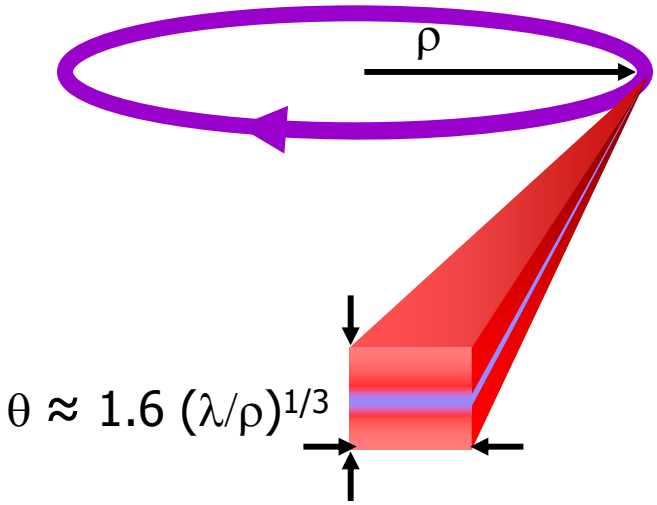
Infrared Microspectroscopy & Imaging

Lisa M. Miller, NSLS-BNL

Typical Infrared Beamline & Programs Today

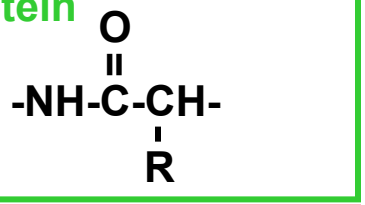


Beamlines

- Bending magnet beamline, wide opening angle for wide spectral range
- Commercially-available FTIR spectrometer and microscope (and software)
  - Single-element detector, mid-infrared (4000-650 cm-1)
  - Beam size (i.e. spatial resolution) is diffraction-limited (2-10 microns in mid-infrared)
- In US today: 6 beamlines @ NSLS; 2 beamlines @ ALS, 2 beamlines @ SRC, 1 beamline @ CAMD; worldwide there are ~30 IR beamlines; all new SR sources are including IR

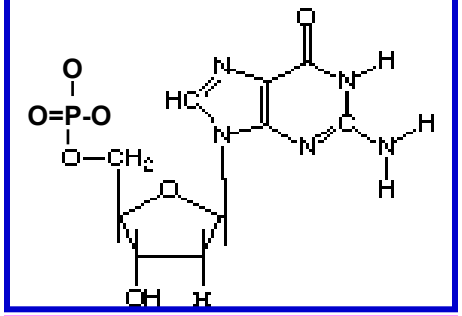
FTIR Spectroscopy of Biological Components

