New Results jf Incoherent Diffraction Imaging (IDI) for X-Ray Structure Analysis

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For more than 100 years, coherent X-rays have been used in crystallography to determine the structure of proteins and molecules via Coherent Diffraction Imaging (CDI) [1]. Recently, it was proposed that also incoherent X-ray fluorescence can be utilized to resolve the spatial distribution of atoms in crystalized proteins or even single molecules, an approach termed Incoherent Diffraction Imaging (IDI) [2].

In order to make use of incoherent fluorescence light for X-ray structure analysis, the spatial second-order photon correlations $g^{(2)}(r_1, r_2)$ must be determined instead of the coherently scattered intensity. Like in the landmark experiment by Hanbury Brown and Twiss to overcome atmospheric fluctuations in astronomy [3,4], this eliminates the phase fluctuations of fluorescence via a two-photon interference process.

Measuring $g^{(2)}(r_1, r_2)$ requires recording the photons within their coherence time, *i.e.*, in the case of X-ray structure within the lifetime of inner core transitions of the investigated atoms. With the latter being on the order of fs or below, this is beyond the temporal resolution capabilities of current detectors. An alternative is using fs-pulses of advanced FEL sources, thus shifting the requirement of ultrafast detection to ultrafast excitation.

We implemented IDI for the first time at the European XFEL, Hamburg, employing pulses of 10fs duration. The latter produced copper Kα-fluorescence at 8 keV from two spots on a thin copper foil, after splitting the FEL beam into two beams by use of a transmission phase grating [5]. In a recent follow-up experiment we retrieved the form factor of copper nanocubes of size ∼88 nm with 20 nm resolution, extending IDI to the destructive single-particle regime [6]. Hereby, we observed unexpectedly a sharp drop in visibility of $g^{(2)}(r_1, r_2)$ above a photon fluence of 10^2 J/cm^2 per pulse, most likely resulting from amplified spontaneous emission (ASE).

To circumvent this problem, one could employ fluorescence photons from Mössbauer transitions, with lifetimes on the order of 100 ns. Here, up to 900 photons per pulse have been observed at FEL facilities recently [7]. This is too low to produce ASE while at the same time ensures high visibilities of $g^{(2)}(r_1, r_2)$ due to the ultra-long lifetimes of the Mössbauer transitions.

References

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