Effects of Partially Coherent Incident Illumination on In-Line Imaging

Gureyev T.E.[1], Nesterets Ya.I.[1], Paganin D.M.[1,2] and Wilkins S.W.[1]

[1]CSIRO Manufacturing and Infrastructure Technology, PB33, Clayton 3169, Australia, Email: Steve.Wilkins csiro.au, [2]School of Physics and Materials Engineering, Monash University, VIC 3800, Australia

We derive an analytical expression for the intensity distribution in in-line images collected in the "near-field" regime, which explicitly takes into account the effect of key parameters of the incident radiation, such as the spatial coherence properties of the source, its wavelength spectrum and the principal geometry of the imaging layout. The expression is valid in the cases of polychromatic quasi-plane and quasi-spherical incident waves, as well as for spatially incoherent, quasi-homogeneous and some other types of sources. We also discuss practical methods for measuring the relevant parameters of the incident radiation. More specifically, our formalism requires measurements of certain three-dimensional functions (such as the spatial distribution of incident intensity and phase at individual wavelenghts) as opposed to five-dimensional functions, such as e.g. mutual coherence, cross-spectral density or generalised radiance required in some previously reported alternative approaches [1-4]. Moreover, the experimental techniques that can be used to measure the relevant properties of the incident radiation ("source characterization") in our approach are exactly the same as the ones employed at the subsequent stages of the experiment for measuring the wave transmitted through objects of interest.

The results are expected to be useful in quantitative in-line imaging, phase retrieval and tomography with polychromatic and spatially partially coherent radiation. An application of the obtained formalism is presented in which analytical expressions are derived for the optimal defocus distance [5] and the critical source size [6] in in-line imaging of objects consisting predominantly of a single material using extended polychromatic X-ray sources. In particular, we show that in order for the in-line phase-contrast effects to be observable, the standard deviation of the intensity distribution of an incoherent source should be less than the following value:

$$\sigma_{\max} = \frac{M}{M-1}\left[R' \frac{\int S(\nu)\delta(\nu)\mathrm{d}\nu}{\int kS(\nu)\beta(\nu)\mathrm{d}\nu} \right]^{1/2},$$

where M is the geometric magnification (the ratio of the source-to-detector and the source - to-object distances), R' is the object-to-detector distance divided by the magnification, $n = 1 - \delta + i\beta$ is the complex refractive index of the object, k is the wavenumber and $S(\nu)$ is the frequency spectrum of the incident radiation.

References

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