Sharpening the focus of microscopes

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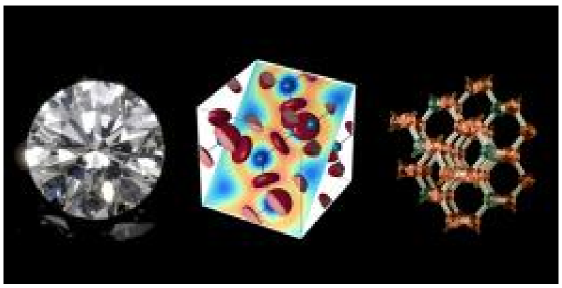

Figure 1: The optical response of a diamond crystal (left) can now be analyzed at the atomic scale with extreme ultraviolet light (center). This technique can provide additional information to the crystal structure (right) typically obtained using x-rays. Credit: Reproduced, in part, from Ref. 1 © 2011 Kenji Tamasaku

A new advanced imaging scheme—with a resolution ten times better than that of its counterparts to date—can resolve objects as small as atoms1. Previously, the maximum resolution of optical instruments, including cameras and microscopes, was fundamentally limited to a precision that corresponded to approximately half of the wavelength of incoming light.

The new scheme, developed by researchers from the RIKEN SPring-8 Center in Harima and Nagoya University, has a resolution up to 380 times better than the UV light used in the experiments. For microscopes using visible light, which means wavelengths of a few hundred nanometers, the best achievable resolution is around 100 nanometers, which fails to resolve the smallest structures on a computer chip.

Imaging smaller nanostructures, or even atoms, requires light of much shorter wavelengths, such as x-rays that are difficult to handle, and which provide different types of images to those captured using visible light.

Led by Kenji Tamasaku of RIKEN, the researchers used a non-linear optical effect to achieve atomic resolution in diamond. Their process is based on the intrinsic interaction between the electrons of the material's crystal atoms and UV light that splits an incoming x-ray beam into a UV beam and a lower energy x-ray beam. The combined energy of these scattered beams is the same as that of the incoming beam. This process depends strongly on the activation of the UV beam, which occurs only in the vicinity of the electrons in the atoms, and only if the optical response of the electrons is a match to the incoming x-ray beam, Tamasaku explains.

Analyzing the scattered beams allowed a precise reconstruction of the motion of the electrons under UV illumination. Using a diamond crystal as an imaging object, the researchers demonstrated a resolution of 0.054 nanometers (Fig. 1). Because Tamasaku and colleagues used a non-linear optical effect, they obtained new information not only about how electrons move but also about atomic position.

There are many possibilities for using this new method, says Tamasaku. "This technique is very useful for the study of the physical properties of materials that couple to light." An example is the study of electronic materials, in which the sensitivity of the technique to the electron's electronic states can be used to probe electrical charges in materials such as high-temperature superconductors. Using the team's new approach, this will now be possible with atomic resolution.

More information: Tamasaku, K., et al. Visualizing the local optical response to extreme-ultraviolet radiation with a resolution of λ/380.

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