Protein

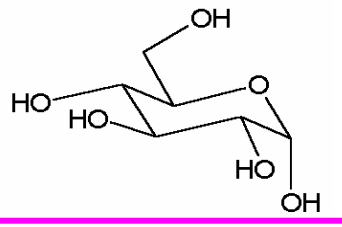


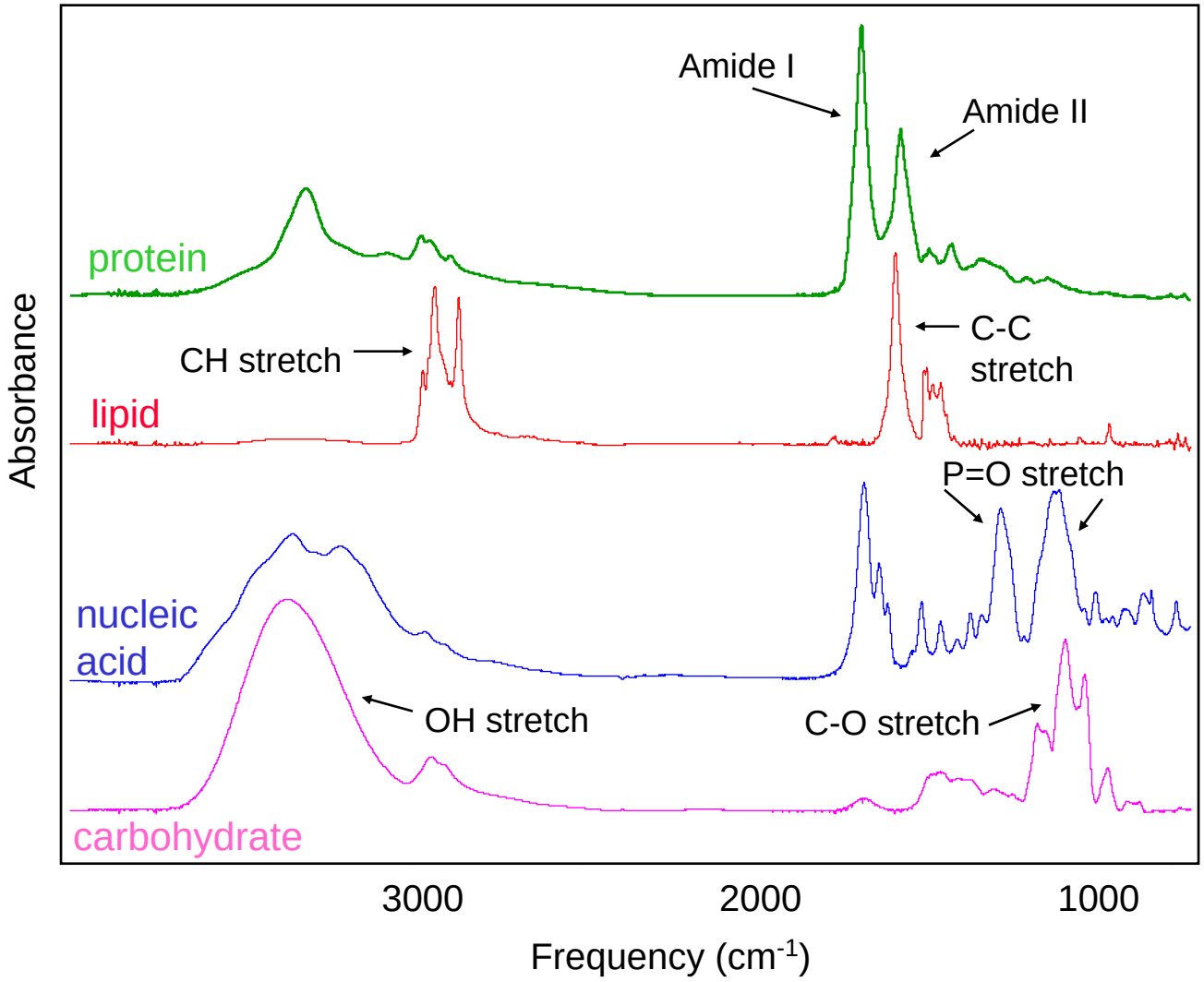
Lipid

Nucleic Acid



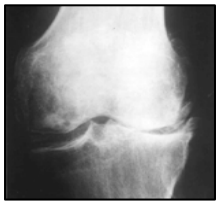
Carbohydrate



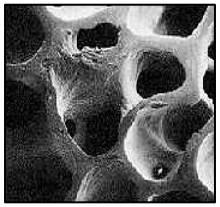


Synchrotron FTIR Programs Today

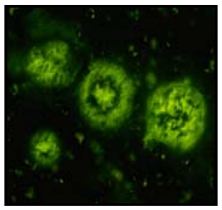
Common Theme: Chemical imaging of biological tissues and cells



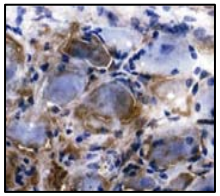
Osteoarthritis:
- Cathy Carlson (Univ. of Minnesota)
- David Hamerman (AECOM)



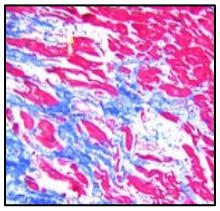
Osteoporosis:
- David Burr (Indiana University)
- Stefan Judex (Stony Brook University)
- Roger Phipps (Proctor & Gamble)



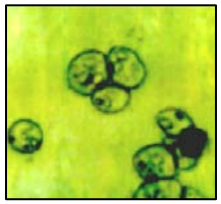
Alzheimer's Disease
- Judit Miklossy (UBC)
- Jane Flinn (George Mason Univ)
- Kathy Gough (Univ Manitoba)



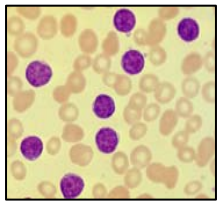
Prion Diseases:
- Dieter Naumann (Robert Koch Inst)
- Michael Beekes (Robert Koch Inst)



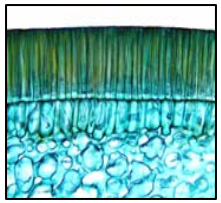
Heart Disease:
- Wasiem Sanad (Charite Hospital, Berlin)
- Kathy Gough (Univ Manitoba)



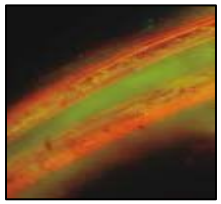
Apoptosis:
- Jean-Luc Teillaud (Inst Curie)
- Paul Dumas (LURE)
- Nadege Jamin (LURE)



Chronic Lymphocytic Leukemia:
- Nicholas Chiorazzi (North Shore-LIJ, NY)



Agricultural Science:
- Peiqiang Yu (Univ. Saskatchewan)
- David Wetzel (Kansas State Univ.)



