ESRF	**Experiment title:** **Coherent scattering from lateral GaMnAs nanostructures**	**Experiment number**: HS-3635
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Report:

Coherent diffractive imaging based on iterative phase retrieval algorithms [1] is well known for its ability to reconstruct the phase of the measured X-ray wave front. An assumption about Fourier Transform relation between direct and reciprocal spaces is used, and it in turn allows us to reconstruct the object under investigation. Such algorithms are an established technique to image small isolated nanoparticles and strain free crystals, when their image in direct space is described by the real-valued function. Application of these phase retrieval methods to the strained crystals, which are expressed by complex-valued numbers, to study the internal strain has proven to be a nontrivial task. Reconstruction of highly inhomogeneous strain fields of the order of 10^{-3} usually leads to algorithm stagnation in the vicinity of the local minima without finding the correct solution [2, 3]. The number of local minima increases with increase of strain inhomogeneity [3]. Recently, we have extended the algorithms adopted for the determination of larger strain of the order of 10^{-3}. In the current work we investigate the strain state in inhomogeneously strained (GaMn)As/GaAs periodical wires using our phase retrieval algorithm.

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Material description

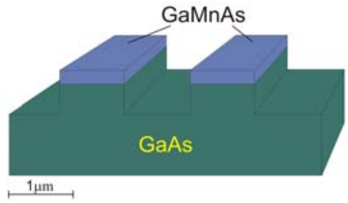

***Figure 1**: (GaMn)As/GaAs periodic wires (2µm period) on GaAs substrate*

Magnetocrystalline anisotropy of diluted magnetic semiconductor layers like GaMnAs can be substantially affected by elastic strains [4]. Due to the lattice mismatch between GaMnAs and GaAs, depending mainly on the concentration of Mn interstitial atoms [5], epitaxial GaMnAs layers deposited on GaAs substrates are biaxially compressed. The local strain status of the layers can be efficiently affected by lateral lithographical patterning of the surface, which creates a periodic sequence of thin wires and groves (surface grating). In the investigated structures the period of wires is T=2 µm and the nominal wire width is 1 µm. A 200 nm thick (Ga,Mn)As layer with a nominal Mn concentration of about 7% was grown onto a (001)GaAs substrate (Fig. 1). The periodic wire structure was prepared by electron-beam lithography and reactive ion etching with an etching depth of approx. 700 nm. The (Ga,Mn)As surface wires were oriented along the [1-10] direction. The technological details can be found elsewhere [4].

Results and discussion

The measurements have been done at the ID01B beamline using photon energy of 8 keV. A two-dimensional reciprocal-space map (RSM) was recorded in vicinity of the 004 reciprocal lattice point (Fig. 2). The RSM $q_x q_z$ plane is perpendicular to the alignment of the wires. Two separated features in the RSM correspond to the 004 reciprocal lattice points of GaAs and (Ga,Mn)As (the corresponding difference in Bragg angles is about 0.2 degree). Performing the phase-retrieval algorithm, we assumed that the unit cells both in (Ga,Mn)As and GaAs crystals are not deformed but only shifted as wholes, so that their structure factors are not affected by elastic deformation. The measured RSM was divided in two regions Ω_L and Ω_S (see Fig. 2), and each of them was used further for an independent reconstruction of the corresponding composite parts (Ga,Mn)As and GaAs of the wire, respectively. We have found the amplitudes and phases of the waves scattered from Ω_L and Ω_S separately [6]. Thus we illustrated the material-specific nature of x-ray diffraction allowing independent analysis of each element of the structure. The results of these individual reconstructions gave the continuous field of displacement, building up the strained inhomogeneous system as a whole (Fig. 3). The reproducibility of the obtained solutions was proven performing a series of inversion cycles starting from different sets of random phases of the scattered radiation. The direct-space resolution achieved is about 10×10 nm^2.

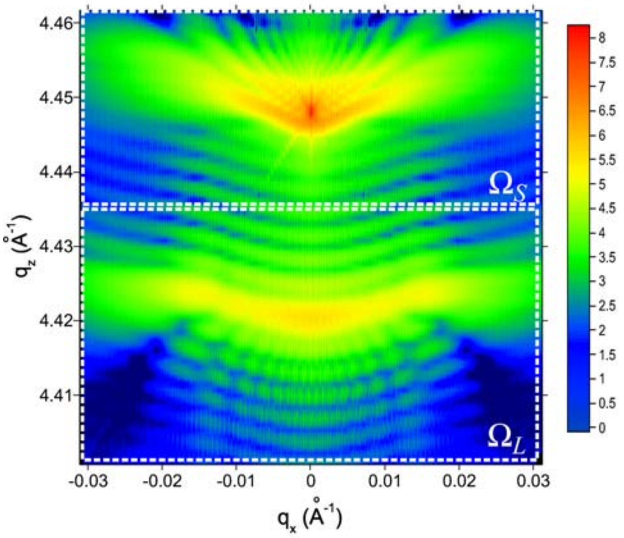

***Figure 2**: Reciprocal space map near 004 reflection of (GaMn)As (lower peak) / GaAs (upper peak) wires in the plane perpendicular to the etched wires direction.*

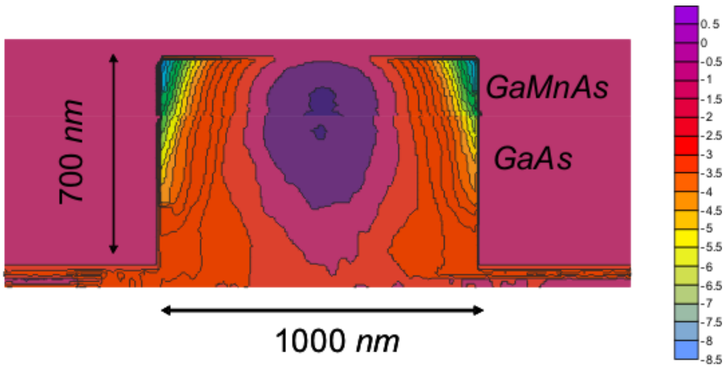

***Figure 3**:Retrieved vertical component of displacement field in (GaMn)As/GaAs single wire (in Å).*

These results offer important perspective for local strain determination at the nanoscale.

References

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