Online Card

Multi-analyzer Reflectometry

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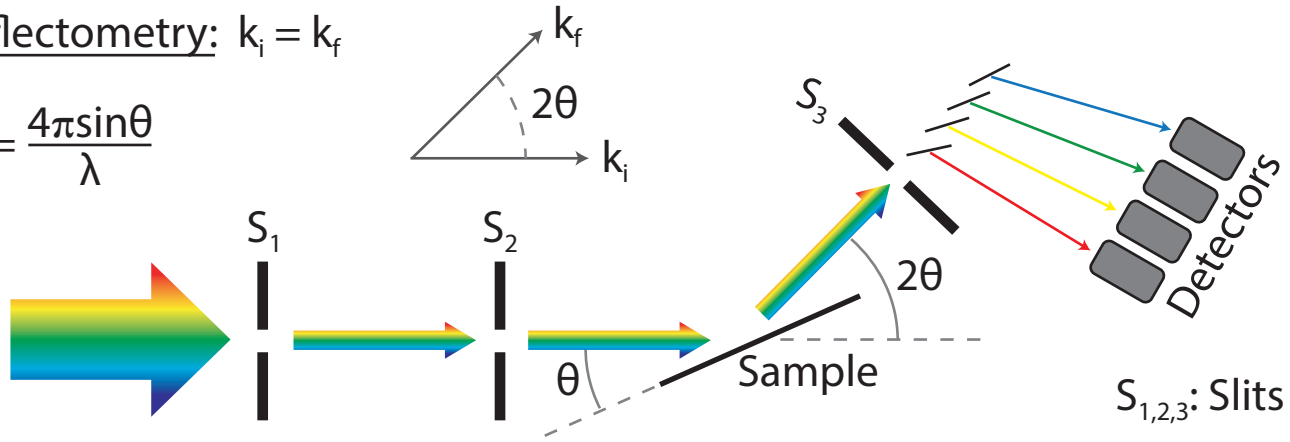
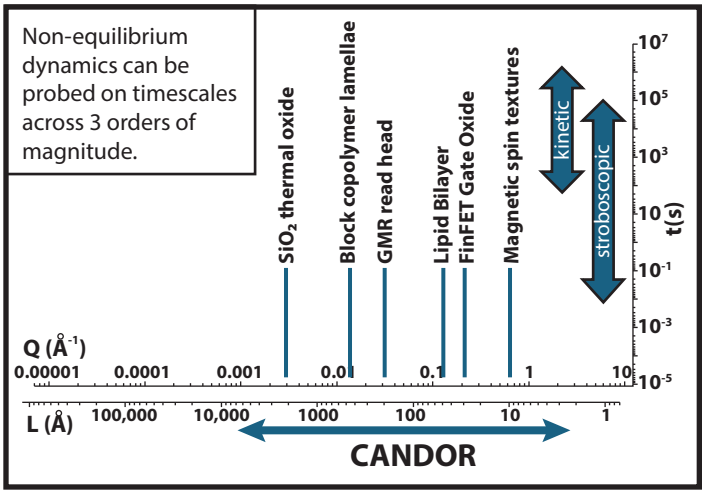
Reflectometry: $k_i = k_f$

$$Q = \frac{4\pi \sin\theta}{\lambda}$$



Non-equilibrium dynamics can be probed on timescales across 3 orders of magnitude.



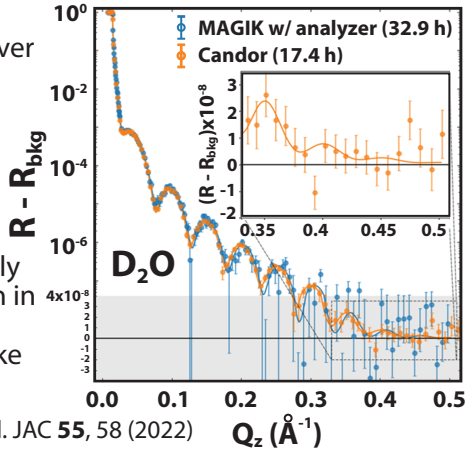
Operating Principles

1) Reflectometry is an elastic scattering technique, $k = k_i = k_f$:
   - **Reactor (continuous):** k traditionally determined by monochromating the incident beam.
   - **Time of flight (pulsed):** polychromatic beam with k determined by arrival time at the detector.
   - **CANDOR:** Combines the advantages of pulsed and continuous sources by using a crystal analyzer to determine k for a polychromatic beam (x20 gain over monocromatic NR).
2) Reflectivity curves (R) are collected by rocking the sample to different angles of incidence (θ) and collecting the reflected beam by rotating the detector arm by (2θ).
3) Curve fitting the data determines the depth profile of composition, density, and magnetic field with sub-Å precision.

