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Fast, scalable, low-dose phase-based x-ray imaging with conventional sources

There is wide agreement on the transformative potential of phase-based approaches to X-ray imaging (X-Ray Phase Contrast Imaging - XPCI). The use of phase was proven to enable the visualization of features classically considered "x-ray invisible", and to enhance the visibility of all details in an x-ray image. This has huge implications in a variety of fields, from the earlier detection of life-threatening diseases in medicine to industrial and security inspection, through materials science, biology, archeology and many other areas.

So far, however, the translation of these advances outside physics labs and into the real world has proven problematic. The main roadblock is XPCI's requirements for source coherence: outside synchrotron facilities, this is obtained either by using microfocal sources, or by strongly collimating the output of a conventional source to make it sufficiently coherent.

In both cases this leads to systems that are suitable for proof-of-concept experiments, but very hard to translate –the limits being low flux leading to excessively long exposure times, delicate and difficult to align optical elements, small field of views, high delivered doses, etc.

We have developed a solution to this problem in the form of the first incoherent XPCI method. The main observation is that illuminating a sharp absorbing edge, also with a weakly collimated beam, makes a system extremely sensitive to small refraction angles. Since refraction is proportional to the first derivative of phase changes, this is sufficient to perform phase retrieval. Preliminary results indicate the potential to resolve refraction angles of 200 nanoradians and below using an uncollimated, divergent and polychromatic rotating anode x-ray source, which matches what much more complex, proof-of-concept systems based on coherent methods are capable of achieving outside synchrotrons.

Unlike those methods, we obtain this high phase sensitivity by means of low aspect ratio x-ray masks that are cheap, easy to fabricate, highly scalable. Indeed, a first prototype with 20 cm coverage (> 3 times over other existing system) has been built and is under test with our industrial collaborator Nikon Metrology UK. The presentation will briefly describe the way the method works, show examples of preliminary applications, and discuss possible strategies for prototype development and scaling up in various areas.

Summary

X-ray imaging methods based on phase have been explored that can completely transform all applications of x-ray imaging, in medicine and beyond. So far, attempts at translating these methods outside specialized facilities like synchrotrons proved problematic and suffered from –among others - long exposure times, excessive delivered doses, extreme sensitivity to vibrations and other environmental factors, small fields of view. We have taken a radical approach to the problem by eliminating the main source of the above limitations: the requirement for high source coherence. This led to a phase-based method that can be implemented with conventional, commercially available x-ray equipment and readily translated to robust, easily scalable, fast and low-dose imaging systems.

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