Scientists manage to observe the inner structure of photonic crystals

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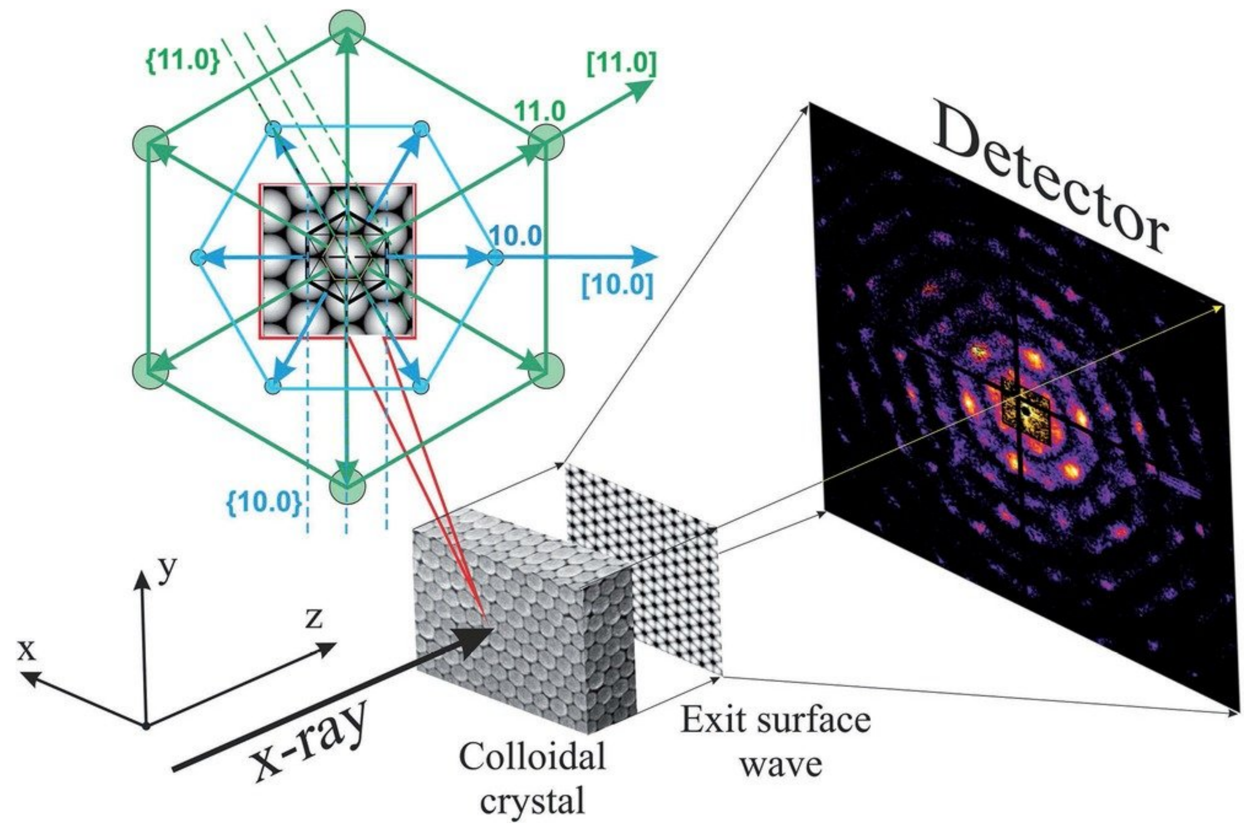


The scheme of analysis of photonic crystals' inner structure with the help of ptychography. Credit: ©NUST MISIS

