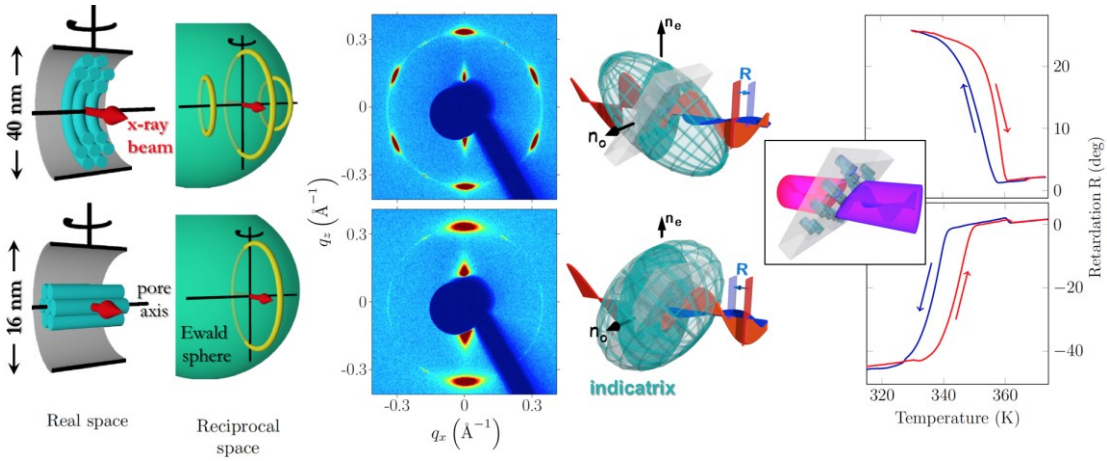
Soft Matter Confined in Nanoporous Solids: From Multiscale Physics to Metamaterials Design

Patrick Huber

Institute of Materials Physics and Technology

Hamburg University of Technology

The advent of self-organized nanoporosity in terms of precise pore size, shape, and orientation allows one to study fundamental properties of soft matter in well defined, extreme spatial confinement [1]. The combination of soft with nanoporous hard matter also provides versatile pathways for the engineering of functional materials [2]. In the first part of my talk I will present experimental studies on fluid sorption-induced deformation [3] and on the capillarity-driven flow of liquids in nanoporous media. In the second part of my talk, I will demonstrate that embedding liquid crystals in nanoporous solids provides novel opportunities for subwavelength control of light-matter interactions on the single-pore scale and thus to fine-tune the optics of these materials. As a function of pore hydrophilicity and thus distinct molecular anchoring at the pore walls a remarkably rich self-assembly behavior, unknown from the bulk state, can be observed, such as a quantized formation of concentric discotic rings [2], a transition from axial to radial aligned discotic columns [4] and the formation of pore-axis aligned supermolecular helices [5]. Intimately related with this surprising self-organization at the nanoscale the soft-hard hybrid materials exhibit novel metaphotonic functionalities encompassing optical anisotropy step-wise changing with temperature [2], enhanced light rotation and extremely fast electro-optically active Goldstone excitations typical of para-to-ferroelectric phase transitions [5].



Self-assembly of radial aligned rings and axial aligned columns of disk-like molecules in cylindrical alumina nanopores as evidenced by X–ray diffraction. This results in an either prolate or oblate ellipsoid of refractive indices (indicatrix) aligned to the pore axis direction. Thus, linear polarized light is split up by a parallel array of such pores into two beams with perpendicular polarizations and distinct propagation speeds. Their relative phase shift (retardation R) after passing the birefringent pore array is positive or negative, respectively, and vanishes upon heating to the isotropic liquid state.

References:

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