Nuclear Spectroscopy & Imaging

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Nuclear Experiments

- Nuclear Forward Scattering – NFS
- SR Perturbed Angular Correlation
- Nuclear Resonance Vibrational Spectroscopy
Nuclear Experiments

• The trick

Source

70 psec

153 nsec

\( h_\nu \)

Signal

off

on

~20 ns

~133 ns

3680 nsec
Nuclear Lifetimes & Energies

- What works
Nuclear Forward Scattering

- ferrocene

![Graph showing time (ns) vs. counts, with inset showing thickness (um)]
Synchrotron Radiation Perturbed Angular Correlation (SRPAC)
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The NRVS Experiment

- **APD #2**
- **Sample**
- **High Resolution monochromator**
- **Storage Ring**
- **High-heat-load monochromator**
- **Undulator**

<table>
<thead>
<tr>
<th>Energy Levels</th>
<th>1 meV</th>
<th>1 eV</th>
<th>100 eV</th>
</tr>
</thead>
</table>

- **Time Delay**
  - 70 psec
  - 153 nsec
  - hν
  - Signal

- **Detection**
  - Source
  - Detector: off
  - on
  - \(\sim 20 \text{ ns} \sim 133 \text{ ns} \)

- **Time Interval**
  - 3680 nsec

**Graphs**

- \(\Omega\)
- \(\Omega - \omega\)
- \(\Omega + \omega\)
FeNₓHᵧ Models

- HFe-N₂
- DFe-N₂
- Fe-¹⁴N₂H₂
- Fe-¹⁵N₂H₂
- Fe-¹⁴N₂H₄
- Fe-¹⁵N₂H₄

Energy (cm⁻¹)
Fe Protein NRVS

- Any redox level
- Low frequency modes
- Quantitative simulation

![Diagram of Fe Protein NRVS](image1.png)

![Graph showing density of states vs. energy](image2.png)
Nuclear Needs

- Nuclear Forward Scattering – NFS
- SR Perturbed Angular Correlation
- Nuclear Resonance Vibrational Spectroscopy
X-Ray Microtomography

Image of yeast cell

Carolyn Larabell - NIH funded facility at ALS
Diffraction-Enhanced Imaging

Radiograph | DEI - Top | DEI - Refraction | DEI - Absorption

http://www.iit.edu/~chapman/AAPM/sld027.htm
‘Nuclear contrast’

- Mössbauer cross sections are 500 x photoelectric c. s.
  - but linewidths are $10^8$ smaller

Why do it?

- less radiation damage
- zero background
Nuclear Imaging

- Fe
- Kr / Xe
- Lanthanide nanoparticle tags
Nuclear Imaging Needs

- Orders of magnitude more flux
- Higher energies (30-70 keV)
- Nano eV (nuclear) monochromators
- Suitable bunch schemes
- Better (picosecond) detectors
Nuclear Future?

• I dream of things that never were ... and say why not? (RFK)

• To accomplish great things, we must not only act, but also dream; not only plan, but also believe. (Anatole France)