Non-interferometric approaches to x-ray phase contrast imaging

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Introduction

X-Ray Phase Contrast Imaging (XPCI) has attracted great attention over recent years due to its capacity to overcome the basic limitations of conventional x-ray imaging – namely limited image contrast arising from small differences in attenuation. As well as enhancing the visibility of all details in an image and enabling the detection of features classically considered "x-ray invisible", phase methods are attractive because they can provide complementary signals on top of the conventional attenuation one – the phase shift itself and "dark field" signatures, which relate to the local degree of microscopic inhomogeneity in the imaged object. However for years phase methods were considered restricted to synchrotron facilities, which significantly hindered wider uptake and commercial translation. Over the last decade, however, methods have emerged that enable the implementation of XPCI with conventional laboratory sources.

Experimental methods

Most attempts at the lab translation of XPCI are based on making the conventional source sufficiently coherent by means of collimators, pinholes or source gratings. While this allows the detection of phase signals, it leads to flux limitations, and typically to systems that are particularly sensitive to external influences such as vibrations and thermal instabilities. We have observed that, by deliberately avoiding the generation of interference patterns and focusing on refraction alone (which is proportional to the first derivative of the phase shift), it is possible to detect strong phase signals also while employing relatively large focal spots. We achieve this by using apertured masks that are specifically designed to isolate the refraction signal, combined with sufficient demagnification of an extended focal spot to avoid mixing signals originating from adjacent apertures.

Results and discussion

We have shown that the above approach enables the detection of refraction angles of the order of 100 nanoradians in a standard lab, while employing fully polychromatic and divergent x-ray sources with focal spots of up to 100 micron (compatible for example with sources currently used in clinical mammography). This makes reasonably high x-ray fluxes readily available. Masks pitches are comparable to the pixel size in the used detector (50-200 micron range), which makes them easy to fabricate and cost effective also on relatively large scales. The resulting imaging system is relatively insensitive to displacements of the order of a few percent of the pitch itself, which is easily realizable in a standard lab also without vibration or temperature control. This has been tested on a range of applications across the life and physical sciences, often obtaining results that compare reasonably well with the synchrotron gold standard.

Conclusion

We expect that the combination of ease of implementation, system stability and relatively high available fluxes will facilitate the translation of XPCI to commercial system. Indeed we are currently working with a number of companies which have developed prototypes for applications in a range of areas, results from which will be presented in this talk.