Bioremediation:
- U. Ghosh (Stanford Univ.)
- M. Fuhrmann (BNL Environ. Sci.)

Cosmetics:
- Paul Dumas (SOLEIL)
- Stefania Nuzzo (L'oreal)

Limitations Today & NSLS-II Improvements

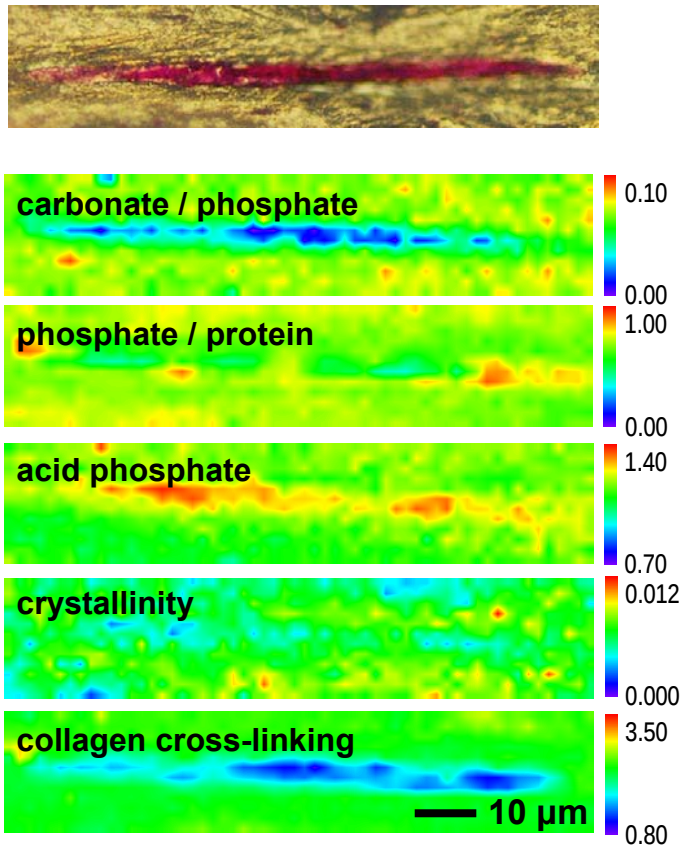
- Spatial resolution is diffraction-limited to 2-10 microns in the mid-IR (4000-650 cm-1)
  - ➢ Brightness of NSLS-II will enable illumination of large array detectors for oversampling and image deconvolution
- Data collection is slow because sample is raster-scanned through beam and data collected 1 pixel at a time
  - ➢ Brightness of NSLS-II will enable illumination of large array detectors for oversampling and image deconvolution
- Beams are a bit noisy, so signal/noise is limited to 0.1%
  - ➢ Stability of NSLS-II will improve the S/N by a factor of 10-100, enabling higher detection sensitivity
- Data are collected at room temperature, static samples
  - ➢ High brightness, high S/N will enable fast data collection and detection of small molecular changes in living cell systems

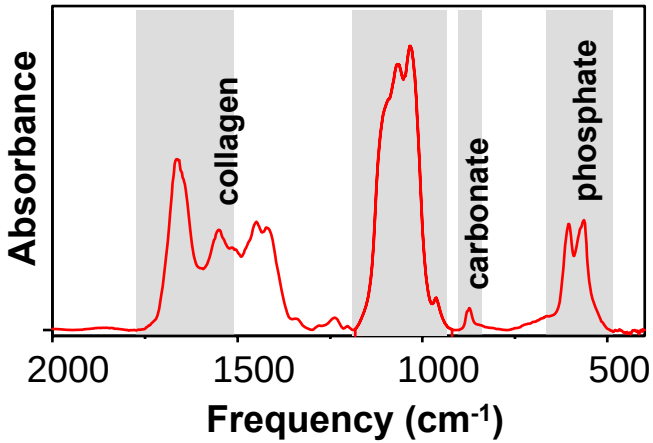
What can be done with a new source such as NSLS-II

- Higher spatial resolution
- Faster data collection
- Higher detection sensitivity

NOW

D. Burr (Indiana Univ), R. Phipps (P&G), M. Ruppel, L.M. Miller (NSLS)





- Microdamaged bone
- 10 micron beam size
- Single pixel detector
- 40 min to collect (40 pixels)

- Bisphosphonates are current treatment for osteoporosis.
- Microdamage increases in bisphosphonate-treated bone.
- Bone composition is different in microcrack region.
- With too much accumulation of microdamage, the quality of bone may be reduced.

