| ESRF | **Experiment title:** Reflection-geometry small-angle scattering by magnetic planar multilayers and lateral multilayer gratings | **Experiment number**: SI-584 |
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**Report:**

The aim of the proposal was to study (a) planar magnetic multilayers (MLs) with giant magnetoresistance properties and (b) laterally structured multilayer gratings (MLGs) by small-angle scattering/GISAX. The ID1 setup has been chosen because it can provide simultaneous use of a scintillation detector for high-intensity coplanar scattering and a two-dimensional gas-filled detector for non-coplanar scattering geometry. Unfortunately, the 2D detector had been broken just before our arrival and a one-dimensional position-sensitive detector had to be used instead. This change made it impossible to accomplish the desired tasks for the (a) magnetic MLs and thus a new experiment (c) with two samples grown by MOCVD with step bunches on a 2.0° [110] miscut GaAs(001) substrate surface was performed instead.

Ad experiment (b): According to the experimental proposal, we were mainly interested to measure 3D GISAX from several MLGs prepared by different photoresist and etching techniques. This was not possible without the 2D detector. Therefore only one sample could have been measured by scanning the PSD oriented perpendicular to the plane of incidence. The scans performed were a non-coplanar rocking curve imaging (angle of exit $\alpha_f$ for the central PSD channel equals the angle of incidence on the sample) and $\alpha_i$-scan imaging with the angle of exit fixed, see figure 1. These scans exhibit the features of coherent coplanar scattering perpendicular to wires along $Q_z$ and coherent non-coplanar enhanced dynamical scattering around an arc of the Ewald sphere. The non-coplanar diffuse scattering

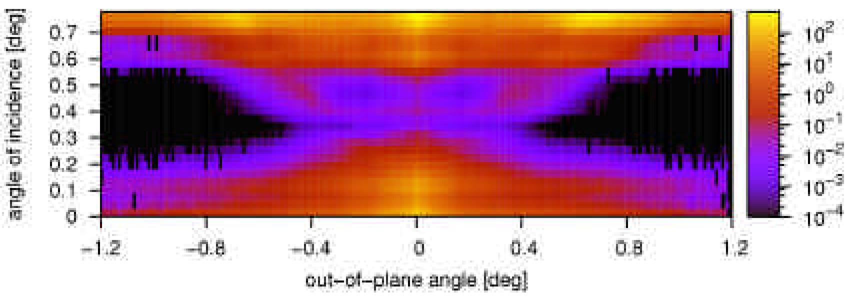


**Figure 1:** Excitation of the Ewald sphere and the first diffuse scattering Bragg sheet in the $\alpha_i$-scan for $\alpha_f$=0.8° parallel to wires.

from lateral and vertical imperfections (roughness of interfaces and side walls — 3D Bragg sheets) is found around the coherent peaks. The scattering features are well resolved as the PSD has sufficiently large dynamical range to follow the coherent non-coplanar scattering. However, the long measuring time needed for these scans has not allowed to compare non-coplanar diffuse scattering in the scattering geometry parallel to wires for several MLG samples with different structural qualities.

Ad experiment (c): Sample I was structured as [2 nm $In_{0.2}Ga_{0.8}As$/ 4nm GaAs]5×, sample II had a single 10 nm thick $In_{0.2}Ga_{0.8}As$ layer capped by 20 nm GaAs. Both sample surfaces reveal well ordered step bunches in Atomic Force Micrographs with a period of about 160 nm along [110]. Figure 2 depicts surface of sample II: a self-organized system of terraces and bunches dominates surface morphology with bunch lengths exceeding perpendicular miscut direction approximately 5 times the bunch width.

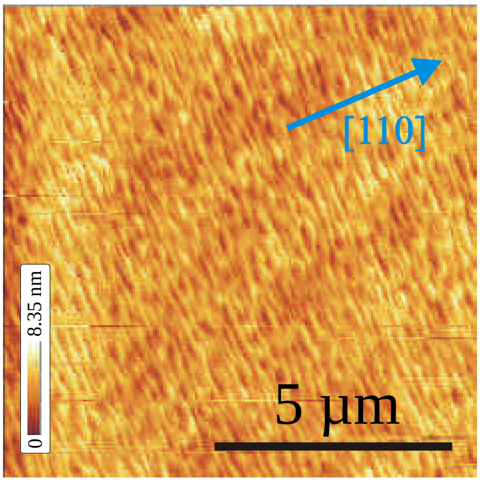

**Figure 2:** Atomic Force Micrograph of sample II.

Grazing Incidence Small Angle Scattering at an energy of 8 keV was applied to test sample morphology at the surface as well as vertical inheritance of morphological information. Surface sensitivity is achieved by small angles of incidence and exit. The scattered in-plane intensity was recorded by a position sensitive detector (PSD) oriented parallel to the sample surface. Vertical divergence was restricted by slits in front of the PSD and accounts for 0.004 $Å^{-1}$. We prepared out of plane measurements by a 1:2 coupled movement of sample rocking and detector out of plane angle. Bunches were oriented parallel to the incoming beam direction. A configuration in this way allows the estimation of ordering perpendicular to bunches as well as information caused by different planes as terraces and bunches. In figure 3 an out of plane map taken on sample II is shown. $Q_x$ denotes the mean surface, whereas $q_z$ runs parallel to the mean surface normal. A strong crystal truncation rod (CTR) at $q_x$ = 0 perpendicular to the mean surface is present as well as two rods inclined by 1.9° and 1.6°, respectively. These highlighted rods are caused by [001] terraces and bunched regions, respectively, which fit good to the initial substrate miscut of 2.0°. Because the evaluated angles correspond directly to the length of the contributing part we assume a similar lateral extent of bunches compared with terraces. The entire map is superimposed by an oscillation with a typical period of about 0.05 $Å^{-1}$ which corresponds to a distance of about 12 nm in real space, which agrees to the thickness of the intermediate $In_{0.2}Ga_{0.8}As$ layer.

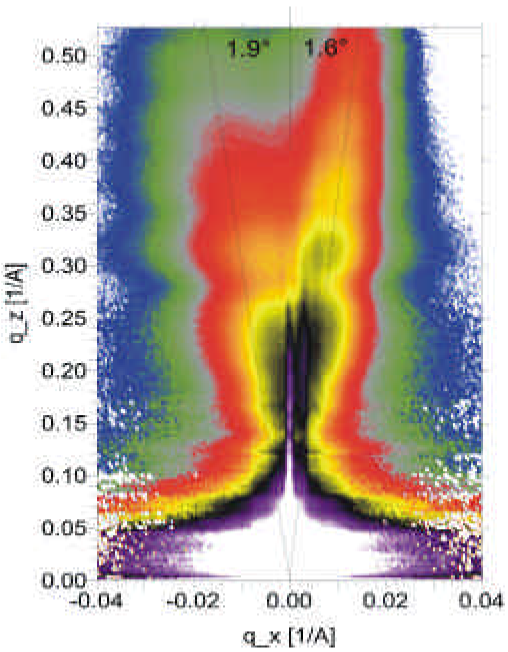

**Figure 3:** GISAXS intensity perpendicular to the sample surface for a fixed sample azimut.