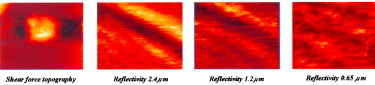


Diapositiva
1

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Near-field Infrared Microscopy: Overview and Perspectives

12 μm by 10 μm images of *PcSi/Si* obtained with free electron laser radiation in near-field condition
Appl. Phys. Lett. 73,151 (1998)



Shear force topography Reflectivity 2.4 μm Reflectivity 1.2 μm Reflectivity 0.65 μm

Antonio Ciferri
ISM-CNR, Roma-ITALY
Vanderbilt University,
Nashville, USA

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2

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Summary:

- First steps: the FEL and the FELIPE technique
- Near-field microscopy (SNOM) in a nutshell
- Practical examples of results:
 - Microscopy tests
 - Spectroscopic SNOM: Diamond films
 - Boron nitride
 - LIF
 - Pancreatic cells
 - Fluorescent markers in cells
- The future: new sources – 4GLS etc.

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3

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OPTICAL MICROSCOPY


The observation is made possible by the reflected or transmitted light through different optical systems (objectives and lenses). The resolution limit for the Distance of two nearest points is $\lambda/2$.

DIFFRACTION LIMIT

to increase resolution

SCANNING ELECTRON MICROSCOPY (the resolution λ)

SCANNING NEAR FIELD OPTICAL MICROSCOPY (SNOM)



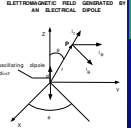
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FAR FIELD AND NEAR FIELD

ELECTROMAGNETIC FIELD GENERATED BY AN ELECTRICAL DIPOLE



The electromagnetic field generated by an electrical dipole contains terms
Proportional to $1/r$, $1/r^2$, $1/r^3$

For $r \gg \lambda$ (**far field**) only the term $1/r$ survives and the Poynting vector S and its flux have a well definite value and the traveling wave can be detected far from the dipole

For $r \ll \lambda$ (**near field**) The terms $1/r^2$ and $1/r^3$ do not contribute to S , they represent the near field whose intensity decay exponentially to zero

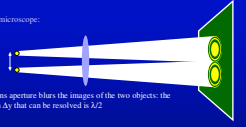
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5

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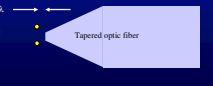
The diffraction limit and how we can beat it

Far-field microscope:



Diffraction by the lens aperture blurs the images of the two objects: the minimum separation Δy that can be resolved is $\lambda/2$.

Near-field scanning microscope: diffraction does not play a role




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6

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IR SNOM -- the strong points

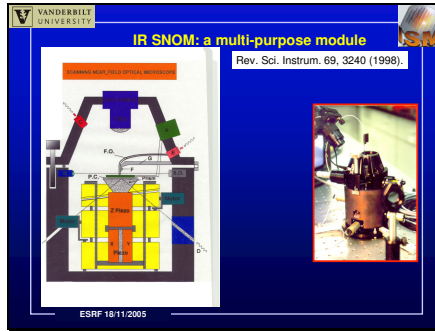
- It beats the diffraction limit thus reaching high lateral resolution
- It can work in any environment and (almost) without any particular sample preparation
- It provides real optical signal
- It can perform spectroscopic measurements
- It does not touch the sample: totally non-destructive technique



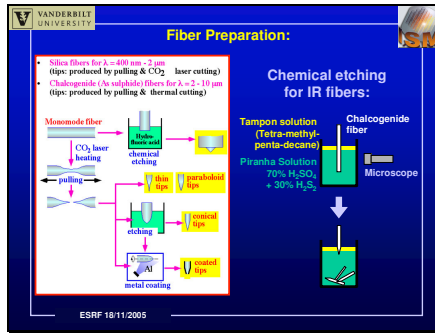
[Image from the Jasco Co. UK Homepage]

