Multi-element Analyzer for Inelastic X-ray Scattering

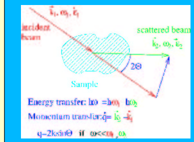
W.A. Caliebe[1], Q.J. Qiang[2], T.A. Tyson[2], B. Blank[3], A. Deyhim[3], C.-C. Kao[1]

[1]National Synchrotron Light Source, BNL, Upton NY 11973

[2]Department of Physics, NJIT, Newark, NJ

[3]Advanced Design Consulting, Lansing, NY

Inelastic X-ray scattering



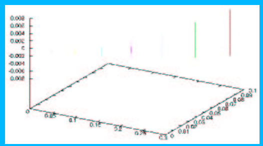
Non-resonant scattering:

$$\frac{d^2\sigma}{d\Omega\, d\omega_2} = r_o^2 \frac{\omega_2}{\omega_1}(\epsilon_1 \cdot \epsilon_2)^2 \sum_{I,F} \left| F|\sum_j \exp(i q \cdot r_j)|I \right|^2 \times \delta(E_F - E_I - h\omega)$$

Resonant Scattering:

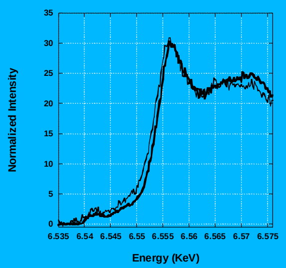
$$\frac{d^2\sigma}{d\Omega\, d\omega_2} = \left(\frac{r_o}{m}\right)^2 \left(\frac{\omega_2}{\omega_1}\right) \sum_{I,F} \left| \sum_N \left\{ \frac{F|\epsilon_2 \cdot \sum_j p_j \exp(-i k_1 \cdot r_j)|N\rangle \; N|\epsilon_1 \cdot \sum_j p_j \exp(i k_2 \cdot r_j)|I\rangle}{E_N - E_I - h\omega_1 - i\Gamma_N/2} \right\} \right| \delta(E_F - E_I - h\omega)$$

Spherical Aberration



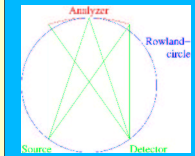
Backscattering: point-to-point focusing
smaller Bragg-angles point-to-line focusing
size depends on analyzer size perpendicular to scattering plane and on Bragg angle (see figure)

Spin-polarized XANES

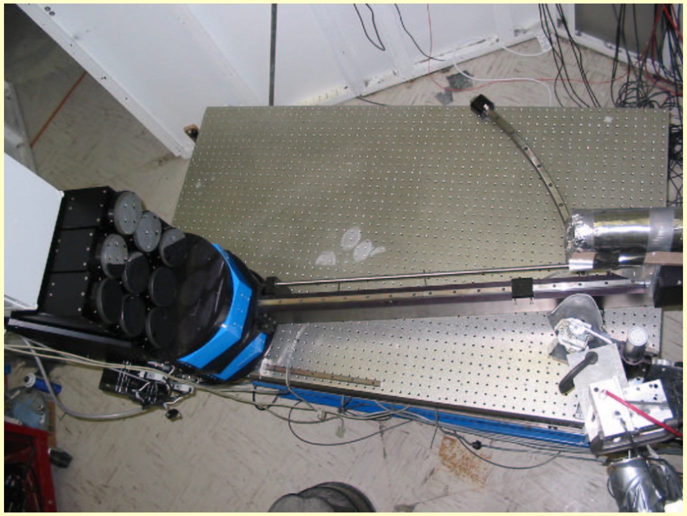


Spin-resolved XANES spectra of $Pr_{0.3}Ca_{0.7}MnO_3$ for the spin-down (thick line) and spin-up (thin line) channels. The splitting of the main edge is due to the spin asymmetry of the different Mn sites. Spectra were measured with only six analyzers.

Rowland-circle Spectrometer



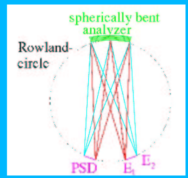
Mount source, analyzer and detector on circle with diameter r, radius of analyzer r: All rays emitted from source hit analyzer under the same angle, if the angle is close to backscattering, and if the size is not too large compared to the size.
Variations: Use cylindrically bend analyzer, with the axis parallel or perpendicular to the scattering plane, dispersion allows to measure larger energy range.



Applications of Inelastic Scattering

- High-resolution spectroscopy (meV and less)
- Phonon excitations at low momentum transfer (not accessible by inelastic neutron scattering)
- Medium-resolution spectroscopy (sub-eV)
- Electronic excitation
- valence band excitations (non-resonant)
- Non-resonant Raman scattering (absorption spectroscopy of soft x-ray edges with hard x-rays)
- Resonant Raman scattering ('improve' the energy resolution in the nead-edge region), spin-resolved spectroscopy

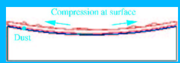
Energy Resolution



- Intrinsic resolution
- Johann geometry
- Bragg angle
- Source size
- Size of analyzer
- Deviation of Rowland geometry
- Bending radius of analyzer or size of individual rectangles

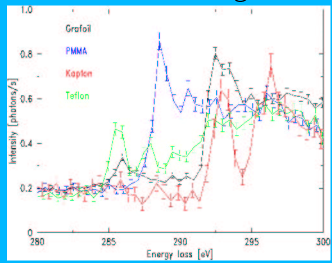
How to make spherically-bent Analyzers

1. Apply thin layer of epoxy on mirror
2. Carefully lay wafer on mirror
3. Lay greased mirror-paper on wafer
4. Place die on paper
5. Apply pressure and bent the crystal
6. Wait a long time (twice the curing time)
7. Release pressure and check mirror



Typical Problems
- Too much epoxy
- Dust-particles (clean room!)
- Compression of surface cause ripples

Non-Resonant Raman Scattering at the C K-edge



The present data are collected with a single-element analyzer system. The power blackout in August 2003 did not allow us to collect data with the multi-element analyzer system before the conference. The counting time for one spectrum was of the order of 12h. More analyzers will improve the statistical noise or reduce the counting time.

Acknowledgment: Financial Support for this project by the NSF under Contract No. 0216858 is greatly appreciated. Research carried out at NSLS, Brookhaven National Laboratory, which is supported by the U.S. Department of Energy, Office of Basic Energy Sciences, under Contract No. DE-AC02-98CH10886.