Example: Ultra-low Background

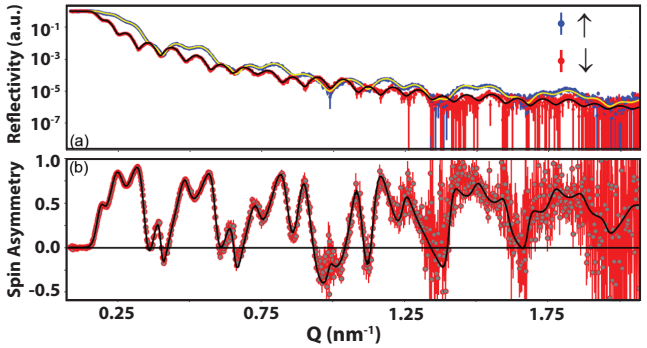
20x speed enhancement over conventional monochromatic reflectometers.

18 orders of magnitude in reflectivity readily achievable, even in difficult sample environments like liquid cells.



Hoogerheide, et. al. JAC **55**, 58 (2022)

Example: Polarized Beam



Polarized beam capability on CANDOR enables magnetic measurements with very high precision.

Difference between ↑ and ↓ neutron reflectivity clearly distinguishes out to 2 nm in a 12 hr measurement.

Instrument Webpage

CANDOR Neutron Reflectometer

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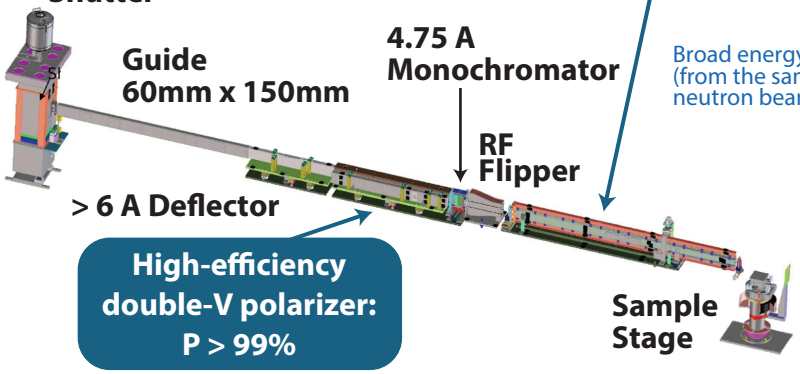
Instrument Webpage: https://www.nist.gov/ncnr/chrns-candor-white-beam-reflectometer

CANDOR is the worlds fastest neutron reflectometer, with an unprecedented number of neutrons on sample and world-leading signal/noise ratios due to the unique combination of a continuous white beam incident on the sample with wavelength analysis of the scattered beam using cold PG analyzer crystals. CANDOR is ideally suited for studying the time-resolved nuclear and magnetic structures of thin films important for fields such as advanced computing, quantum communications and encryption, storage technologies, and biological functions across membranes.

Beam Preparation

Be/Bi Filter
8" Be: eliminates < 4 A neutrons
8" Bi: eliminates gammas

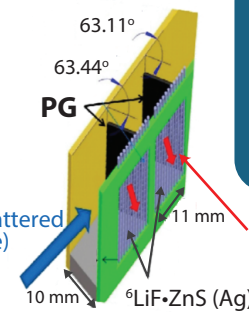
Converging guide increasing neutrons on sample using tunable beam divergence



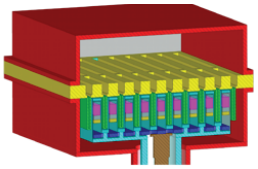
High-efficiency double-V polarizer: P > 99%

Chromatic Analysis

Scattered beam is diffracted into thin film ^{6}LiF•ZnS (Ag) neutron detectors invented specifically for CANDOR



Detector banks are cooled below 20 K to minimize background



Cryostats

System	Range
- Mini-cryostat	4 K - 320 K
- Furnace	200 °C - 600 °C
- Cryostat-compatible multi-sample holder	4 positions

Pressure and Humidity

System	Range
- RH and temp. control	up to 100% and 90 °C
- Gas Loading	H, D, CH_4, CO_2
- Pressure Cells	1 Gpa He, Ne, Ar

Magnets

System	Range
- Permanent magnet mount	20 mT
- Electromagnet	700 mT
- Superconducting magnet	3T
- Helmholtz coils	

Other

- Sample changing and liquid handling for solid/liquid interfaces.
- In-situ voltage application up to 5 kV

Operational Range

- **White Beam:** wavelengths from 4 Å - 6 Å
- **Monochromatic Beam:** 4-bounce monochromator fixed at 4.75 Å
- **Q range:** 0.05 nm^{-1} - 30 nm^{-1}

Beam Divergence

- Two variable incident slits, with background reduction slit for scattered beam.
- Converging guide with variable beam divergence.
- Two operational detector banks, with option for 18 more covering 2° of scattered beam each.

Polarization

- Before sample: Double-V supermirror polarizer and polarized guide path.
- After sample: ^{3}He polarization analysis
- RF flippers and guide fields