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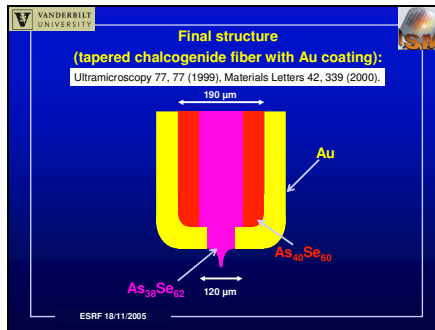
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7



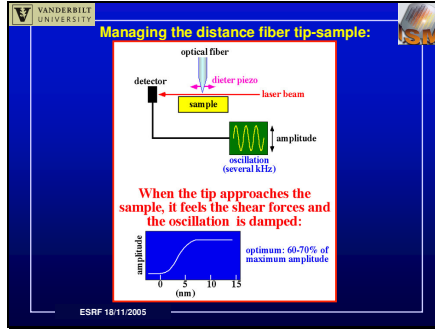
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8



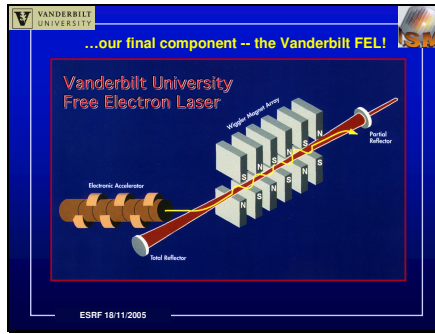
Diapositiva
9



Diapositiva
10



Diapositiva
11



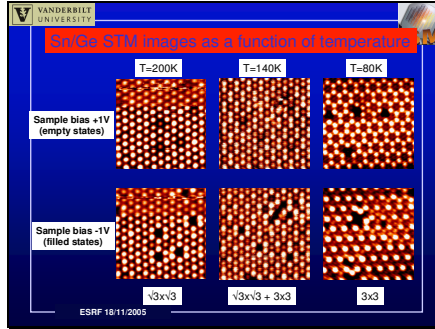
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12

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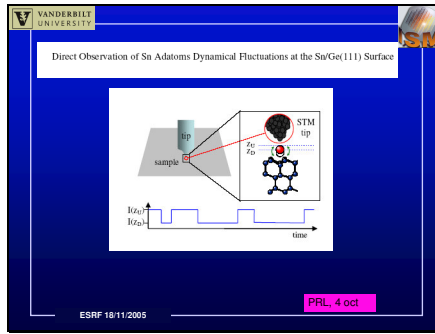
Logged Energy vs. Wavelength

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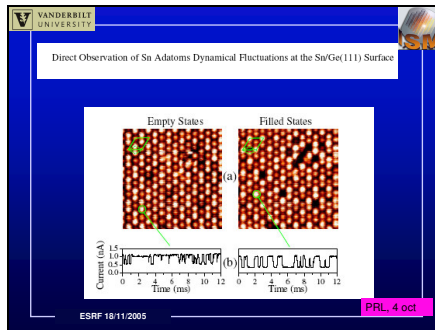
Diapositiva 13



