

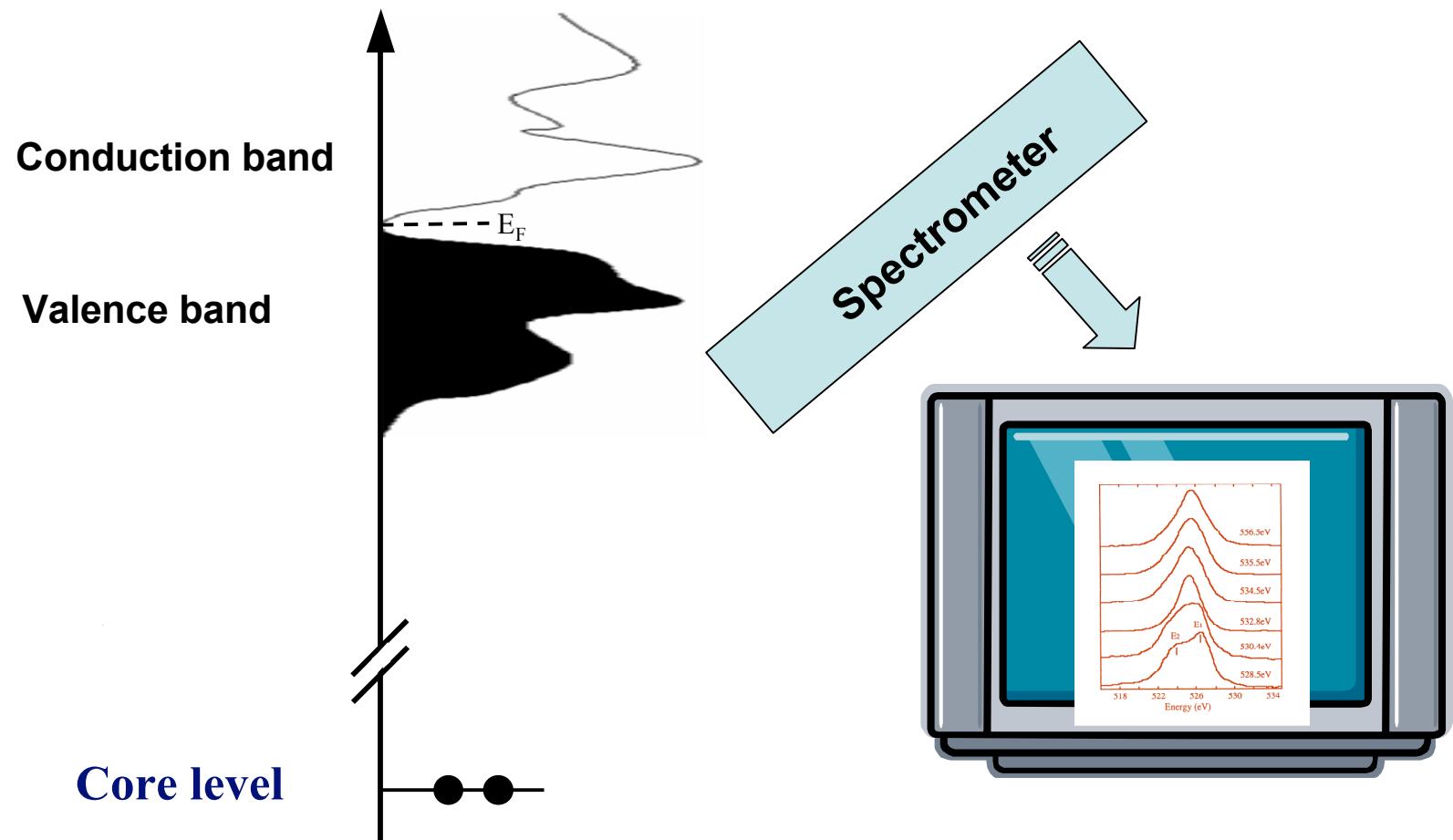
# *In Situ* Probing by Resonant Soft X-Ray Fluorescence Spectroscopy



Joseph Nordgren  
Uppsala University

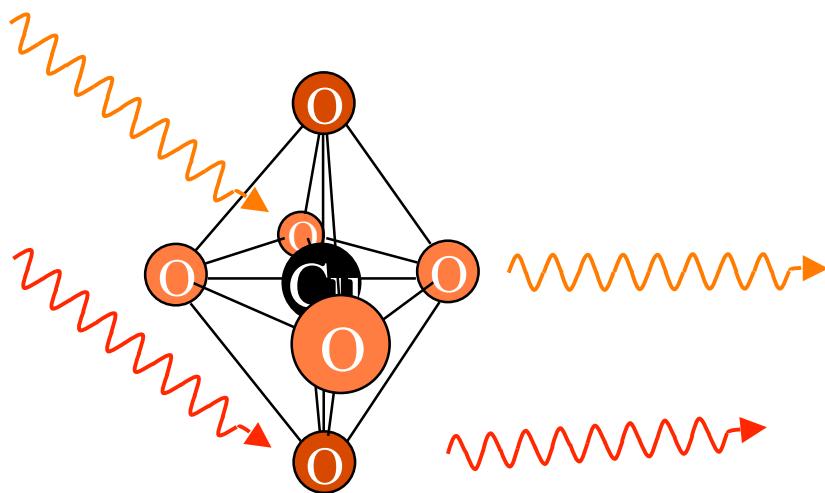
- **Resonant soft X-ray fluorescence spectroscopy**
- ***In situ* applications in materials science**
- **Experimental forward-look**

