situ* studies are essential to learn about physical processes

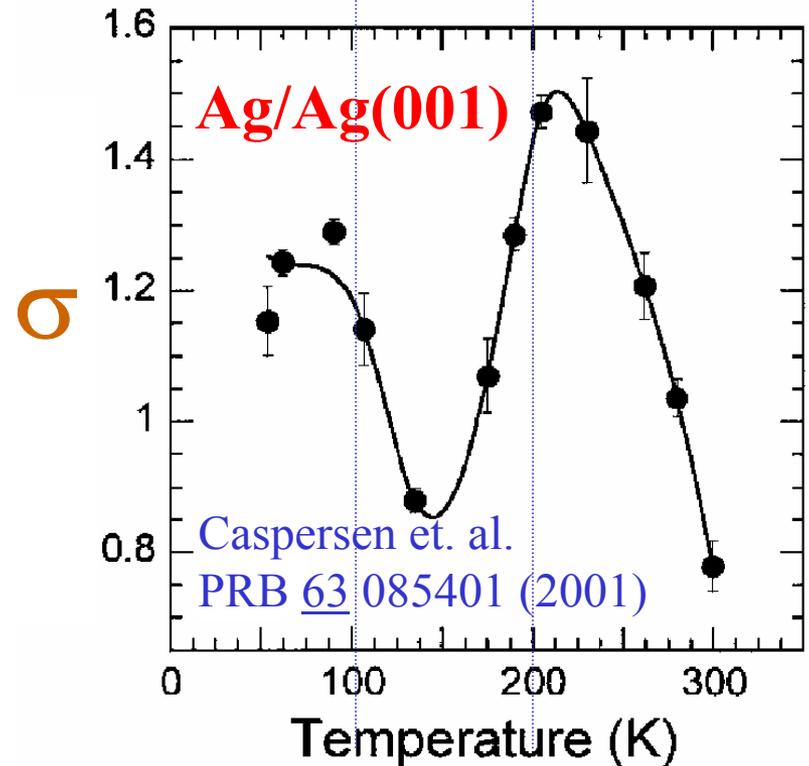
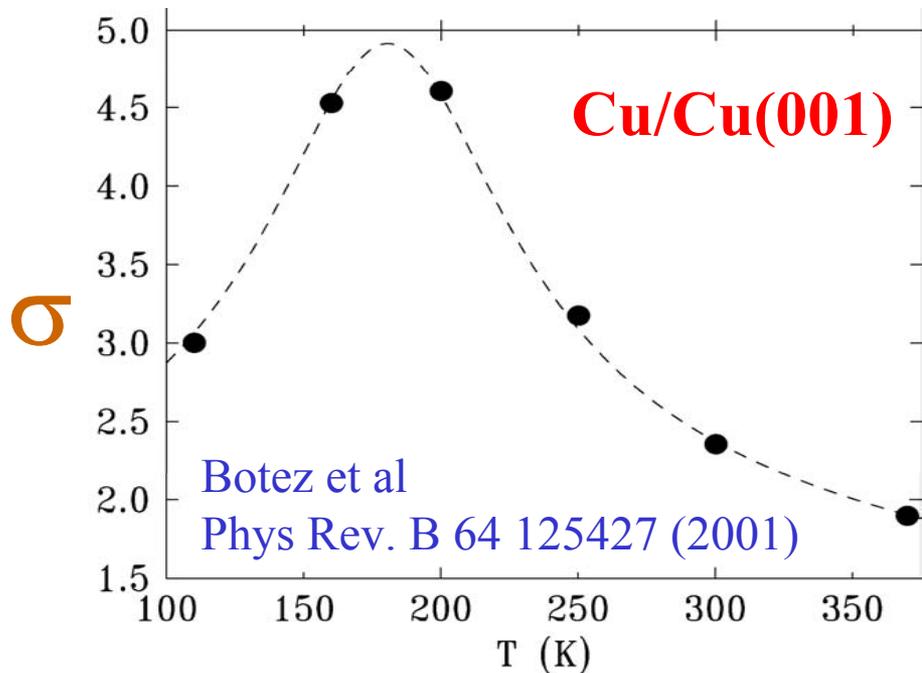
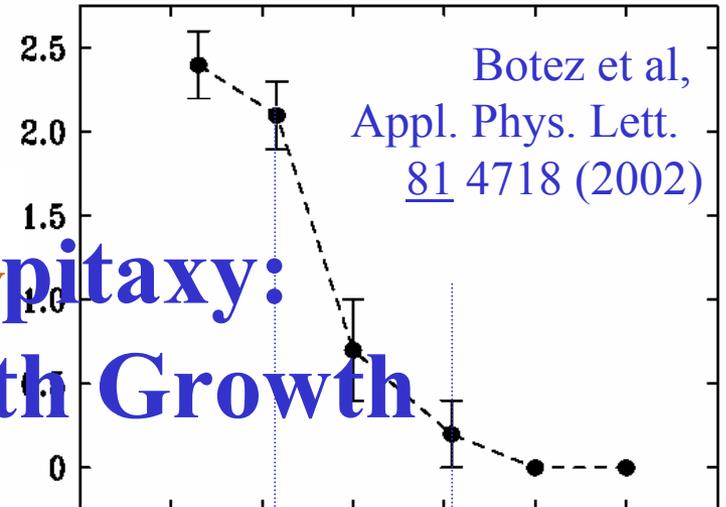
Examples:

- vacancies in thin metal films
- Pb nanocrystals

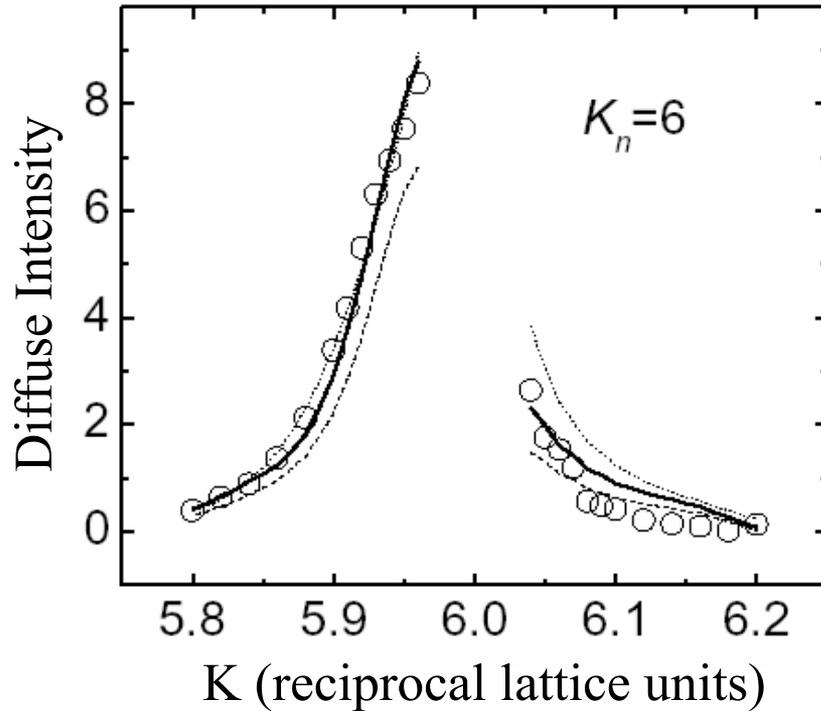
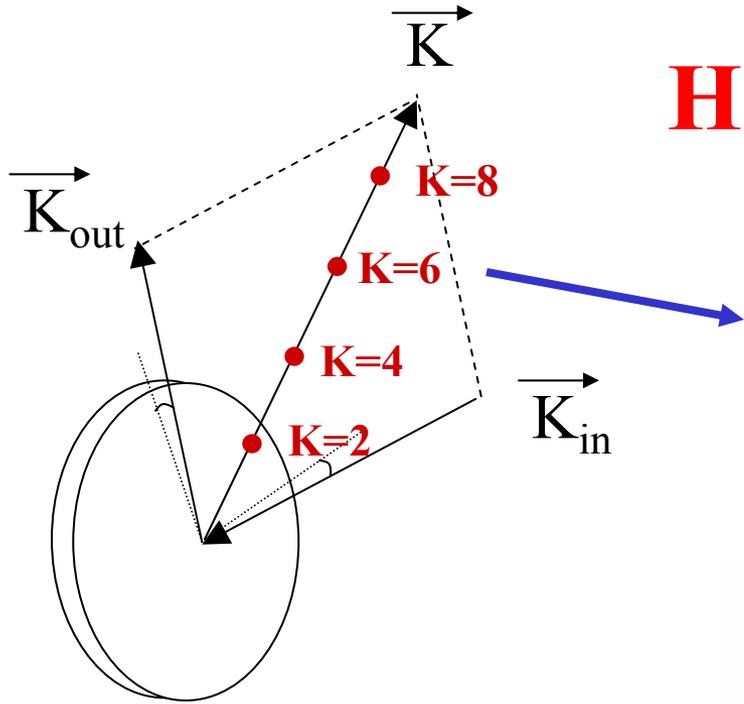
# Vacancy Incorporation from X-ray Reflectivity

