

Giant Berry-phase-Driven X-Ray Beam Translations in Strain-Engineered Semiconductor Crystals

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Abstract: X-rays propagating in deformed crystals undergo large translations, due to the so-called *Berry-phase effect*. By engineering the deformation landscape of selectively hydrogenated GaAsN epilayers we trigger >100 μm beam translations, interesting for X-ray optics applications.

The manipulation of light through its interactions with artificially structured media is a cornerstone of visible/IR photonics. The rescaling of this concept to the X-ray realm is hindered by the inherent difficulty of realizing photonic structures with the sub-nanometric resolution dictated by X-ray wavelengths. A promising approach to this challenge is based on the so-called *Berry-phase effect* [1], the large beam translations undergone by X-ray photons propagating in a deformed crystal, due to the simultaneous presence of Berry curvatures [2] in real and reciprocal space. In this work, the strain modulation required to induce this effect is obtained by pairing the lattice expansion observed upon H irradiation of GaAsN with the spatially selective hydrogenation technique described in, *e.g.*, [3]. By performing a series of X-ray transmission experiments on purposely fabricated, ordered GaAsN/GaAsN:H dot arrays, we consistently measure beam translations in excess of 100 μm (see Fig. 1), while also revealing a clear dependence of the observed translation on the dot size [4]. These experimental results are compared with an extensive numerical analysis of the propagation of X-rays in the deformed lattice, based on the direct computation (via FEM calculations) of the deformation landscape within the sample. These results open new, enticing prospects for the realization of tailor-made X-ray photonic structures, interesting for applications in pump-and-probe experiments and in X-ray interferometry.

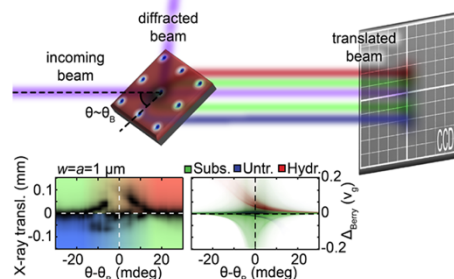


Fig. 1 Top: Sketch of the experimental configuration employed to measure the X-rays transmitted by selectively hydrogenated GaAsN samples. For $\theta \sim \theta_b$ (where θ_b is the Bragg angle, see [4]), the Berry-phase translation effect can be observed, with the appearance of two or more transmission branches corresponding to the interaction of the propagating X-rays with different regions of the deformed sample. Bottom left: False-color image of the intensity profile of the transmitted X-ray photons—measured along the vertical axis of the detector, see top sketch—plotted as a function of $\theta - \theta_b$. The figure refers to a GaAsN:H sample patterned with dots spaced by $a = 1 \mu\text{m}$ and with diameter $w = 1 \mu\text{m}$. Bottom right: False-color plots of the distribution of the beam deviation computed in each point of the sample (see [4]). The beam deviations associated with points located within the substrate and in the untreated/hydrogenated regions of the epilayer are displayed in green, blue, and red, respectively.

References

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