# Resonant excitation of soft X-ray fluorescence

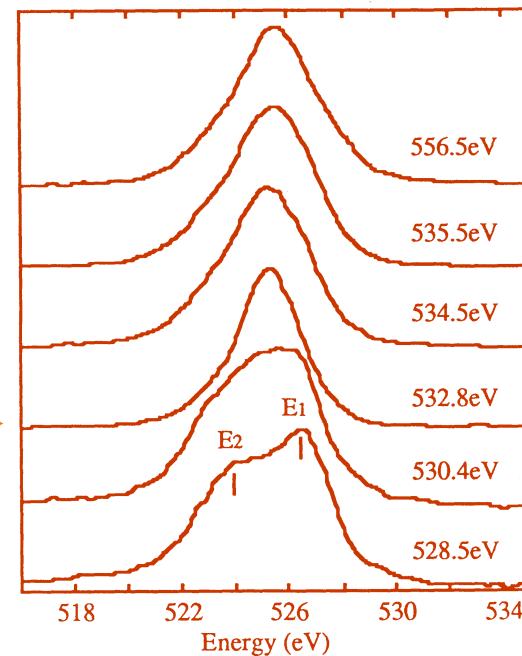


# Resonant O K emission of $\text{La}_{2-x}\text{Sr}_x\text{CuO}_4$

Tuning of excitation selects site



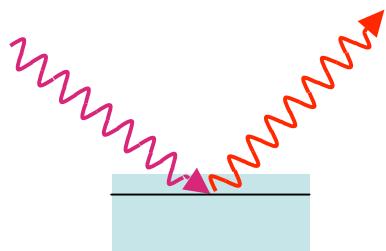
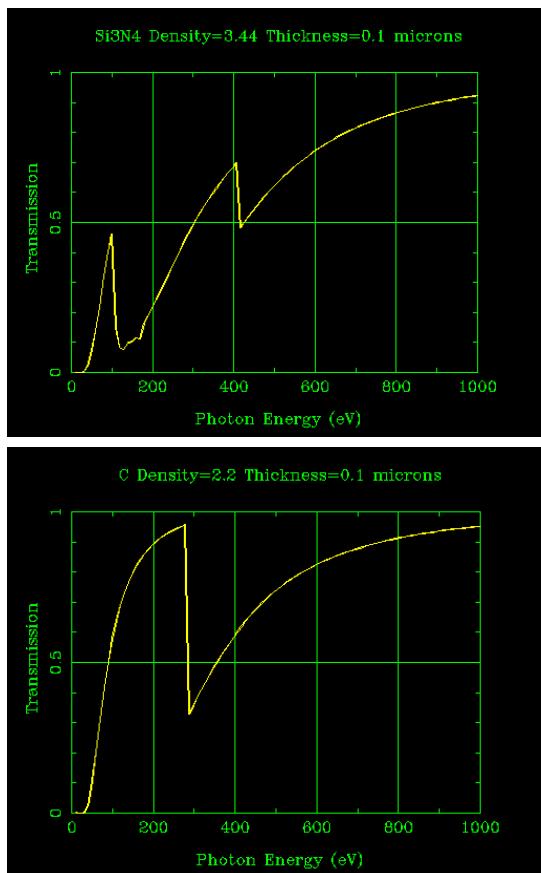
Oxygen K emission



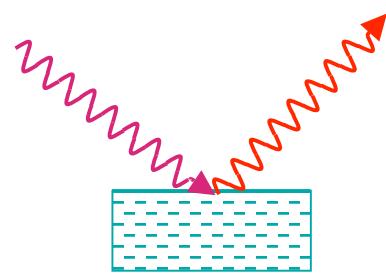
S. Butorin *et al.*, J. Electr. Spectr. **110-111** (2000)

# *In situ* probing by soft X-ray fluorescence

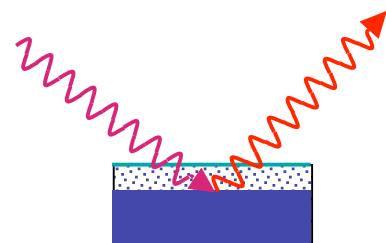
Transmission of 100 nm  
 $\text{Si}_3\text{N}_4$  and C windows



Buried layers  
Bulk properties



Capped samples  
Liquids



Ambient pressure  
Gas phase

# Hydrogen uptake in metals

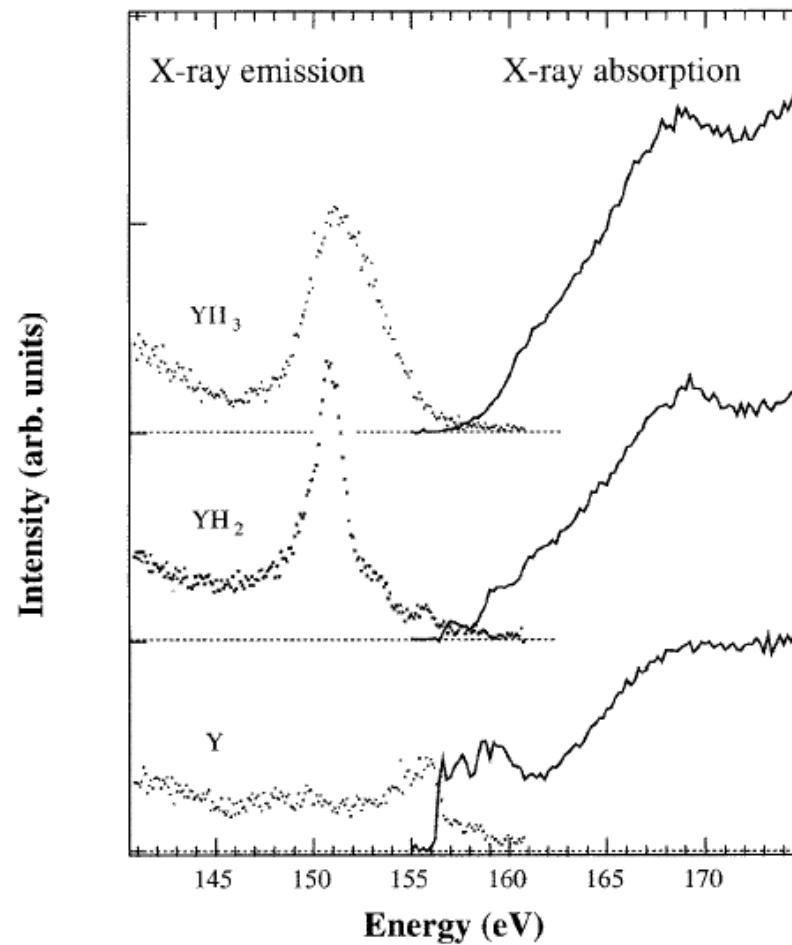
TM switchable mirror



R&D 100 Awards 2004

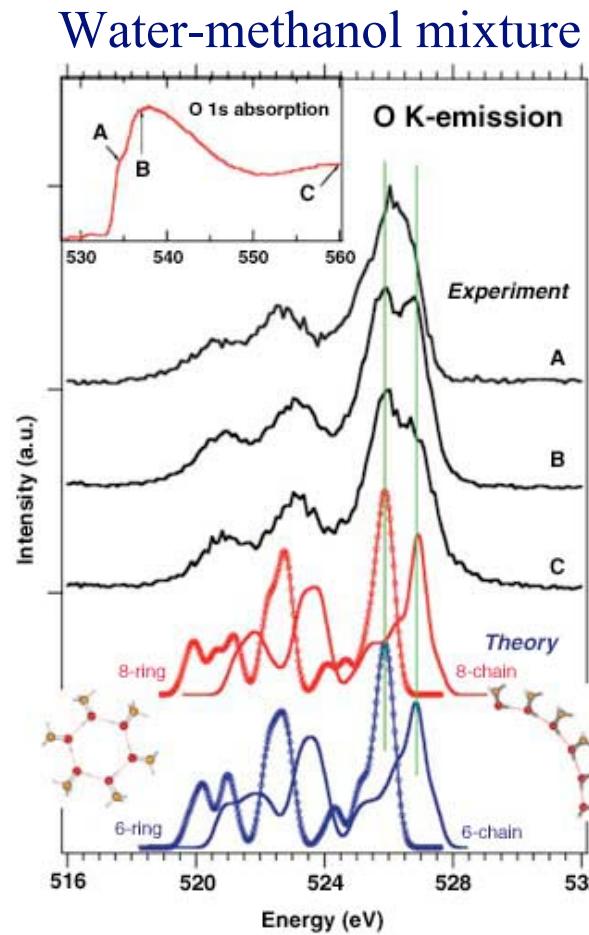
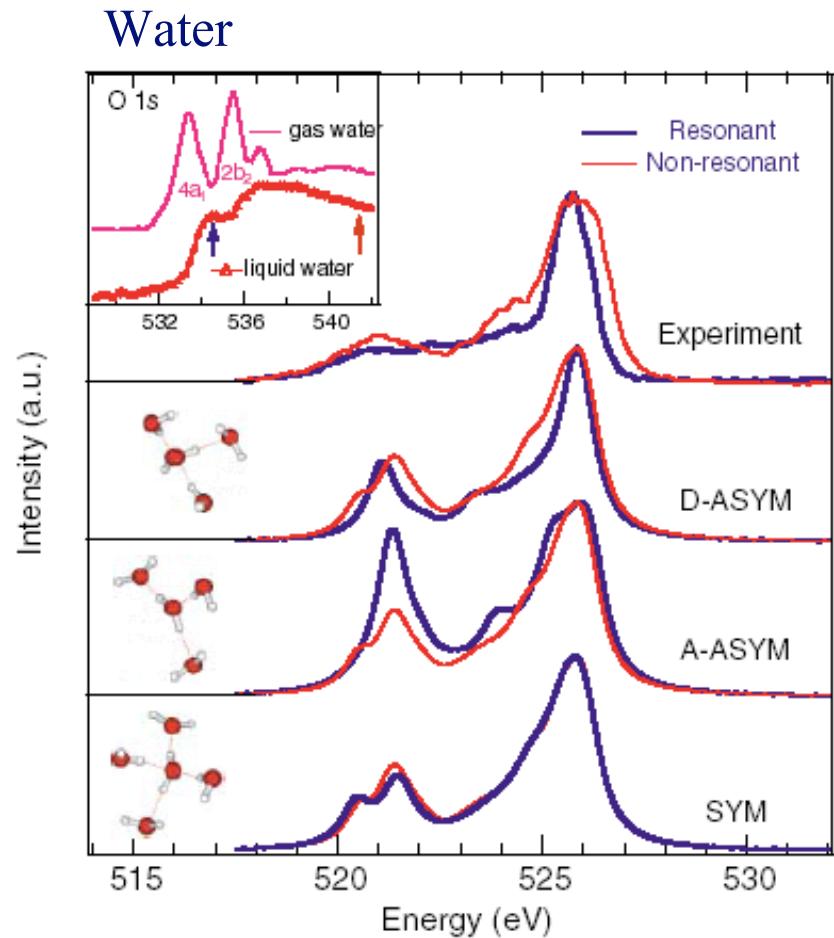
T. Richardson and J. Slack,  
LBNL 2004