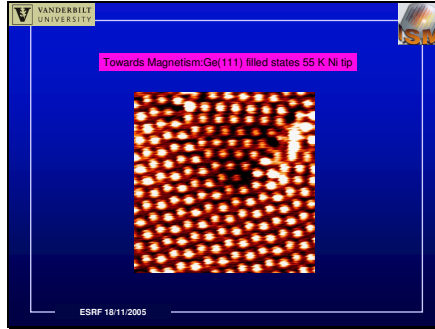
Diapositiva 14



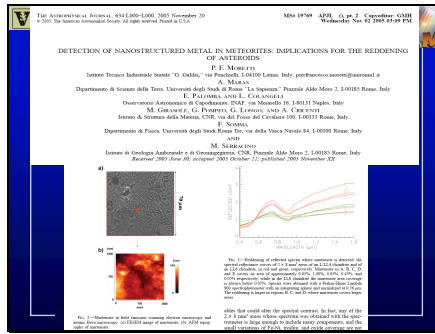
Diapositiva 15



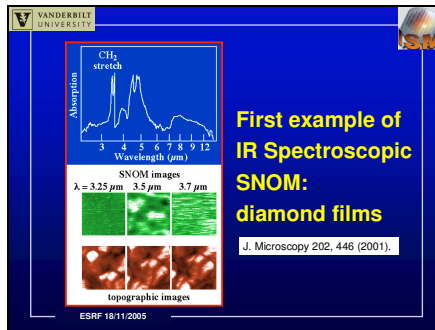
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16



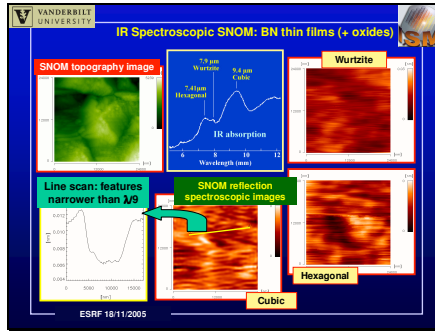
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17



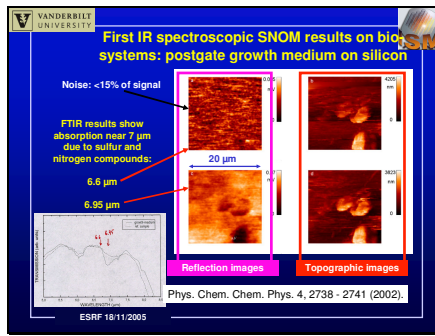
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18



