20 μm Resolution Multipixel Ghost Imaging with High-Energy X-Rays

S Shwartz[1], A Ben Yehuda[1], O Sefi[1], Y Klein[1,2], Z Sobol[1], B Bloch[1], H Schwartz[1], and E Cohen[3]

[1] *Physics Department, Bar-Ilan University, Ramat Gan, Israel*
[2] *Nexus for Quantum Technologies, University of Ottawa, Ottawa, Canada*
[3] *Faculty of Engineering, Bar-Ilan University, Ramat Gan, Israel*
Contact Email: sharon.shwartz@biu.ac.il

Hard X-ray imaging is essential across many fields due to its deep penetration, allowing visualization of structures that are opaque at other wavelengths. However, the resolution of conventional systems is constrained by detector pixel size and the thickness of scintillators, which must be increased at high photon energies, leading to scattering and image blur. While ongoing efforts aim to improve resolution by developing thinner scintillators or enhancing X-ray sources and lenses, these approaches face significant technical challenges. As a result, most current systems are limited to resolutions of a few hundred microns—insufficient for detecting micro-cracks or subtle anatomical features. Computational ghost imaging (CGI) offers an alternative by illuminating objects with known patterns and reconstructing images from intensity correlations [1]. CGI is robust to scattering and effective in low-light conditions, though standard implementations are too slow for large objects.

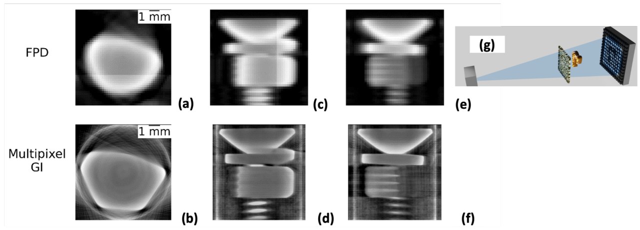

Figure 1: Results – Comparison between tomograms of a M4 screw reconstructed using the FPD (top row) and using our multipixel CGI method (bottom row). The tomograms are shown from top view (a and b), from front view (c and d) and from side view (e and f). (g) – Schematic description of the experimental system

We extend CGI to a multipixel approach using a tungsten X-ray tube (80 keV), a gold-patterned mask (15 µm features), and a flat-panel detector (205 µm pixel pitch). The mask was mounted on high-precision motorized stages and placed close to the object to reduce penumbra. Low-resolution images taken at various mask positions are processed with the CGI algorithm to reconstruct overlapping high-resolution patches, which are then stitched together.

We applied this method to reconstruct a high-resolution 3D CT volume ($8.6 \times 8.6 \times 8.8$ mm^3) of an M4 screw assembly, clearly resolving fine features such as thread pitch and nut facets, which are barely visible in conventional FPD CT as shown in Fig. 1.

In summary, we demonstrated a scalable, high-resolution X-ray imaging technique based on patterned illumination, achieving a 420,000-pixel image with only 1,000 measurements, $\sim$100$\times$ faster than standard CGI, and extended it to 3D imaging for potential use in non-destructive testing, biomedical imaging, and mammography.

References

[1] F Ferri, D Magatti, A Gatti, M Bache, E Brambilla and L A Lugiato, Phys. Rev. Lett. **94**, 183602 (2005)