Electronic structure changes by exposing Yttrium to hydrogen



Hjorvarsson, B. et al., J. Phys. C, **11**, L119 (1999)

# O K X-ray emission of liquid water

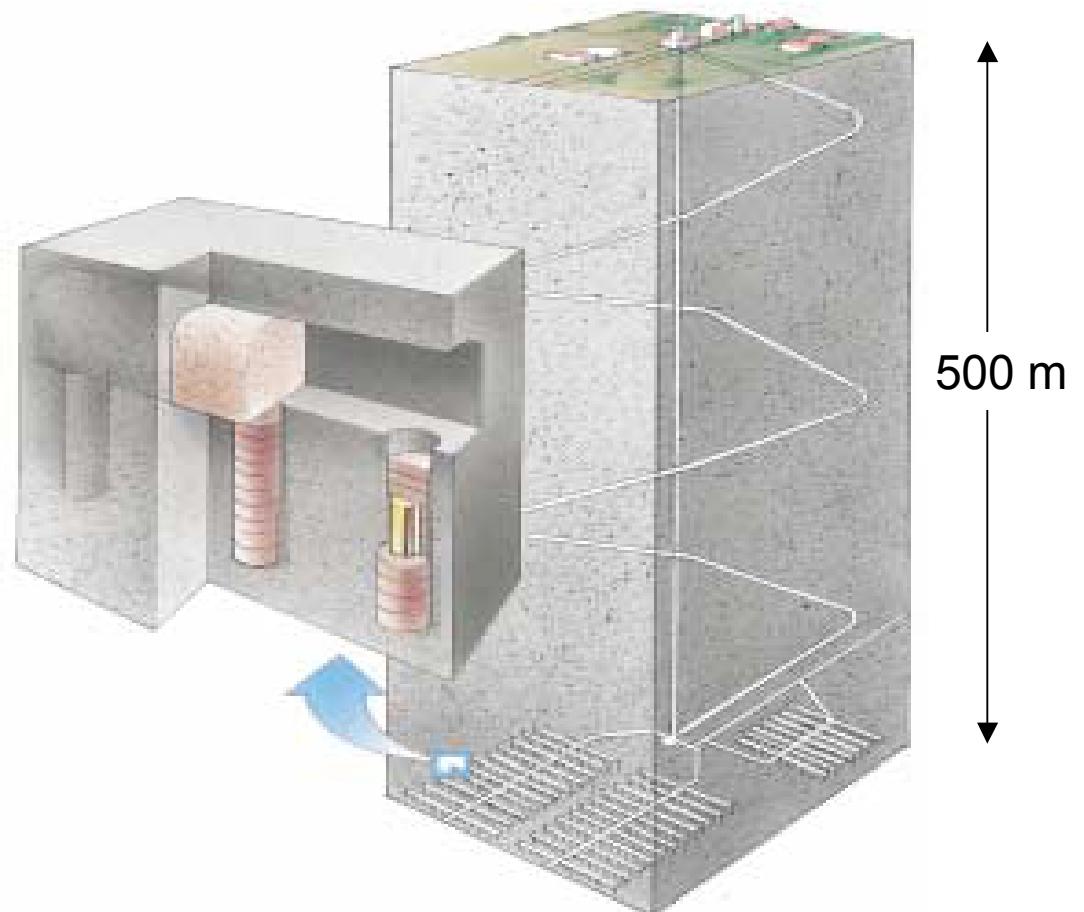
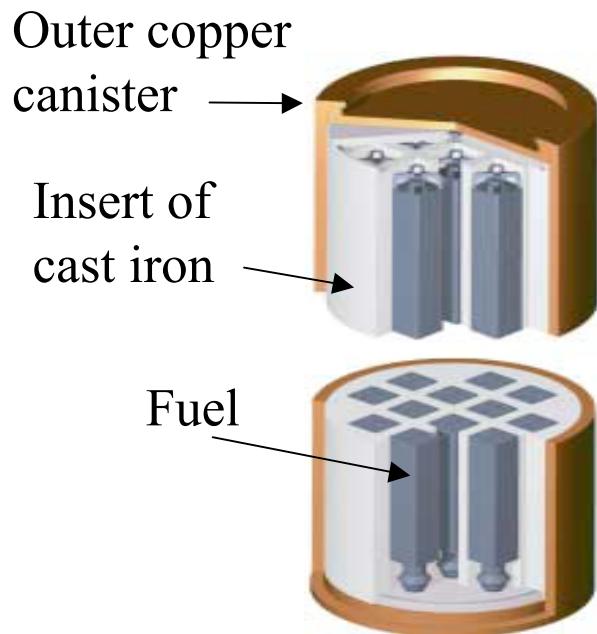


J.-H. Guo, *et al.*, Phys.Rev.Lett., 89, 137402 (2002)

J.-H. Guo , *et al.*, Phys. Rev. Lett. 91, 157401 (2003)

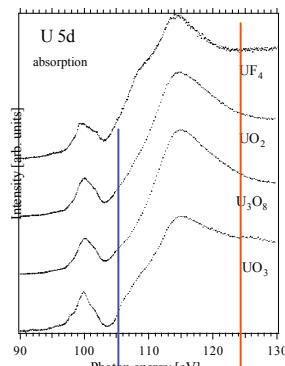
# Long-term storage of spent nuclear fuel in Sweden and Finland