Botez et al  
Phys Rev. B 66 195413 (2002)

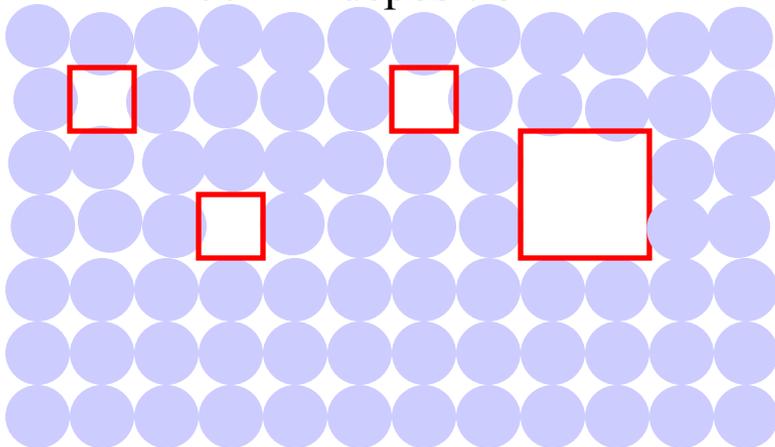
## Metal Homoepitaxy: Reentrant Smooth Growth



# Huang Diffuse Scattering



100 ML deposition



**Vacancy cluster size  
~ 100 atoms**

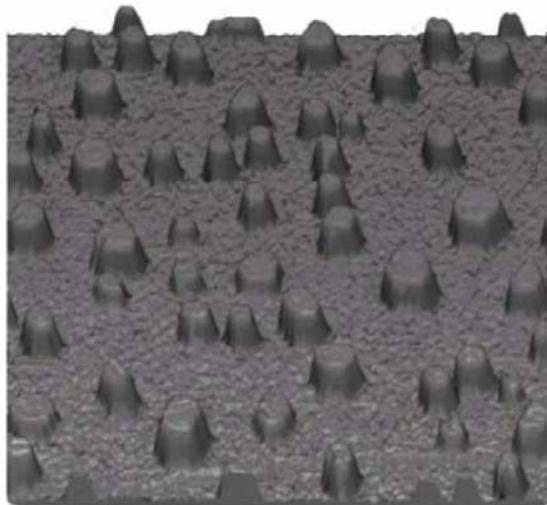
STM can't see the vacancies

&

Theorists didn't consider vacancies  
(and eliminated them from their models)

- Surface and subsurface are intimately related!  
Important to have a probe to study both

