Popular Science Description: X-ray Imaging at High Brilliance Sources

Khachiwan Buakor

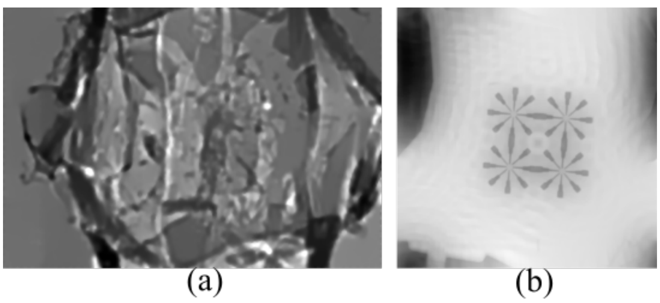
In 1895, the physicist Wilhelm Conrad Roentgen discovered the unknown radiation when he was working in his laboratory. The radiation was invisible to the eye and able to pass through a heavy dark paper, where visible light cannot. Roentgen used the term 'X-ray' to refer to the discovered radiation.

The first use of X-rays done by Roentgen is the imaging of his wife's hand wearing the wedding ring. A shadowy image was created by passing X-rays through the hand. The image showed different contrast shadows due to the variation of X-rays absorbed by materials. For instance, finger bones and the metal ring absorb more X-rays than flesh resulting in darker shadows in the image. This X-ray imaging technique used by Roentgen became a revolution of the diagnosis of injuries and illnesses. Also, X-rays went into use by wide-spread scientific research such as exploring crystal structures.

Nowadays, X-ray imaging techniques are also based on 'phase contrast', while the early technique invented by Roentgen was only based on the X-ray absorption properties of materials or absorption contrast. Phase-contrast X-ray techniques exploit the principle of phase-change of X-rays induced by the density or material variation of a sample. The variation of phase changes of X-rays passing through a sample can be used for creating an image of the sample. This method is called 'phase-contrast X-ray imaging' or 'coherent imaging'. It is more sensitive for low-absorption materials than the absorption-contrast technique. Such techniques have the potential to distinguish between soft tissues, which is hard to be detected by absorption-contrast techniques.

Phase-contrast X-ray imaging techniques require high coherent sources similar to a laser. Such sources are known as high-brilliance sources. Examples of the high-brilliance sources are X-ray free-electron lasers (XFELs) and diffraction-limited storage rings (DLSRs), such as MAX IV. Specifically, XFELs can provide ultrashort and intense pulse X-rays that allow recording a process happening in a very short time and a very small scale such as molecular and chemical dynamics. Phase-contrast imaging techniques or coherent imaging techniques together with XFELs could open the possibility to the recording of molecular movies at very high resolution, which is not possible before. Besides, coherent imaging techniques provide the opportunity to build microscopes to resolve the nanoscale at DLSRs.

The purpose of this work is to develop a framework to process the data collected at high-brilliance sources with phase-contrast and coherent imaging techniques at resolutions that are not possible with other X-ray imaging techniques. An example of the results collected using the novel phase-contrast X-ray imaging techniques at the European XFEL is presented in figure (a). Furthermore, the implementation of a microscope to explore the nanoscale resolution at MAX IV is presented and the result is shown in figure (b). This work could hopefully be one step forward towards the development of novel X-ray imaging techniques that can record sample movies at least 100 times faster than state-of-the-art techniques and to achieve images with nanoscale resolution at MAX IV.



Example images showing (a) one frame of laser-induced dynamics in water-filled capillary collected using ultrafast X-ray imaging at the European XFEL and (b) a sample image of the Siemens star pattern collected at MAX IV.