Exploded view of spent fuel  
disposal canister



# RIXS of Uranium oxides

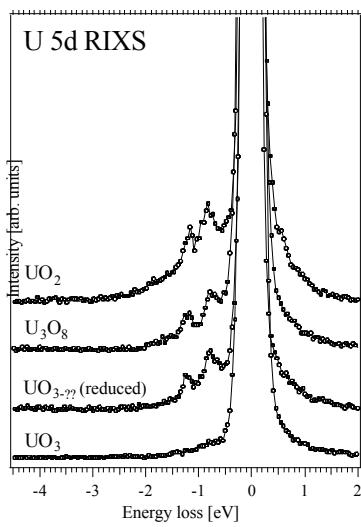
U 5d x-ray absorption



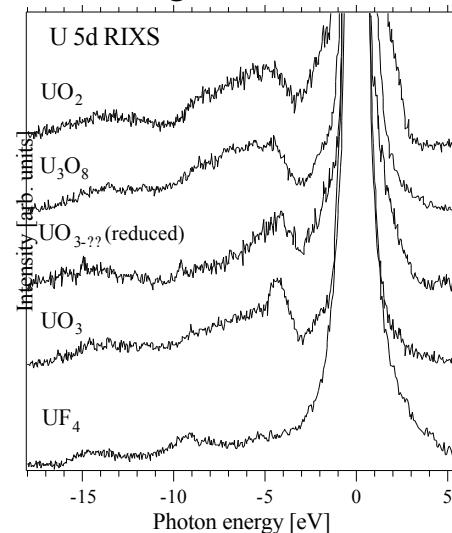
S. Butorin,

J. Electr. Spectr., **110-111**, 213 (2000)

*f-f* excitations

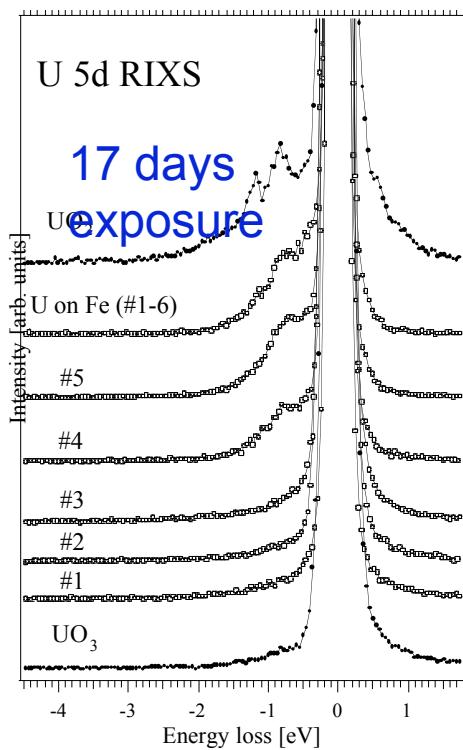


Charge-transfer excitations

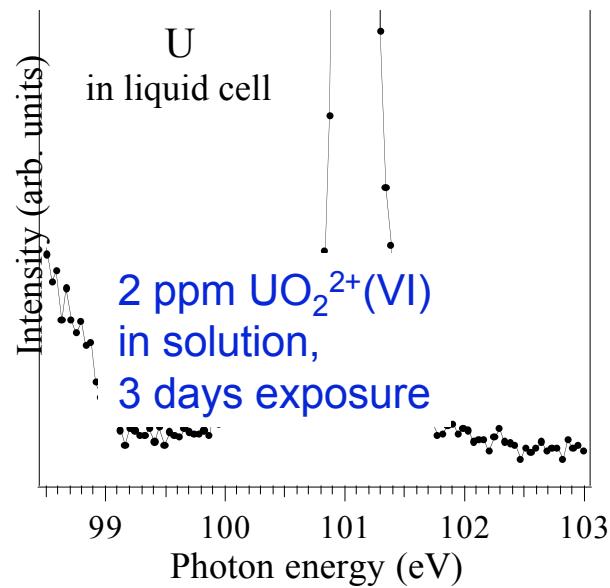


# Uranium on Fe foils exposed to U(VI) solutions

*Ex situ* measurement of U 5d RIXS on Fe exposed to  $\text{U}^{6+}$



*In situ* measurement of U 5d RIXS on Fe exposed to  $\text{U}^{6+}$

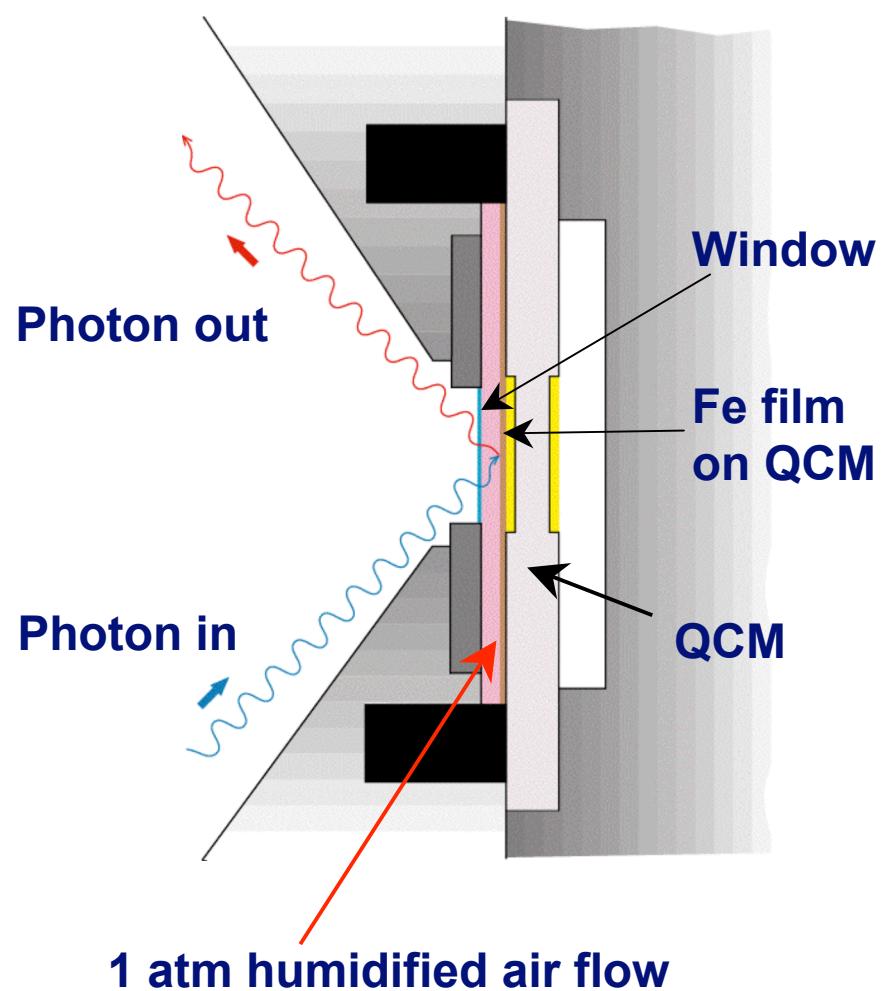


See S. Butorin in Friday-Saturday workshop "Soft-X-Ray Photon-In and Photon-Out Spectroscopy: New Frontiers"