M. Ruppel, et al. *Bone*, 39(2): 318 (2006).

What can be done with a new source such as NSLS-II

- Higher spatial resolution
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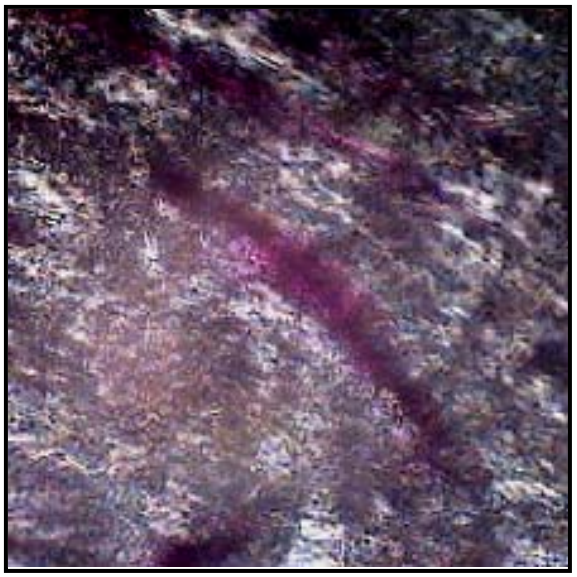
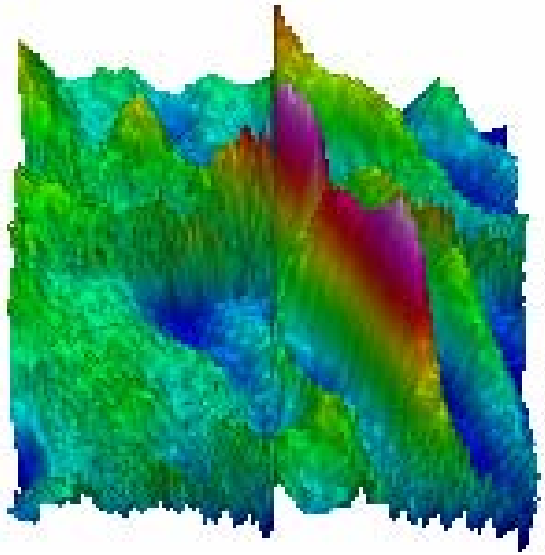
FUTURE





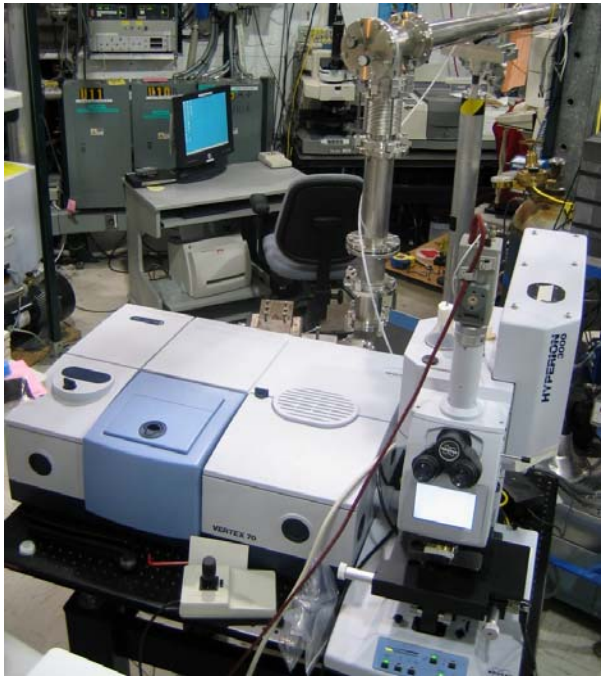
- Microdamaged bone
- 2x2 FPA image (128x128 pixels)
  - 0.5 pixel resolution
  - 32 min to collect (16,384 pixels); 11 days with single-point detector

- **Faster data collection**: more anatomical regions
- **Spatial resolution**: drug-binding to initial mineral crystal nodules
- **Sensitivity**: image drug binding and distribution in new bone growth

My next infrared beamline

Beamline

- Bending magnet beamline with large opening angle
- FTIR spectrometer and IR microscope with focal plane array detector (e.g. 128 x 128 pixels); adapted microscope for conventional microscopy: polarization, epifluorescence, confocal
- Climate-controlled hutch
- Cell culture incubator adapted to FTIR microscope stage



Bruker Hyperion 3000 (NIH-SIG)

Laboratories and ancillary facilities

Labs

- Cell culture facilities
- tissue prep (cryo, RT, ultra microtomes)
- Offline microscopes (light, epifluorescence, confocal)

IT

- FTIR array images will generate 1 GB data/min: data storage, backup
- remote access: firewall, cyber security issues

Other

- Methods for imaging samples with other techniques, e.g. micro/nano-XRF, micro/nano-diffraction