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Anashe Bandari

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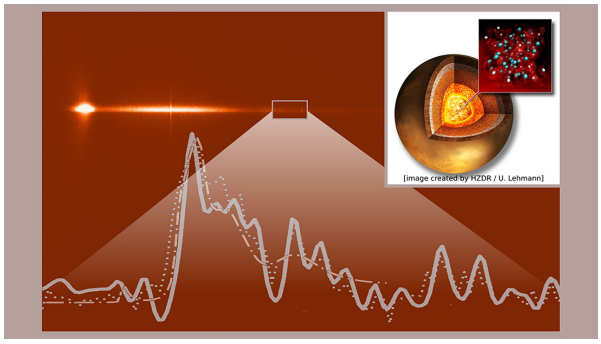
By combining complementary X-ray scattering measurements taken with the very bright free electron laser, carbon can be studied at extreme pressures and temperatures.



Studying chemistry at extreme conditions is the key to understanding warm dense matter, which is relevant to research topics such as planetary interiors. Due to the complicated interactions between parameters, it is challenging to tell apart the specific dynamics within warm dense matter using standard methods. Voigt et al. performed experiments and simulations and demonstrated the capabilities of X-ray Raman spectroscopy (XRS) to characterize chemical bonds under extreme conditions when combined with complementary X-ray scattering techniques.

Thanks to the exceptional brightness of the European X-ray Free Electron Laser, the team showed XRS can be used to observe phase transitions, pressure and temperature effects, as well as the chemical bond structures of carbon under extreme pressure and temperature conditions. By averaging over thousands of shots, they were able to record a full range of spectra and obtain structural information about the sample.

The group focused X-ray pulses onto their carbon sample to run the diagnostics, from which they compared the results with various simulations.

“Most exciting towards the future is the prospect that future measurements will provide key insights into the chemistry of light elements and their mixtures at planetary interior conditions,” said author Katja Voigt. “A detailed knowledge of these aspects is required to understand the formation and evolution of the gas and ice giants and therefore the whole solar system.”

In addition to enabling the study of carbon in extreme conditions similar to planetary interiors, the team says the method can be expanded for studying other elements such as oxygen and nitrogen, to aid in the understanding of extraterrestrial atmospheres.

Source: “Demonstration of an x-ray Raman spectroscopy setup to study warm dense carbon at the high energy density instrument of European XFEL,” by K. Voigt, M. Zhang, K. Ramakrishna, A. Amouretti, K. Appel, E. Brambrink, V. Cerantola, D. Chekrygina, T. Döppner, R. W. Falcone, K. Falk, L. B. Fletcher, D. O. Gericke, S. Göde, M. Harmand, N. J. Hartley, S. P. Hau-Riege, L. G. Huang, O. S. Humphries, M. Lokamani, M. Makita, A. Pelka, C. Prescher, A. K. Schuster, M. Šmíd, T. Toncian, J. Vorberger, U. Zastrau, T. R. Preston, and D. Kraus, *Physics of Plasmas* (2021). The article can be accessed at https://doi.org/10.1063/5.0048150.