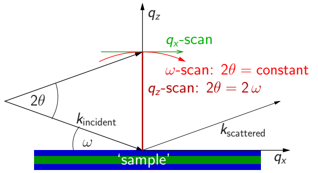
Jochen Stahn, Christof Niedermayer, Justin Hoppler, Thomas Gutberlet
Laboratorium für Neutronenstreuung, ETH Zürich & PSI
Jacques Chakhalian, Christian Bernhard MPI für Festkörperforschung, Stuttgart

Magnetic induction in perovskite HTSC / FM multilayers

Intro

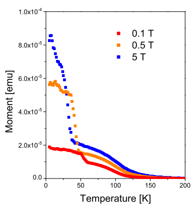
The magnetic field profile at the interface of the ferromagnet $La_{2/3}Ca_{1/3}MnO_2$ (LCMO) and the superconduct0r $YBa_2Cu_3O_7$ (YBCO) in superlattices has been studied by specular (q_z-scan) and off-specular (ω-scan) neutron reflectometry.



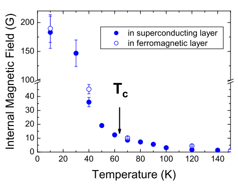
q_z is normal to the sample surface, in-plane structure is averaged over several μm.
q_x probes lateral inhomogeniouties (interface roughness and domains).

These investigations were motivated by Low-Energy μSR and bulk magnetization measurements which showed an unexpected magnetic behaviour below T_c:

magnetisation



Low-Energy μSR

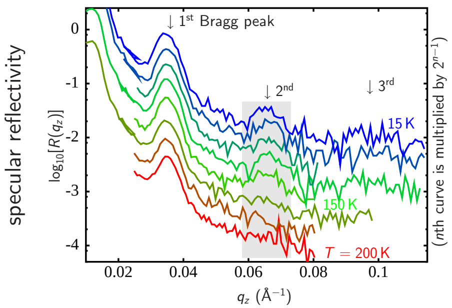


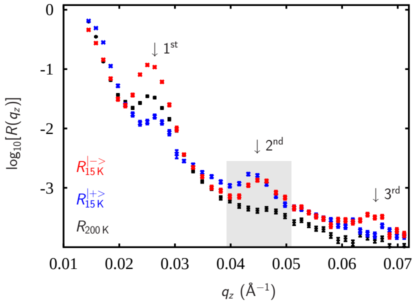
The depth-resolution of these methods (if any) is not sufficient to allocate the increased magnetic flux to certain regions.

Neutron Reflectometry

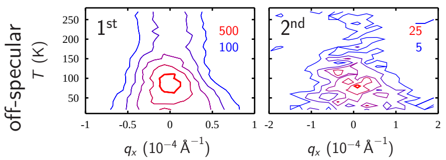
Unpolarised neutron-reflectometry		Specular reflectivity for polarised neutrons
Morpheus@SINQ	instrument	ADAM@ILL
$[YBCO(100\,Å)/LCMO(100\,Å)]_7$	sample	$[YBCO(150\,Å)/LCMO(140\,Å)]_6$

cooled and measured in $H = 100\,Oe$

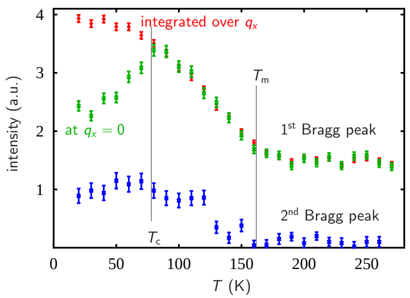




$I(q_z, T)$ map for the 1st and 2nd Bragg peaks



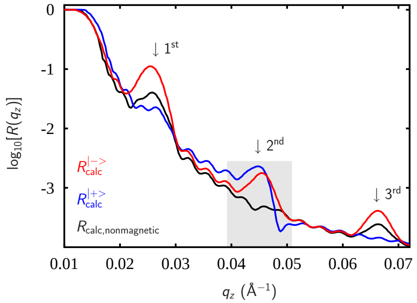
Bragg peak intensities



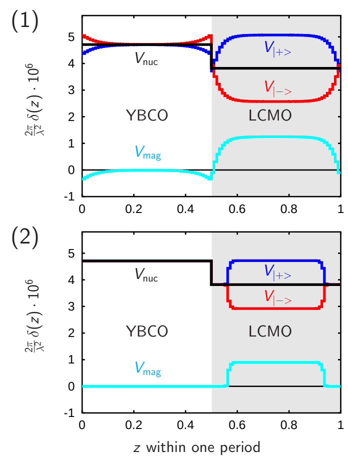
- change of 1st Bragg peak intensity below T_m
  ⇒ increased contrast for $|-\rangle$ neutrons
  decreased contrast for $|+\rangle$ neutrons
- 2nd Bragg peak fobidden by symmetry of $V^{nuclear}$
  ⇒ B has an other z-dependence than $V^{nuclear}$
  (see simulations)
- $I_{specular} \propto I_{integrated}$ for $T > T_c$
  ⇒ no detecatble magnetic roughness
- $I_{specular} < I_{integrated}$ for $T < T_c$
  ⇒ increasing magnetic roughness
- exchange bias
  ⇒ AFM layers must be present at the interface

Simulation

Calculated with the computer code EDXR of P. Mikulík.

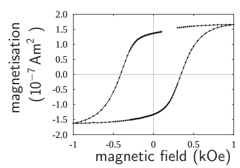


Suitable model potentials:



Magnetometry

SQUID measurement by F. Treubner, Uni. Konstanz — thanks!



$[YBCO(100\,Å)/LCMO(100\,Å)]_7$

$T = 5\,K$
Cooled in $H = 100\,Oe$
exchange-bias field:
$H_e = -60\,Oe$

Summary

Evidence for a characteristic difference between the structural and magnetic depth profiles is obtained from the occurrence of a structurally forbidden Bragg peak in the FM state and the anomalous temperature dependence of the intensity of the first Bragg peak.

The comparison with simulated spectra allows us to identify two possible magnetization profiles:
(1) A sizable magnetic moment develops within the SC layer that is antiparallel to the one in the FM layer.
(2) A significant "dead" region in the FM layer that has no net magnetic moment.

Both are compatible with exchange bias.
Scenario (1) is supported by an anomalous SC-induced enhancement of the off-specular reflection which testifies for a strong mutual interaction of SC and FM order parameters and may be the signature of a spatially inhomogeneous SC/FM interface state.