ESRF	**Experiment title:** Local strain imaging using Bragg diffraction Fourier Transform Holography	**Experiment number:** MI689
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Report:

The aim of this experiment was the demonstration of Bragg Fourier Transform Holography (FTH). The method used the direct encoding of the phase in the intensity pattern. In the specific case of Bragg FTH, a reference crystal (RC) is placed near the object crystal (OC) to image. The two crystals must have comparable lattice parameters so that the interference of the diffracted wavefields occurs in a high intensity reciprocal space region. The inverse Fourier Transform of the intensity itself gives in principle the image of the OC, cross-convoluted with the RC. If the OC-RC distance $\mathbf{R}$, is large enough, the two cross-terms, centered in $\mathbf{R}$ and $-\mathbf{R}$ become separated from the central self-convolution terms.

The monochromatic beam (wavelength $\lambda = 0.154$ nm) was delivered by a Si-111 monolithic channel-cut monochromator, resulting in a longitudinal coherence length of about 1 μm. In order to increase the coherent flux at the sample position, a coherently illuminated Fresnel Zone Plate made of Au was placed 129 mm upstream the sample. The measured size of the focused beam (FWHM V $\times$ H) was about 350 nm and 400 nm. The sample was placed horizontally onto a translation stage allowing for the nanometric positioning of the sample. The beam direction was perpendicular to the object-reference axis. The intensity acquisition was performed with a pixel detector (Maxipix, 256×256 pixels of 55×55 μm^2 size) mounted 0.93 m downstream the sample.

Several samples have been tested during the experiment. The holographic samples were patterned from a $Si_{1-x}Ge_x$ continuous layer (200 nm thick, $x = 8\%$) grown epitaxially onto a Si <100> substrate. The patterns were obtained either with a Focused Ion Beam (FIB) or by e-beam lithography.

However, it appeared that the FIB patterning was too destructive with respect to the crystalline structure, thereby avoiding the acquisition of relevant x-ray data. On the contrary, the e-beam lithographic samples, such the one described in the following gave access to well structured coherent diffraction patterns. The results described below were obtained on an e-beam lithographic sample. The OC and RC structures were defined in a positive photo resist using a reactive ion etching to transfer the pattern into the SiGe layer. The etching depth was chosen in order to remove the SiGe layer outside the OC and the RC, over an area of 100×100 μm^2. Atomic Force Microscopy (AFM) measurements were performed to characterize the two structures of the holographic sample (Fig. (a)). The nanostructure outer dimensions (length $\times$ width $\times$ thickness) could be estimated to $570 \times 310 \times 190$ nm^3 for the OC and $180 \times 130 \times 100$ nm^3 for the RC. The distance $|\mathbf{R}|$ between the two crystals is about 470 nm.
The coherently scattered intensity was measured around the SiGe (004) Bragg peak (Bragg angle $\theta = 34.5°$) as a function of the wavevector transfer $\mathbf{Q}$. The 3D diffraction pattern was acquired by scanning the incident angle in steps of 0.01° over an angular range of 0.2° while measuring the 2D intensity distribution at each position along the rocking curve. Strong fluctuations of the intensity values observed in the regions where the two systems of fringes overlap demonstrate the coherent interference between the two crystals (Fig. (b)). The 21 slices are stacked into a 3D matrix for the inversion process.
The direct space result calculated by the single inverse Fourier transform of the 3D intensity pattern is shown in Fig. (c). The 3D image crystals are clearly visible in $\mathbf{R}$ and $-\mathbf{R}$. The detailed analysis of this successful demonstration of Bragg FTH is now under review for publication in Phys. Rev. Lett.
The main difficulties encountered during this experiment were related to the delicate insertion of the newly installed FZP. In addition, beam to sample stability was difficult to achieved due to some drift of the sample translation stage, during the rocking curve. As a consequence, a good set of data was only measurable during the very last shift of this beamtime. These experimental problems are now solved at the ID01 station.

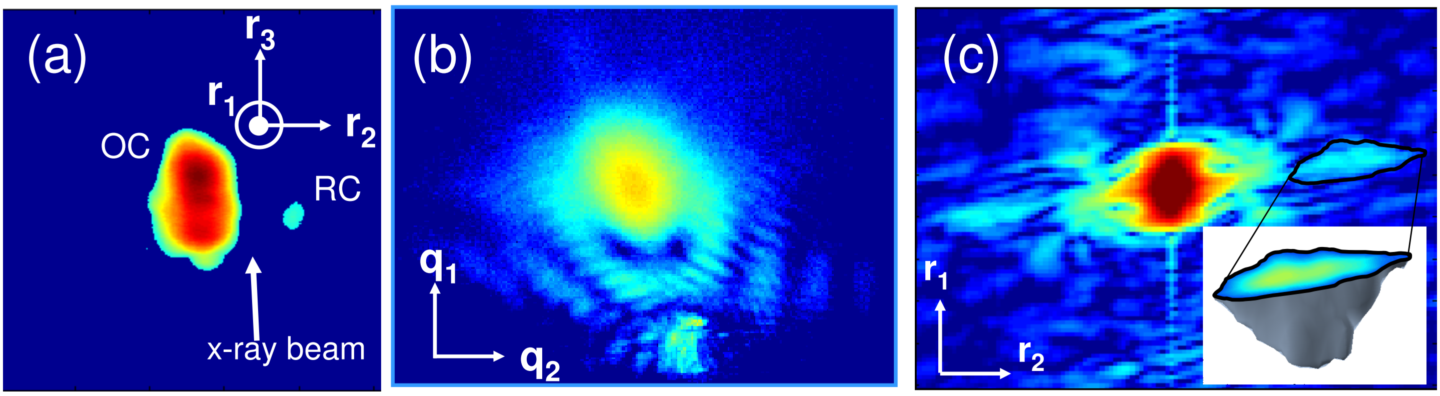

Figure:(a) AFM measurement of the SiGe holographic sample (OC and RC). (b) One of 21 2D coherent intensity patterns measured at the 004 SiGe Bragg peak. (c) One slice out of the 3D direct space image obtained by a single inverse Fourier Transform of the 3D intensity matrix. The two image crystals are observed on both sides of the central self convolution terms. The inset shows a cut of the 3D retrieved image crystal.