Extending Hanbury Brown Twiss Measurement to Higher Orders for X-Ray Structure Analysis

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For more than 100 years, X-rays have been used in crystallography to determine the structure of proteins and molecules via coherent diffraction imaging (CDI) [1]. The technique relies on coherent scattering, where incoherent fluorescence emission is generally considered as a detrimental effect. Recently it was proposed that also fluorescence light can be used to resolve structures on the atomic scale, *i.e.*, crystalized proteins or even single molecules, an approach termed incoherent diffraction imaging (IDI) [2]. This can be achieved by exploiting second order photon correlations, introduced by Hanbury Brown and Twiss almost 70 years ago in astronomy for overcoming atmospheric fluctuations [3,4]. IDI covers a larger volume in q-space than CDI and allows thus for a higher resolution. Moreover, it is element specific, thus combining imaging with spectroscopy. Recently, we implemented IDI for the first time using X-ray fluorescence photons at 9 keV from the Kα-line of copper to produce an image of a source, in this case two fluorescing spots generated by the European XFEL on a thin sheet of copper after splitting the XFEL beam into two beams by a transmission phase grating [5]. Beyond IDI, we also recently showed that exploiting photon correlations of higher than the second order can be even more beneficial as it enables resolving incoherently scattering objects with higher fidelities and potentially sub-Abbe resolution [6-9]; this has been demonstrated in the soft X-ray domain using the FLASH laser facility at DESY, Hamburg [9]. Here, we discuss that using photon correlations of higher than the second order can further be used to retrieve the phase of the structure factor of the scattering atoms, required to reconstruct the geometry of the object via Fourier transform [10]. We provide a detailed analysis of the underlying scheme and discuss the uniqueness of the solution constructed from the third and fourth order correlation function.

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