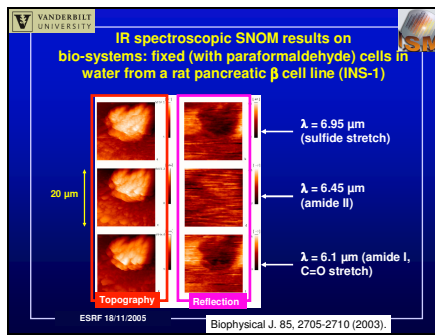
Diapositiva 19



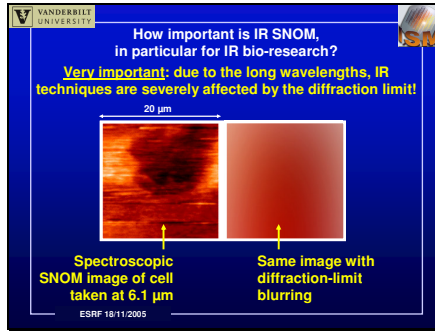
Diapositiva 20



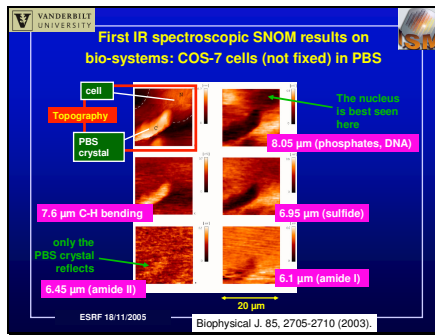
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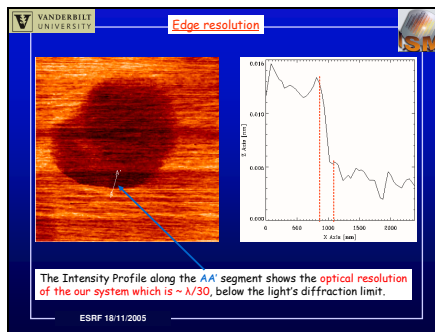
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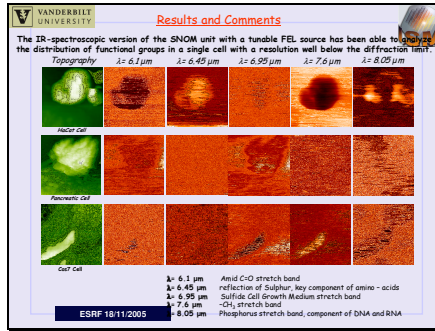
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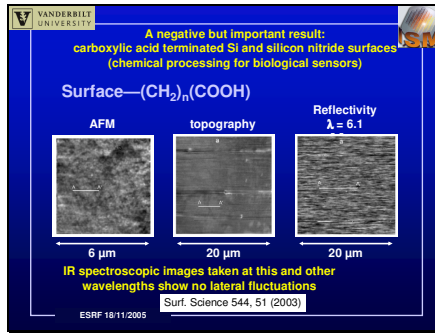
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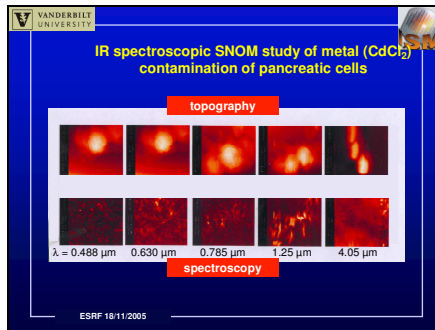
Diapositiva
25



Diapositiva
26



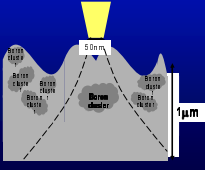
Diapositiva
27



Diapositiva
28

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A tapered optical fiber probe is placed within a fraction of a wavelength in close proximity to a sample and scanned over the surface.
It provides a tiny aperture through which the light is coupled.
The spatial resolution is given approximately by the tip diameter.









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29

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IR Spectroscopic SNOM:
Boron-doped (ion-implanted, annealed)

topography	reflectivity	photocurrent
		
		

10 μm
Wavelength: 1.03 μm

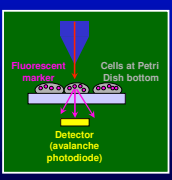
J. Appl. Phys. 91, 3937 (2002)

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30

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Spectroscopic SNOM results on bio-systems:
preliminary tests on internal cell structures
labeled by a fluorescent marker



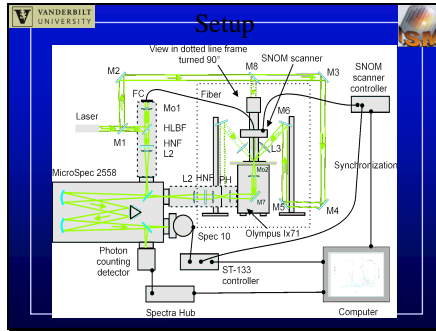
Fluorescent marker

Cells at Petri Dish bottom

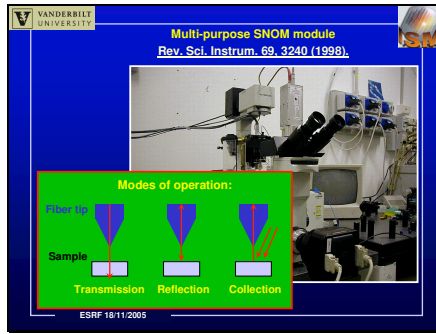
Detector (avalanche photodiode)

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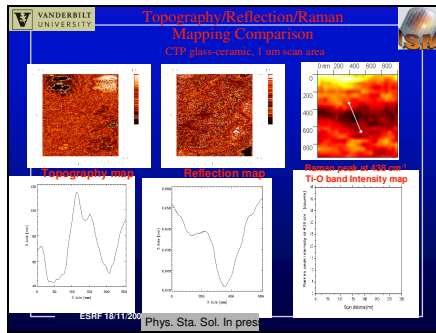
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31