# Pb nanocrystals on Si(111) 7x7

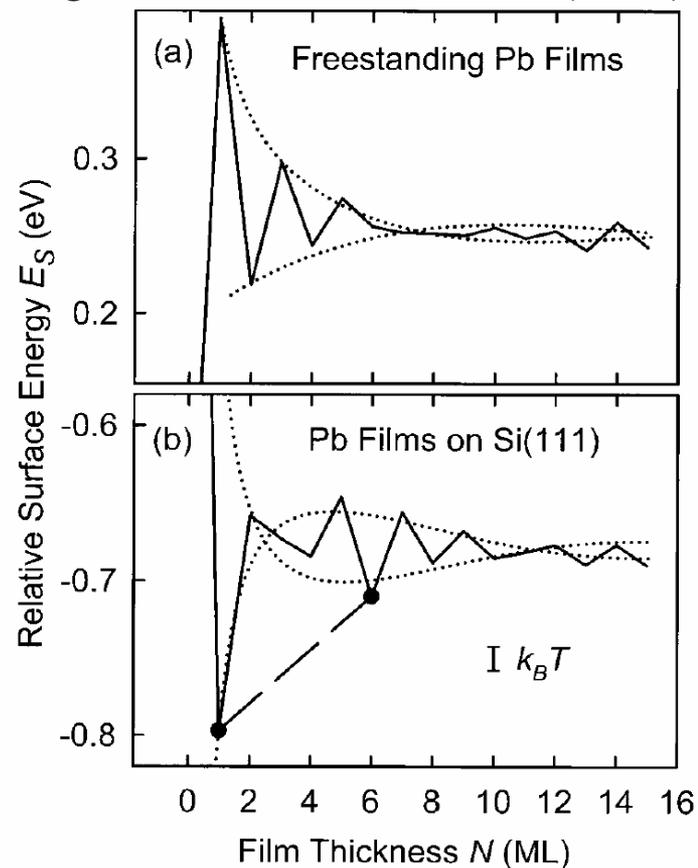
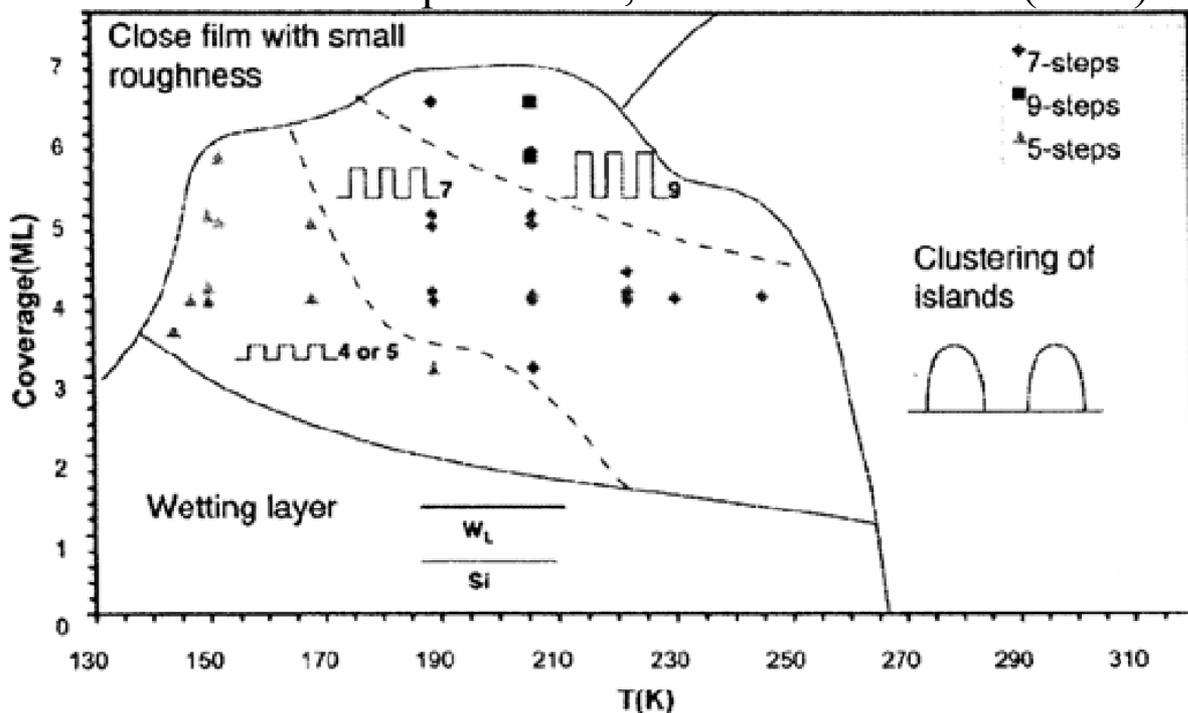


