Coded Apertures for X-Ray Imaging with Spectral Selectivity

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Motivation

- Laser wakefields can be used for electron acceleration, and to generate a high energy electron beam[1]
- This electron beam can be used for x-ray generation, via numerous mechanisms:
  - Betatron, Bremsstrahlung, Inverse Compton, Synchrotron / XFEL
- Can be used as an x-ray backlighter for imaging

Advantages	Disadvantages
– Small source size (µm[2])	– Low flux
– Short pulse duration (fs[3])	– Broadband spectrum
– Large x-ray energy ranges attainable (0 – 10 MeV[4])	

- Innovative detectors are required to optimally image objects using these sources, and spectrally differentiate the energies

Coded Aperture X-Ray Imaging

- Emission from an unknown source is backscattered from the object to the aperture
- The pinholes collectively create a coded image on the detector
- This can be decoded to reconstruct an image of the original object

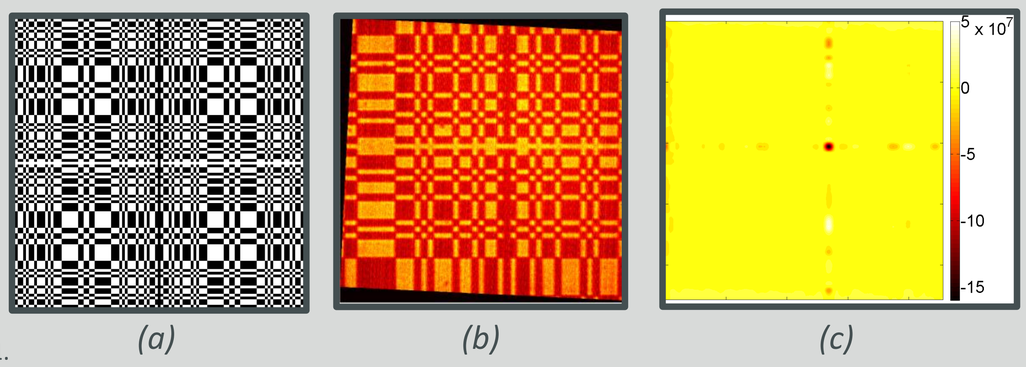

Figure 1.
(a) A typical MURA[5] mask, smallest element of 320 µm. This was used to image a blue LED onto an Andor Neo camera, *(b)*. This was deconvolved to reconstruct the image of the LED, *(c)*.

- Assumes black region of the mask is optically thick to the energies imaged
  - Noise is uniform after image reconstruction, regardless of its original structure[5]
    - Compared with a single pinhole:
      - Greater signal throughput whilst conserving the spatial resolution
        ∴ can image with greater sensitivity
      - More directional field of view