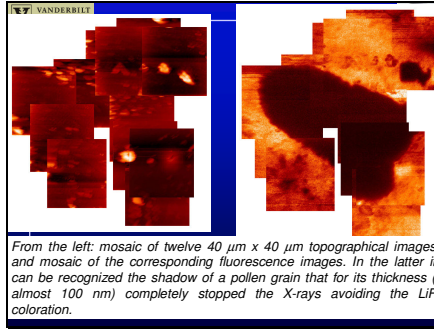
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32



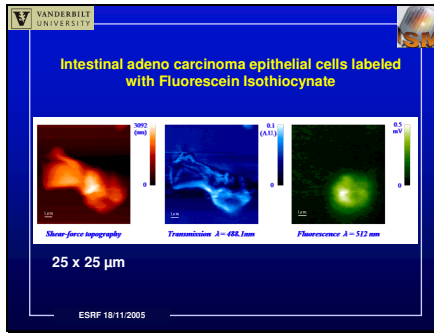
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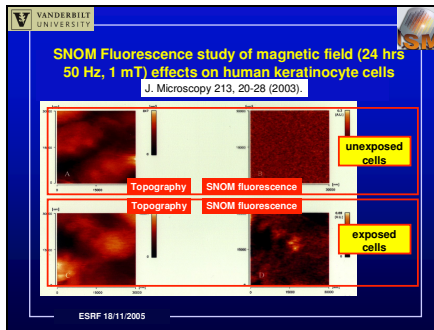
Diapositiva
34



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35



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36



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37

New types of synchrotron sources:

- Ultrabright storage rings (SLS, new Grenoble project) approaching the diffraction limit
- Self-amplified spontaneous emission (SASE) X-ray free electron lasers
- VUV FEL's (such as CLIO)
- Energy-recovery machines
- Inverse-Compton-scattering table-top sources

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38

THE "4 GLS" CONCEPT AT DARESBURY

The diagram illustrates a ring configuration of four Free Electron Lasers (FELs) and an energy recovery machine (ERM). The components include a Photoinjector, High Average Current Injector, SASE FEL, VUV-FEL, XUV-FEL, and ERM. The diagram also shows bending magnets and undulators for radiation production.

The 4GLS concept involves the use of an energy recovery ring (ERM) in a ring configuration. This is extremely flexible and will allow the easy incorporation of, for example, a single VUV-FEL that would allow the generation of coherent pulses of electron laser radiation up to several hundreds of eV in energy.

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39

Conclusions

1. SNOM experiments with an FEL are possible and yield resolution levels well beyond the diffraction limit
2. Vibrational spectroscopy SNOM provides chemical information on a microscopic scale
3. Results on biological systems finally open up the possibility to perform infrared microscopy of cells and internal cell structures
4. IR Spectroscopic SNOM tests were successfully performed in different SNOM modes
5. The experimental performances did not yet reach saturation and substantial improvements can be foreseen
6. In the near future, even better IR sources will further boost the capabilities of IR SNOM

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Diapositiva
40



Nashville country music: 

Swiss cheese & Frascati wine: 

Thanks to all the partners of this work:

- Frascati - ISM-CNR: A. Oricenti, G. Longo, A. Usilone, V. Mussi, M. Girasole, R. Generosi, M. Luce, M. Rinaldi, P. Perfetti
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- EPFL: D. Vobornik, G. Margaritondo, S. Caticas, P. Steiner, H. Hirling
- Vanderbilt: D.W. Piston, M.A. Rizzo, J.K. Miller, B. Ivanov, R. Haglund, N.H. Tolk
- US - NRL: D. Talley, P. Thielon, J. S. Sanghera, I. D. Aggarwal
- Frascati - ENEA: G. Baldacchini, F. Bonfigli, F. Flora, T. Marolo, R. M. Montereali
- MISDC -VNIIFTRI Mendeleev, Moscow: A. Faenov, T. Pikuz
- University of Roma: A. Congiu Castellano

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