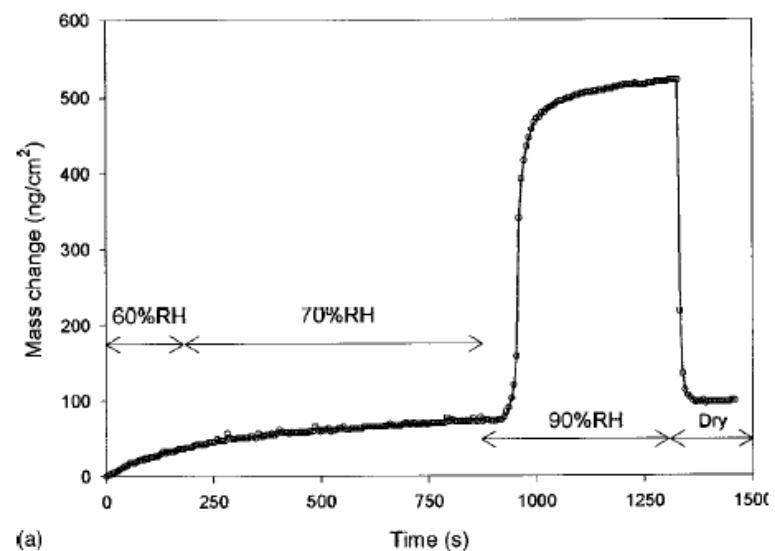
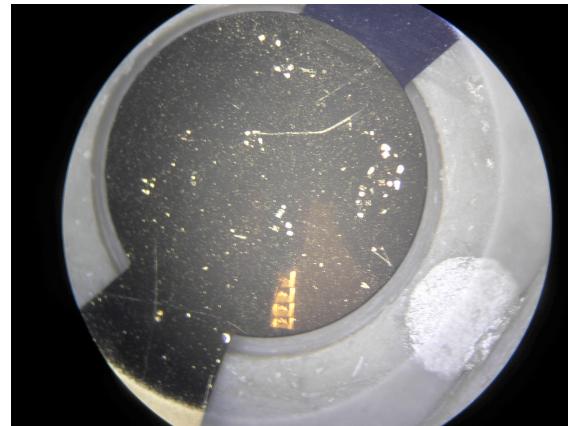
# Corrosion – a 3% GDP problem



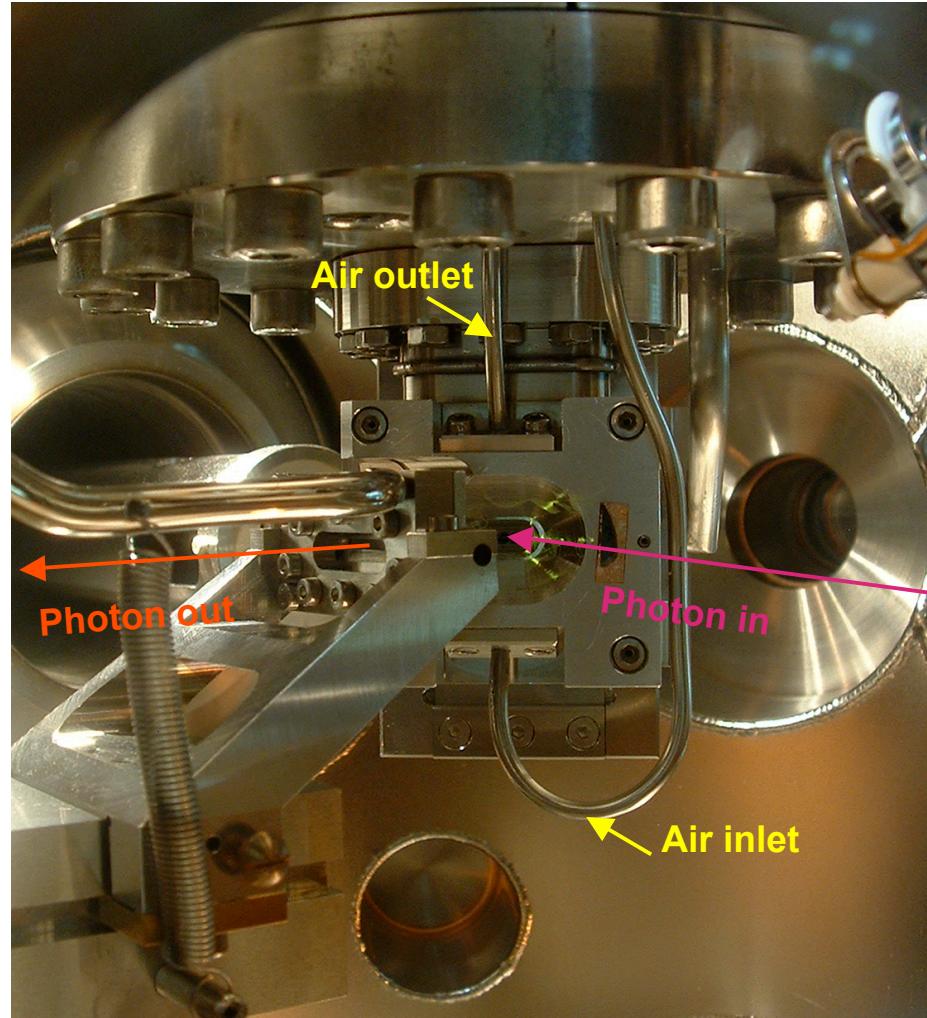
# Sample cell for study of atmospheric corrosion



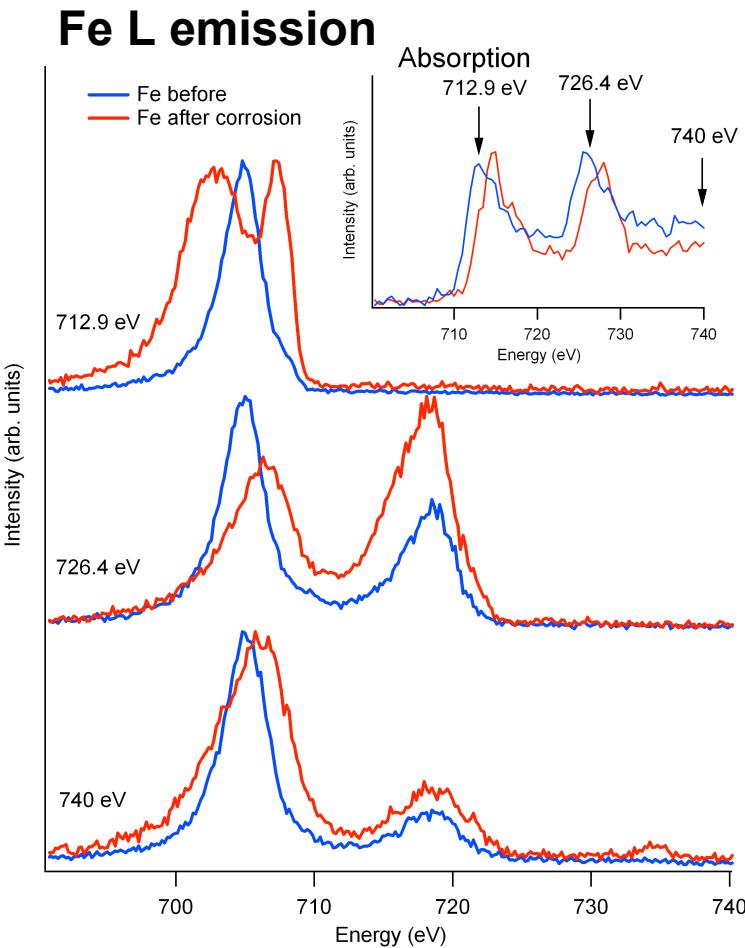
QCM



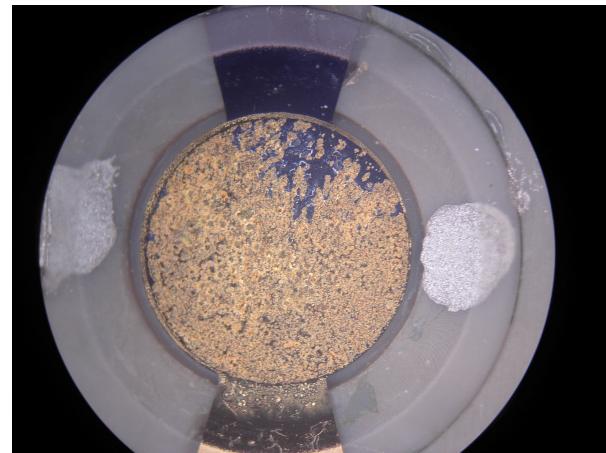
# Sample cell for study of atmospheric corrosion



