X-ray Interference in Colloidal Nanocrystal Superlattices: a Parallel with Multilayer Epitaxial Thin Films

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The term “nanocrystal superlattices” refers to solids composed of numerous nanocrystals self-assembled in periodic and highly ordered structures, mimicking the arrangement of atoms in crystals. The name has been borrowed from the field of thin films grown through physical methods, where a stack of repeating identical layers is referred to as a superlattice. At first glance, similarities between colloidal nanocrystal solids and epitaxial thin films may seem limited to the name alone. However, this is not the case. Indeed, the observation of interference fringes decorating the Bragg peaks of lead-halide perovskite superlattices led to the rediscovery of an interference effect that is well known for epitaxial thin-films, but was never reported for colloidal nanocrystals before [1].

Multilayer Diffraction, as we call it, occurs when X-rays are diffracted by nanocrystals arranged periodically: here, the X-rays scattered by each particle interfere with those diffracted by neighbors, creating fringes of constructive interference [2]. Since the interfering radiation comes from nanocrystals, the fringes are visible only in correspondence of their Bragg peaks, thus explaining the unusual peak shape. Being a collective interference phenomenon, Multilayer Diffraction is highly sensitive to disorder, and requires that nanocrystals stack with extreme precision to be observed, a condition that is indeed typical of self-assembled nanocrystal superlattices.

In this talk, we will discuss how a theoretical model developed in the 80’s for epitaxial multilayers can be repurposed to quantitatively fit the diffraction patterns of state-of-the-art colloidal nanocrystal solids [3]. We will also propose an answer to many stimulating questions: why Multilayer Diffraction is best seen in the low-angle part of the pattern, why it has not been reported for other popular nanocrystals, how this effect can be used to investigate the surface of nanocrystals [4], and much more. Finally, with the help of literature and simulations we will show that Multilayer Diffraction is a much more common phenomenon that one might think [5], and is routinely observed without being recognized in a variety of appealing nanomaterials behind the borders of halide perovskites: your sample might be next!

References

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