X-Ray Imaging with Spectral Selectivity

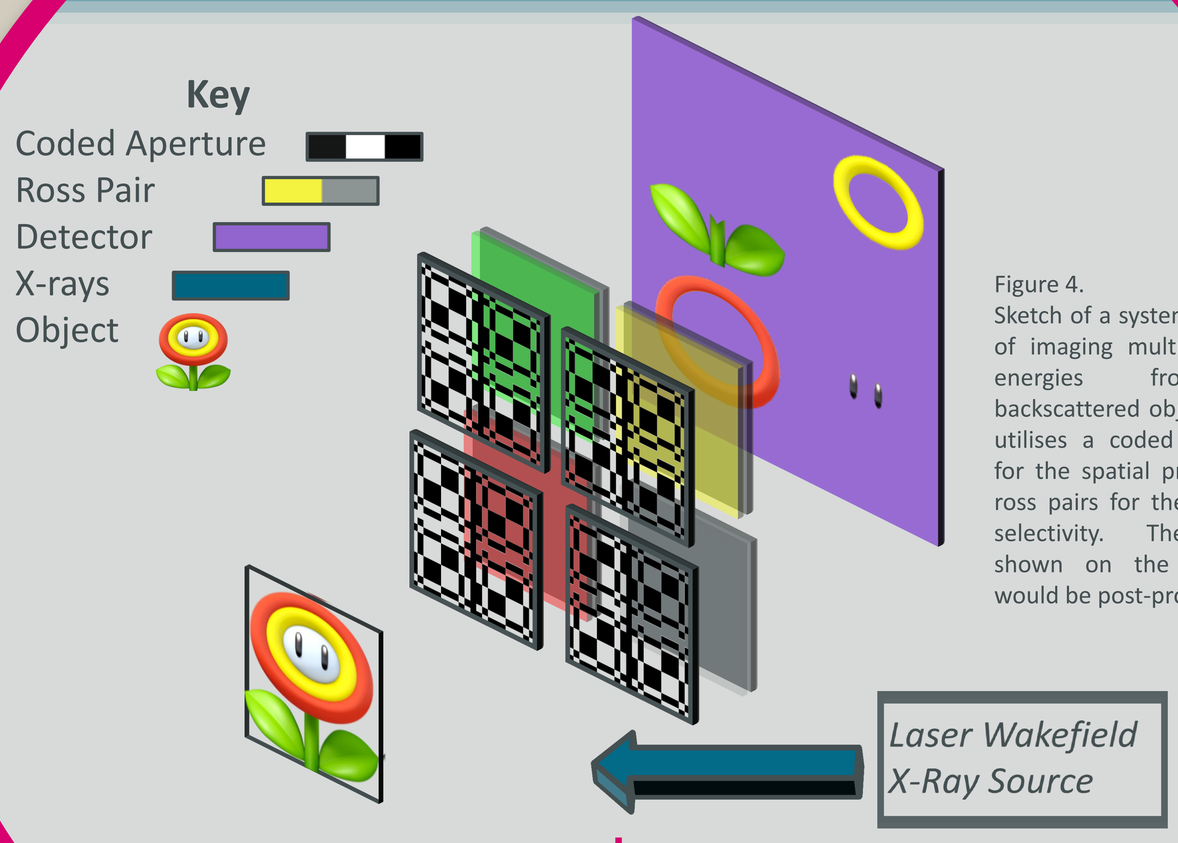

Figure 4.
Sketch of a system capable of imaging multiple x-ray energies from a backscattered object. This utilises a coded aperture for the spatial profile and ross pairs for the spectral selectivity. The images shown on the detector would be post-processing.

- Coded aperture images the object onto the detector
  - Increased throughput makes backscatter imaging viable
- The energy of each image is known from the ross pair
- The disadvantages of laser wakefield x-ray sources can be overcome

Spectral Selectivity

- Ross pairs can be used to selectively transmit specific energy regions[6]
  - Two elements of near-adjacent atomic number
  - Thicknesses chosen to match transmission intensity for all regions except between the *K* absorption limits
  - Creates a "pass band" filter between the two limits

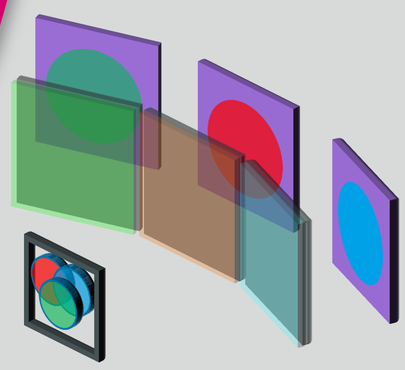

Figure 3.
Sketch depicting how multiple ross pairs can be used to separate the energy bands within source. Colour has been used as an analogy for energy.

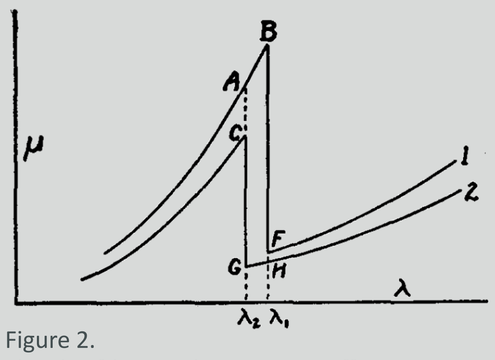

Figure 2.
Sketch of linear absorption coefficients, μ, against wavelength, λ, for a ross pair. The dissimilarity of the *K* jumps is exaggerated. Image reproduced from[6].

Conclusions & Further Work

- Coded apertures may be used in conjunction with ross pairs and filters to image an object with spectral selectivity
- To utilise the resolution limit of a smaller x-ray source, coded apertures may be necessary to increase throughput
- Further simulation is necessary to aid design for an implementable imaging system
- Investigation into micro-machining techniques may be necessary for micron-resolution coded aperture masks

Acknowledgements

This work was supported by the Engineering and Physical Sciences Research Council [EP/L01663X/1], Scitech Precision, and the Science and Technology Facilities Council.

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