Intense X Rays Can Free Bound Electrons

Measurements indicate that intense x-ray pulses can change the electronic structure of a material on femtosecond timescales, a finding that could improve imaging of light–matter interactions.

By **Rachel Berkowitz**

The x-ray free-electron laser (XFEL) is a revolutionary tool for investigating light–matter interactions. The quick-fire pulses of high-energy radiation used in this tool can capture a fast succession of snapshots of a material's atoms, revealing the fine-scale, three-dimensional details of atomic movements without destroying a sample. Still, the intense irradiation of an XFEL has the potential to alter both the electronic and atomic configurations of a material, which complicates the determination of a solid's structure. Now Ichiro Inoue of RIKEN in Japan and his colleagues have pinpointed when and how an XFEL's pulses alter the crystal structures they are designed to reveal [**1**]. The results could help resolve limitations of the technology and could be used to improve accuracy in future XFEL imaging.

XFEL experiments reveal the atomic structure of a material through the diffraction of x-ray pulses by the material's atoms. Inoue and his colleagues measured such diffraction signals for silicon nanocrystal films, varying the peak x-ray intensity of their XFEL beam.

Credit: RIKEN

For XFEL intensities of 10^{19} W/cm^2 and above, the researchers observed a nearly 50% drop in the measured diffraction intensity, compared with the diffraction of lower-intensity x rays. The ultrashort duration of the x-ray pulses prevented the XFEL beam from producing atom displacements. Thus, the team was able to link the drop in diffraction intensity to a change in the material's electronic structure. Simulations confirm the link, as well as the XFEL intensity threshold for the diffraction intensity drop. The simulations suggest that the reduction comes from the creation of highly ionized atoms, which causes a massive excitation of inner-shell electrons that reduces diffraction efficiency.

Rachel Berkowitz is a Corresponding Editor for *Physics Magazine* based in Vancouver, Canada.

REFERENCES

1. I. Inoue *et al.*, "Femtosecond reduction of atomic scattering factors triggered by intense x-ray pulse," **Phys. Rev. Lett. 131, 163201 (2023).**