# *In situ* study of atmospheric corrosion of iron



Corroded Fe film on QCM

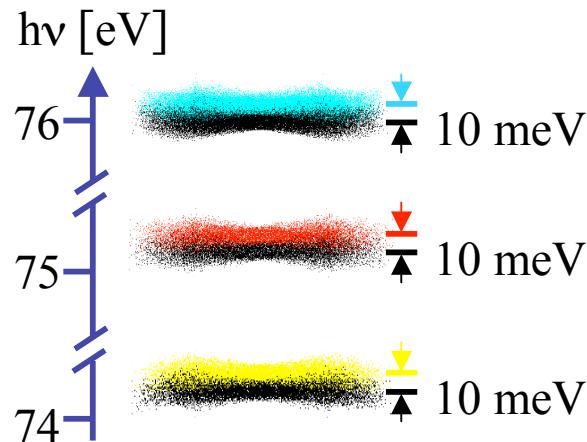


See L. Duda in Friday-Saturday workshop "Soft-X-Ray Photon-In and Photon-Out Spectroscopy: New Frontiers"

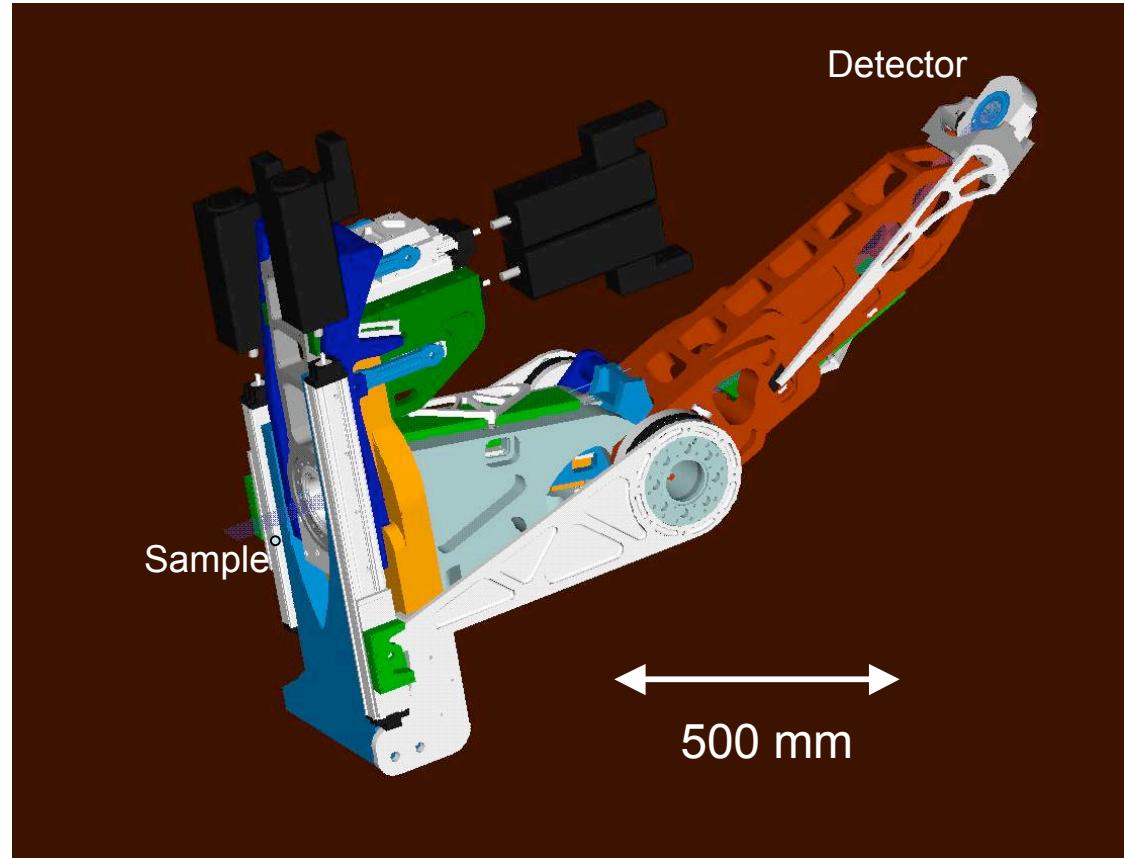


# Parabolic Mirror Plane Grating Spectrometer

Ray tracing of detector image  
3 lines at ~ 75 eV. Source size  
5 micron, neg. order, angle of  
acceptance 5000 mrad<sup>2</sup>