Hupalo et. al.,  
PRB **64**. 155307 (2001)

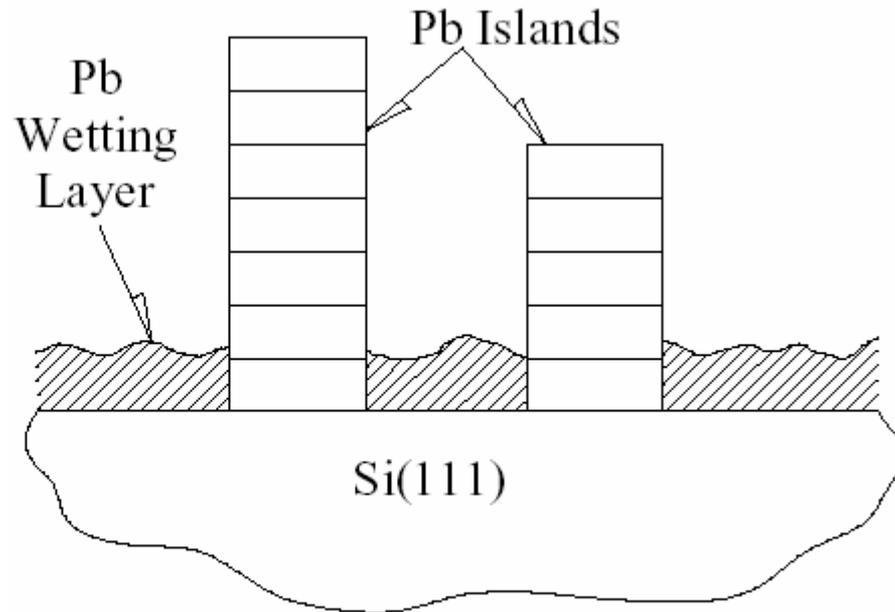
**Quantum Size Effect:  
“Magic” Island Heights**

Hong et. al., PRL **90**, 076104 (2003)

Hupalo et. al., Surf. Sci **493**. 526 (2001)

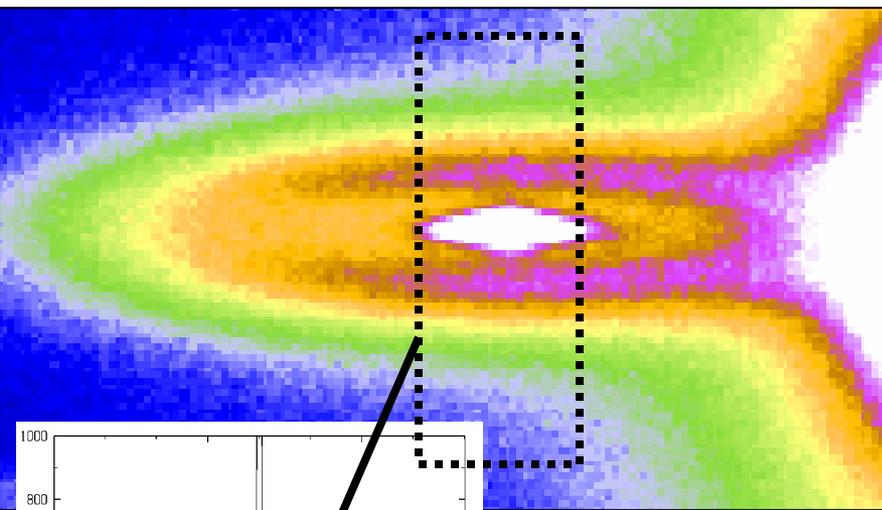


**Do the Pb nanocrystals grow  
Specular and Diffuse X-ray Scattering:  
on top of the wetting layer?  
Pb nanocrystals consume the wetting layer**

