Illuminating the unavoidable imperfections of nanostructures

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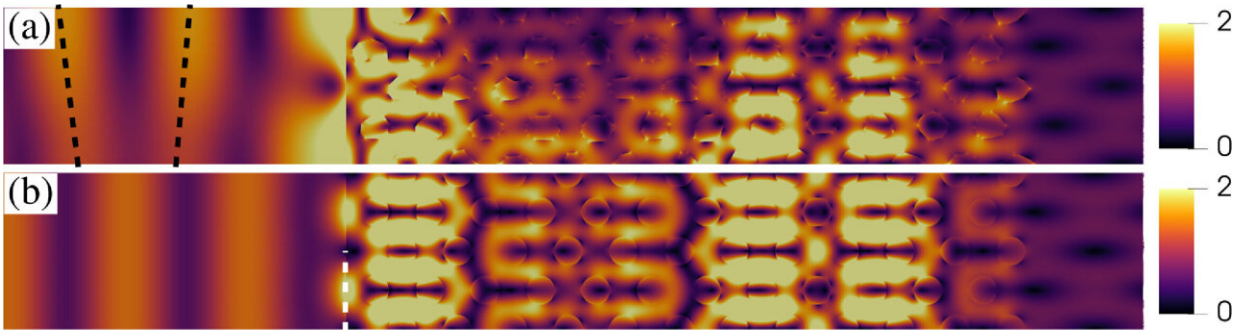

Light distribution (E-field) in a) the real crystal and b) utopian crystal. Lighter colors correspond to brighter light. Bright light is confined inside the real crystal, but absent in the utopian model. Credit: *Optics Express* (2024). DOI: 10.1364/OE.519464

A new study by a collaborative team from the University of Twente and the e-Science Center in Amsterdam compares the transmission of light through a utopian model with a real 3D nanostructure. These nanostructures are integral to our daily technologies, such as smartphones and solar panels.

The research was done by Lars Corbijn van Willenswaard, Stef Smeets, Nicolas Renaud, Matthias Schlottbom, Jaap van der Vegt, and Willem Vos from the University of Twente. The paper is published in the journal *Optics Express*.

The team's innovative approach uses the real 3D nanostructure itself, obtained through precise X-ray imaging, as input for their optical study. This way, the researchers could directly compare the real nanostructure with an idealized, or "utopian," model. The findings reveal that, unlike the ideal design, the real nanostructure exhibits a strong confinement of light which is completely absent in the utopian design.

Chip predictability

Device predictability is crucial for applications ranging from metrology for chip fabrication, and smart lighting with light-emitting diodes, to atmosphere observations with nanosatellites. However, no matter how expensive and well-equipped the facility, inevitable deviations appear during nanofabrication.

Two consecutively made nanostructures are never exactly the same down to the level of the placement of the atoms since, for example, fabrication equipment slowly varies in time. Ultimately, even if all equipment works perfectly, entropy and chaos forbid exact copies to be made, making devices less predictable.

New device functionalities

The Twente-Amsterdam team's research not only enhances our understanding of these deviations but also opens the door to new device functionalities. Vos explains, "There are major differences between the real and the utopian structure. For example, where the utopian structure forbids light from entering, the real structure holds a high energy density of light (see figure above).

"The real light distribution has a peculiar pattern where light is prevented from exiting to the right, as originally designed. The intense and

confined light may even be used for completely new functions, such as an optical switch or a sensor."

More information: Lars J. Corbijn van Willenswaard et al, Non-utopian optical properties computed of a tomographically reconstructed real photonic nanostructure, *Optics Express* (2024). DOI: 10.1364/OE.519464

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