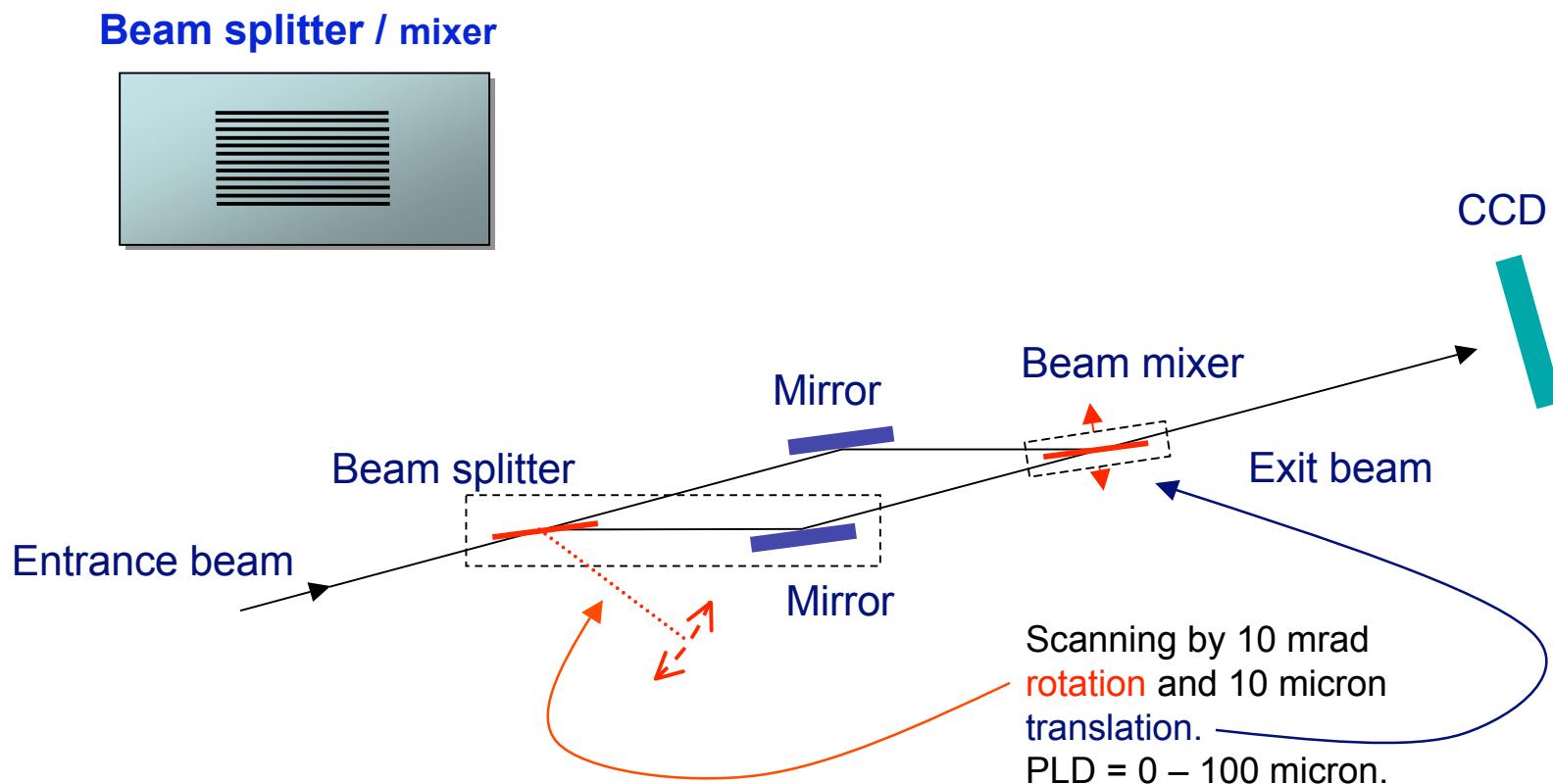


Very high resolution mode  
positive order, 1000 mrad<sup>2</sup>



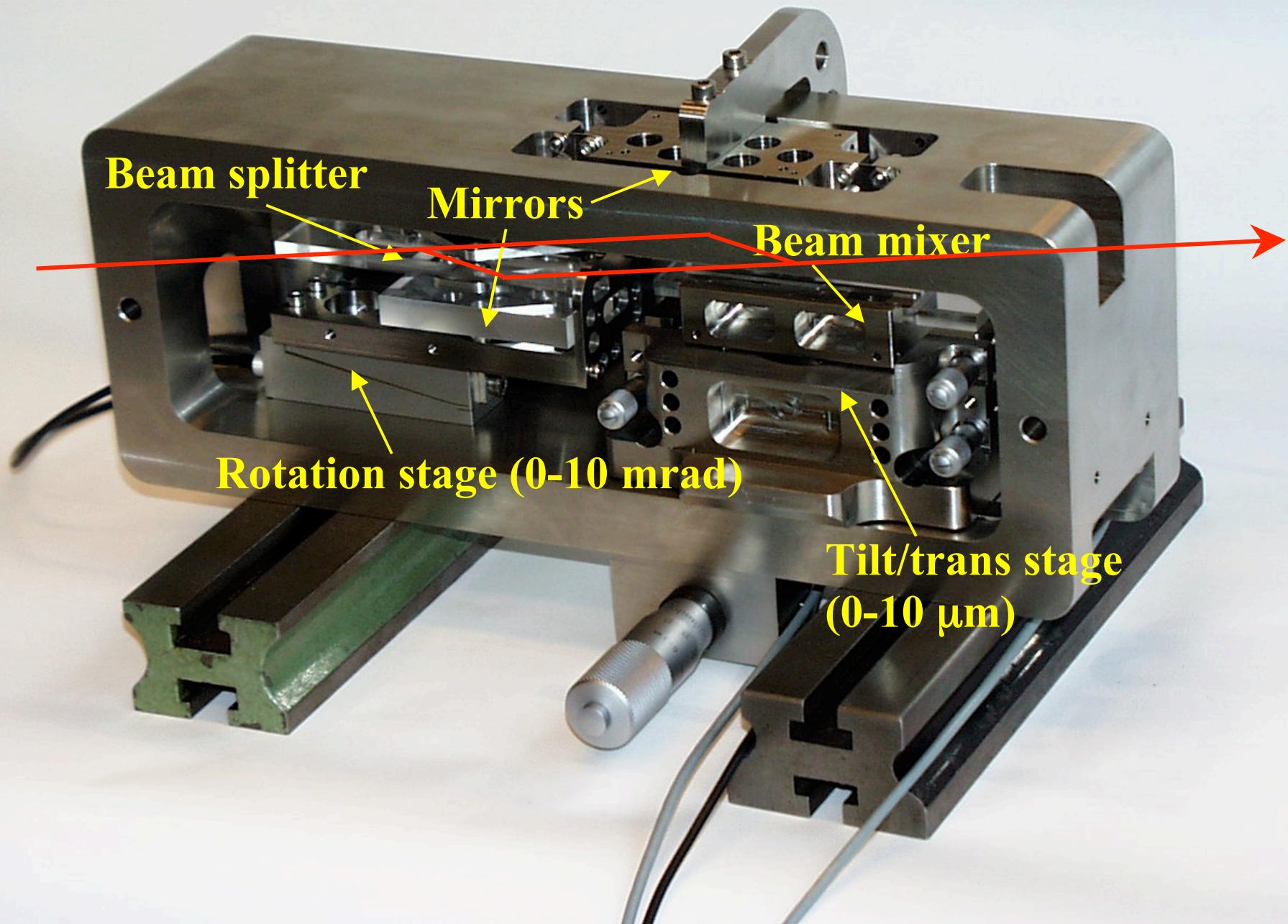
- Soft X-rays from sample collimated by parabolic mirror.
- Parallel radiation illuminates 30 cm plane grating.
- Highest efficiency or resolution by independent choice of incidence and diffraction angles.