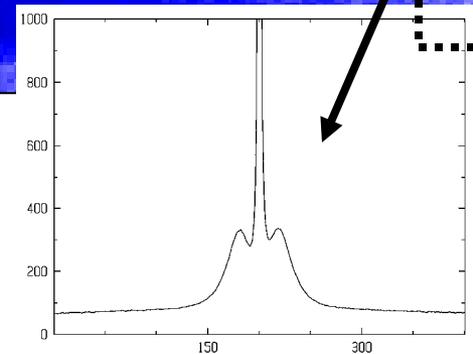


Feng et. al., Appl. Phys. Lett. **85**, 3866 (2004)

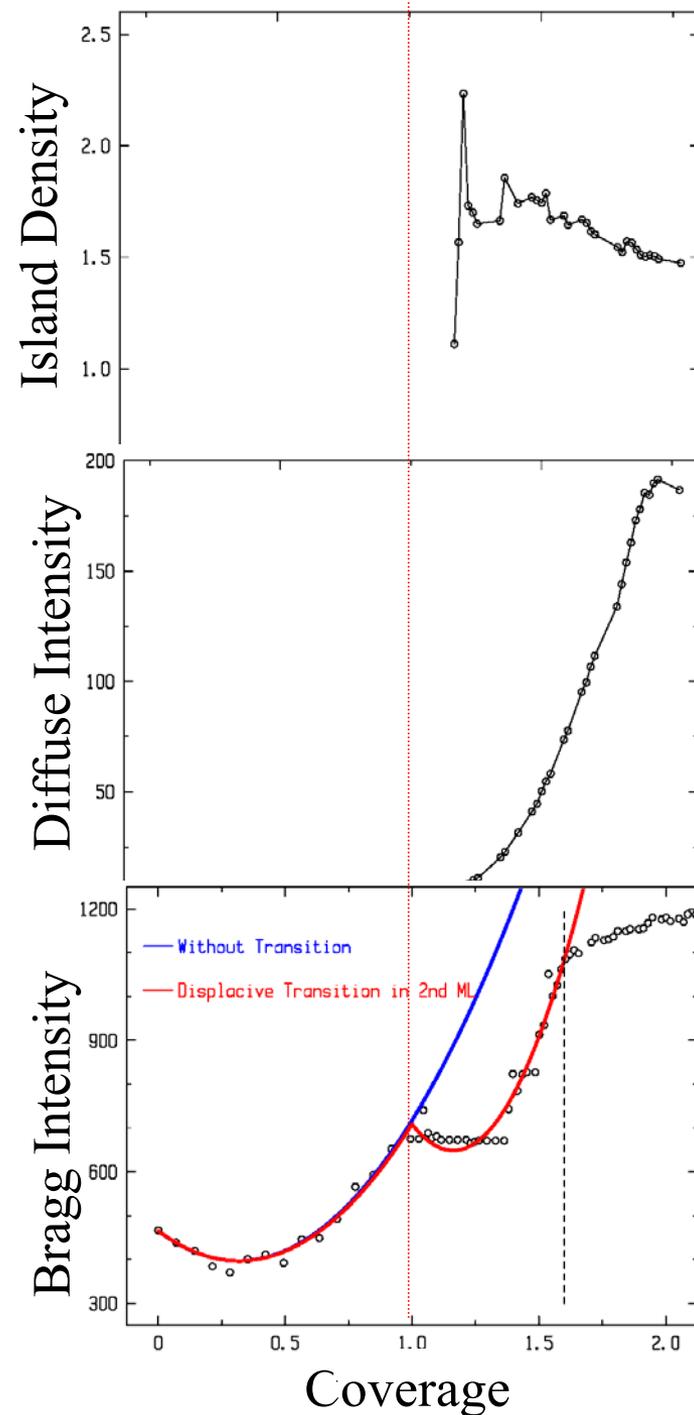
# Nucleation & Growth of Pb nanocrystals



CCD image of Pb(111)



- 5 sec. exposures
  - see early stages of island nucleation
  - see transition in 2<sup>nd</sup> monolayer
  - island density flux dependence:
- Quantum Size Effects



# What do we need?

- Beam Time!
  - in situ studies are essential, although time consuming
  - training! Next generation of scientists to learn techniques
- Surface Scattering will continue to be an essential tool in the future:
  - Reflectivity, truncation rods, surface crystallography
  - Morphology from diffuse scattering
    - surface correlations (anti-Bragg)
    - interfacial defects (specular-Bragg)
    - Huang scattering (near Bragg)
- Invest in detector development: better utilize our sources
  - area detectors:
    - faster readout, larger dynamic range, energy res.

