Polarized Neutron Scattering

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BornAgain School and User Meeting, 2018

Overview

Approximations

- Elastic scattering: time-independent Schrödinger equation
- Far field Green's function
- First order in perturbation potential
- Small angle scattering: locally constant perturbation potentials

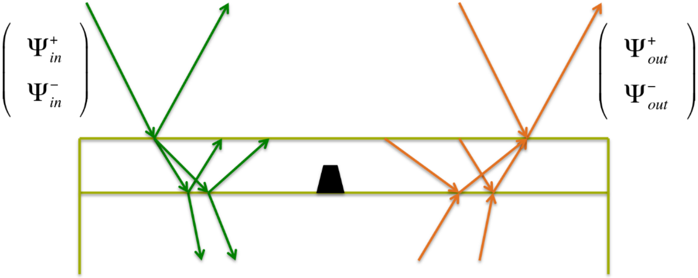
Theory

- First, we solve the perfectly smooth multilayer in the presence of magnetization in the layers.
- Then we use the Green's function method to obtain the first order contribution to the scattering amplitude.
- For magnetic dipoles, the scattering depends only on the magnetization perpendicular to the wavevector transfer:

$$\delta v_{\perp}(\mathbf{r}) \sim \sigma \cdot \mathbf{m}_{\perp}(\mathbf{r})$$

Homogeneous solution

- The magnetic fields will cause birefringence of the plane waves.
- The Green's function will again contain the homogeneous solution as a function of the source location **s**.



Birefringence of homogeneous solution

Required parameters for magnetic neutron scattering

- Magnetic materials for layers and/or particles
- Beam polarization
- Detector polarization analysis

Magnetic materials

- Magnetic materials are defined by their magnetization in A/m.
- The external guide field is a parameter of the multilayer and is also expressed in A/m.
- In both cases, one needs to input the three different components of the magnetization (along the three principal axes).

Beam polarization

- A spin 1/2 particle's state is fully determined by its density matrix, which is positive semidefinite, Hermitian, trace 1:

$$\hat{\rho} = \sum_j p_j \left|\psi_j\right\rangle\left\langle\psi_j\right|$$

- The density matrix can be defined by its Bloch vector $\mathbf{a}$:

$$\hat{\rho} = \frac{1}{2}\left(I + \sigma \cdot \mathbf{a}\right)$$

with $|\mathbf{a}| \leq 1$.

- The length $a = |\mathbf{a}|$ determines the probability for the spin to be in the direction $\mathbf{a}$ (and thus also of the opposite state):

$$p_+ = \frac{1}{2}\left(1 + a\right)$$

Polarization analysis

- Orientation of polarization analysis: unit vector $\hat{\mathbf{u}}$.
- Transmission ratios of up and down components: T_+ and T_-.
- Efficiency:

$$P_{eff} = \frac{T_+ - T_-}{T_+ + T_-}$$

- Total transmission:

$$T_{total} = \frac{T_+ + T_-}{2}$$

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