# Operation of VUV interferometer



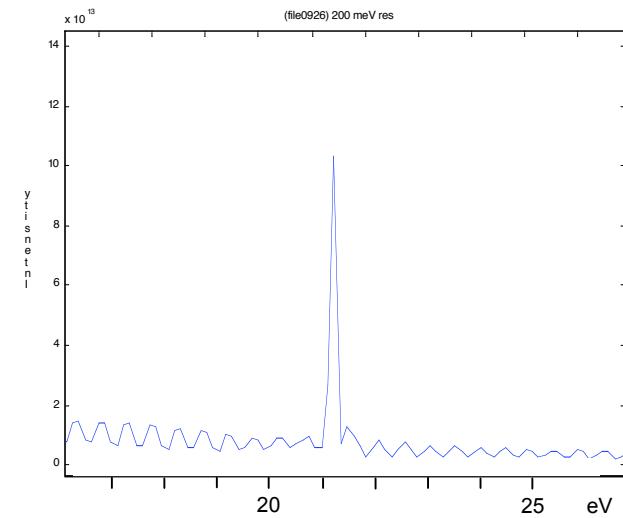
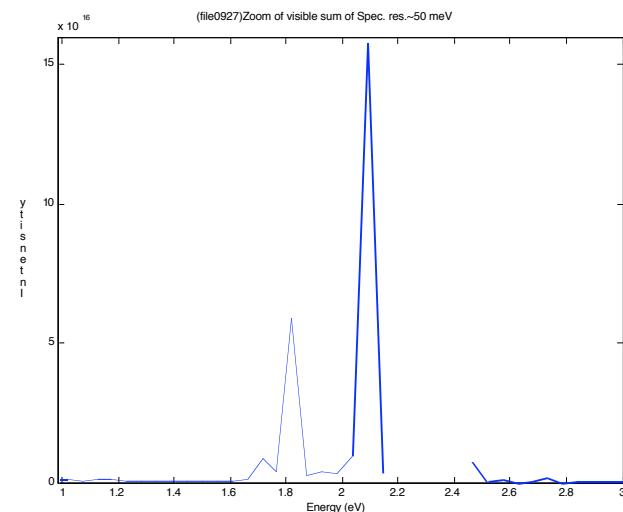
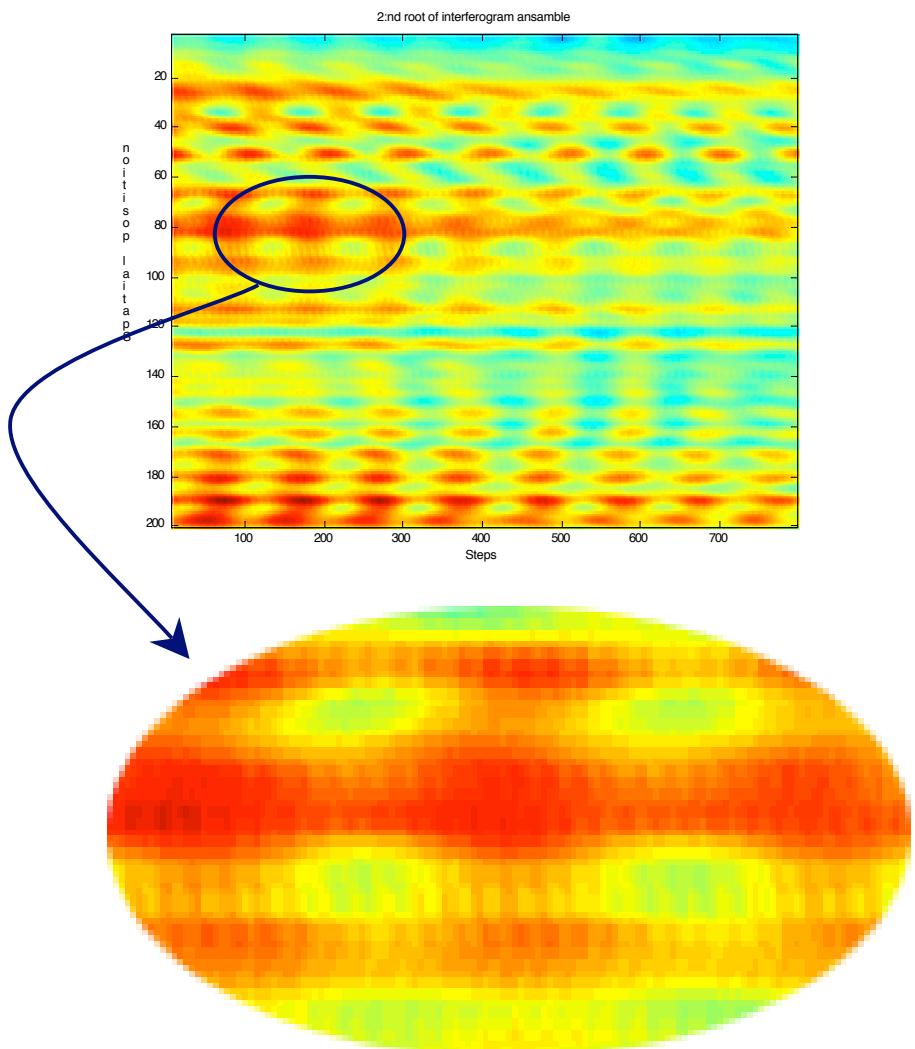


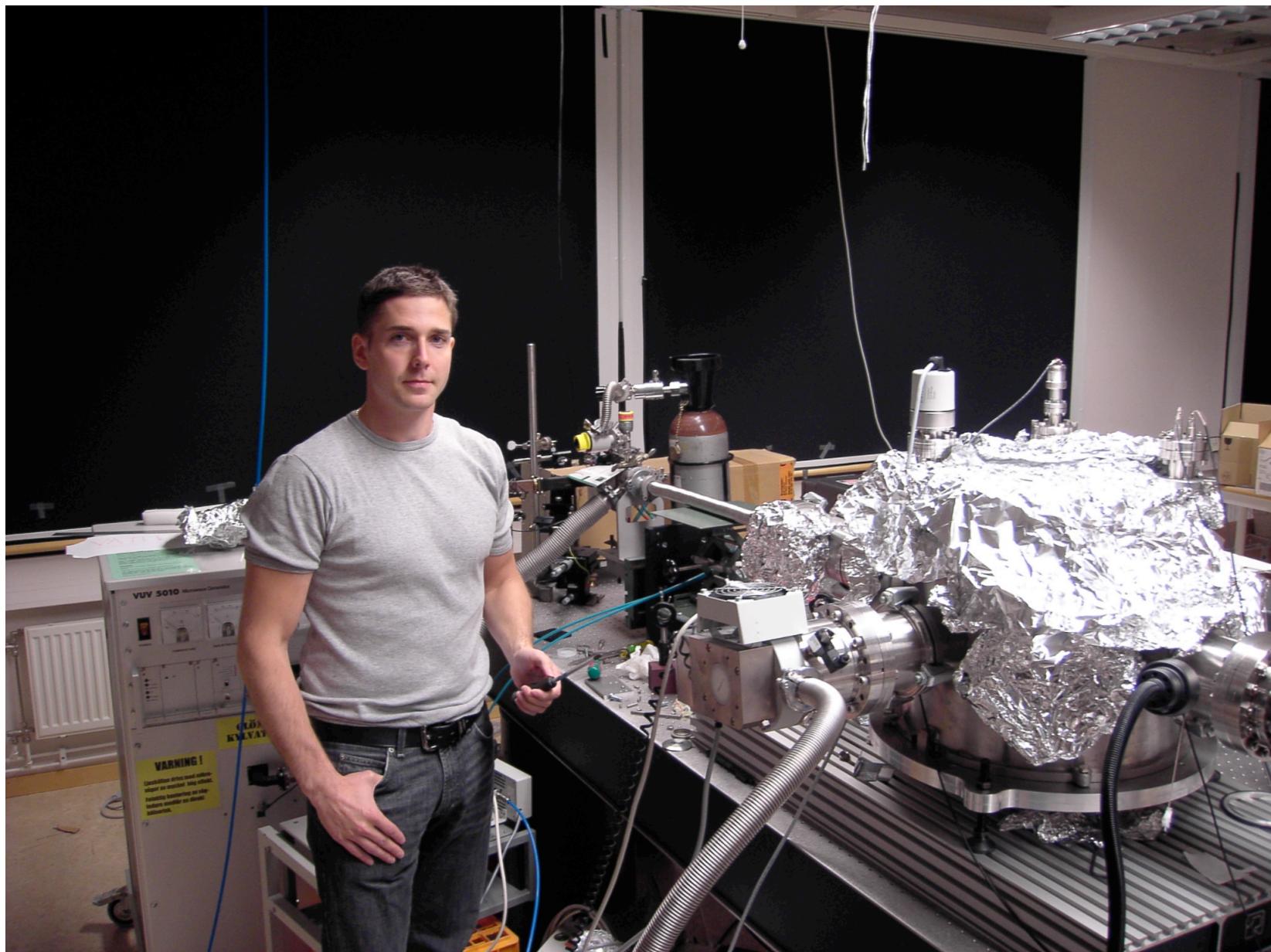
# Soft X-ray interferometer



# VUV FTS Spectroscopy

## First results...





# Acknowledgement

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