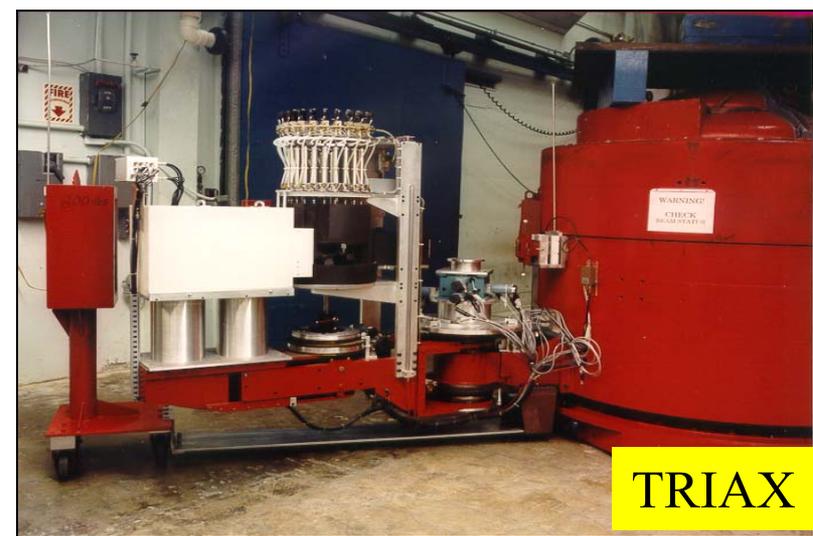
# Neutron Scattering

**University of Missouri Research Reactor (MURR)**

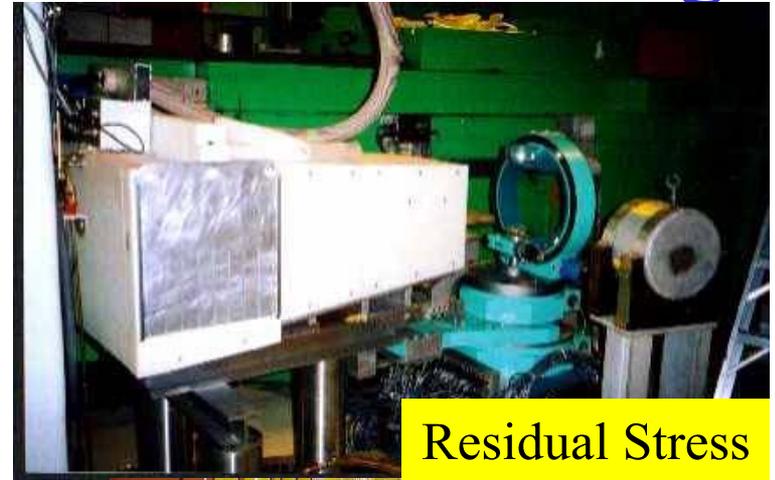
**University of Missouri-Columbia**



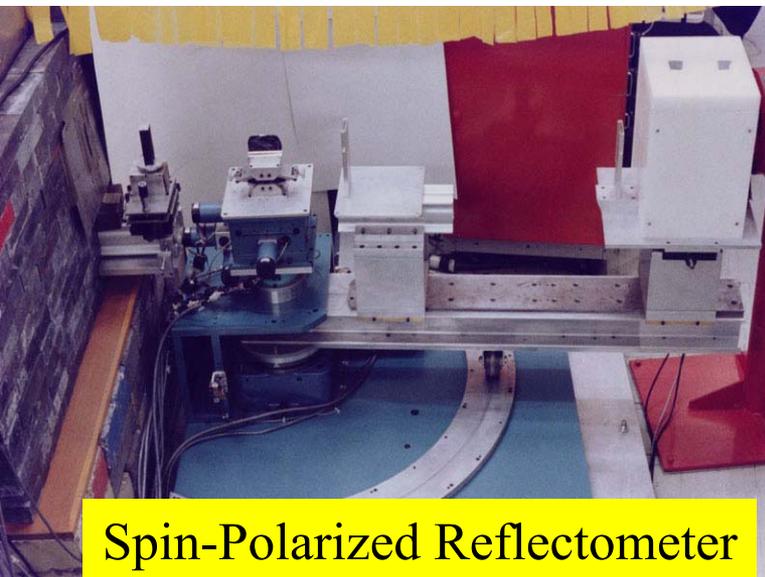
# 10 MW & 5 instruments for Neutron Scattering