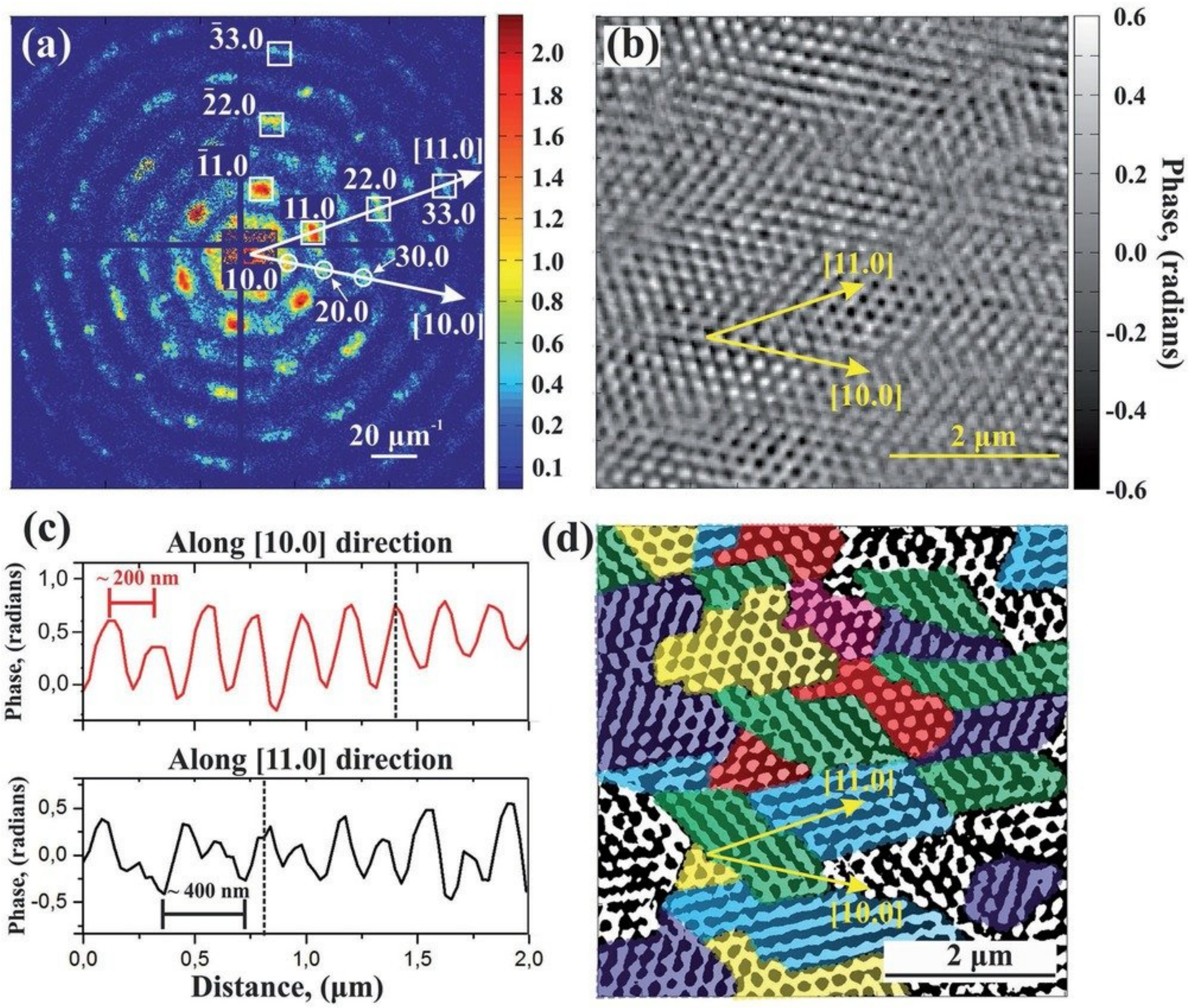
With the help of electronic microscopy, scientists have tracked defects in the surface of two-dimensional photonic crystals. But there are difficulties with bulk photonic crystals. There is no way for scientists to research the interiors of these unusual crystals. So scientists have been searching for a method to better measure these crystals for some time.

Ilya Besedin, an engineer from the NUST MISIS Laboratory of Superconducting Metamaterials, jointly with a group of scientists from Germany, the Netherlands, and Russia has demonstrated that there is a method of non-destructive analysis of the inner structure of the substance, which cannot be seen with the use of conventional X-rays. The new system will help to create microprocessors for optical computers. The work was published in *Small*.

The research group, led by Professor Ivan Vartanyants from MEPhI, has applied the recently developed method of ptychographic to photonic crystals. The method's essence is that the substance is illuminated by X-ray radiation of an exactly defined wave. Sources of such radiation are called synchrotrons, and the experiments were conducted at DESY in Germany.

"With conventional X-rays you can scan either macroscopic or very ordered structures. In our case, for structures of polystyrene spheres of nearly micron size, the accuracy of the image will be even worse than in fluoroscopy. At least, it won't be possible to discern a single object [smaller] than a micron," said Ilya Besedin.

Thanks to such a high quality X-ray, Ilya Besedin and his colleagues have managed to observe the structures of crystals ordered at a scale of tens and hundreds of nanometers. Most importantly, scientists have managed to identify internal defects of mesoscopic structures.



Photonic crystal received with the help of the method of ptychography. Credit: ©NUST MISIS

As Ilya Besedin explained, if the crystal is perfect, the beam can pass through or be reflected. However, because of defects, the beam might deviate from a straight line. "By knowing information about packaging defects, we can understand the logic through which the beam changes its direction. This means we can try to collect logical designs based on photonic crystals. Another thing is that we are not able to control the formation of these defects, we can only try to reduce [the defects] at the macro level," explained Besedin.

"A photonic crystal is like a waveguide for the light, only better. The waveguide is almost impossible to bend, and it's impossible to create photonic microchips on waveguides. A photonic crystal is most suitable for the creation of integral optical microchips where the light can spread where the developers need it to," noted Ilya Besedin. This is why the main value of this work is in the analysis of photonic crystals' inner structure with the help of ptychography.

"We have shown that now, with the help of X-rays, we can observe defects in periodic mesoscopic structures. The next stage of specification is to expose these structures to radiation with an X-ray laser. This can give a more accurate picture of the internal structure, but there are also some difficulties. The laser beam is, by definition, more powerful than just an outgoing one from synchrotron. While increasing the power, the probability of destroying the investigated structure increases significantly, which is not [good]. Ptychography also allows researchers to study the inner structure of a crystal without destroying it. That is why such a method will definitely find its application," Besedin concluded.

More information: Sergey Lazarev et al. Ptychographic X-Ray Imaging of Colloidal Crystals, *Small* (2017). DOI: 10.1002/smll.201702575

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