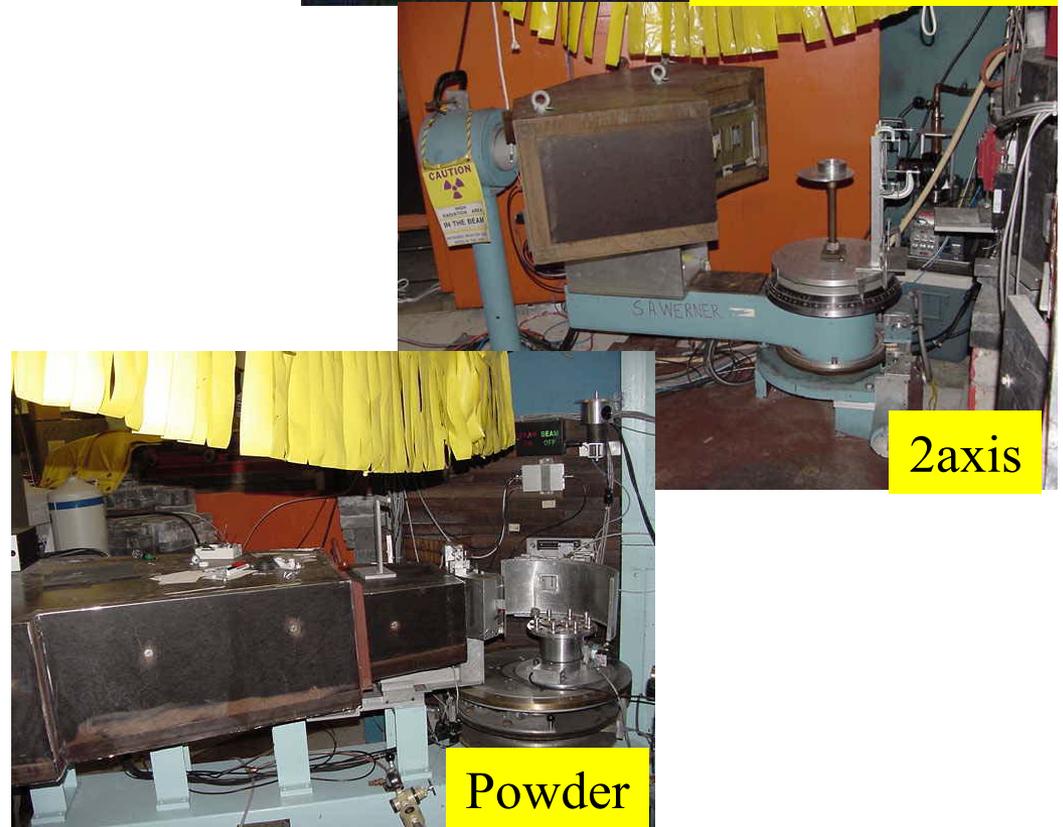
TRIAX



Residual Stress



Spin-Polarized Reflectometer



2axis

Powder

# Neutron Scattering at Small Reactor Facilities

- **Use to Support the Mission of the National Sources**
  - good flux & instruments for neutron scattering
  - exploratory experiments/ concept development
  - challenging/difficult (time consuming) experiments
  - overflow proposals: experiments that don't need the SNS flux
  - excellent environment to train grad students
  - Europe has followed this model for decades!
- **Requires a small investment in support staff**