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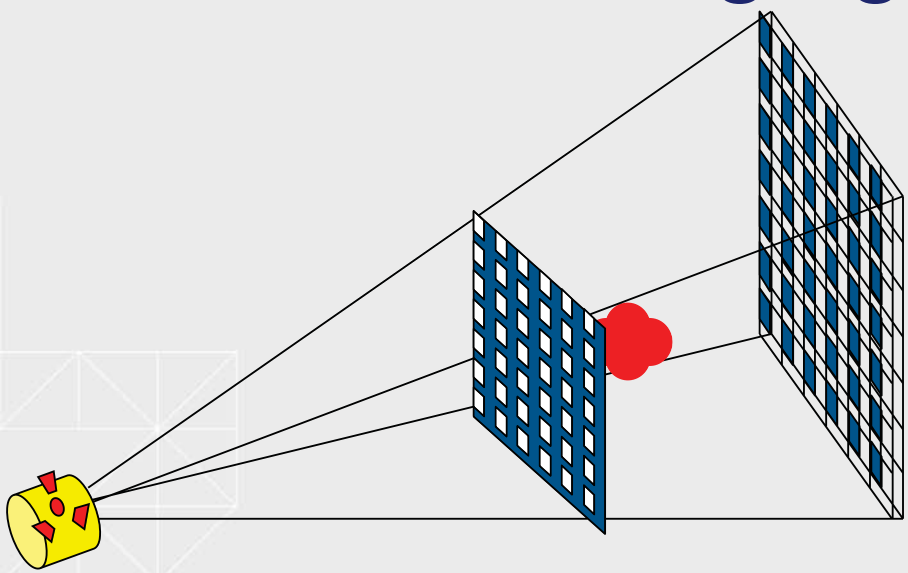
Enhanced Detection of weapons and explosives through x-ray phase contrast and dark field imaging



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ASDA 2014
Northeastern University, Boston, Mass - May 10-11 2016

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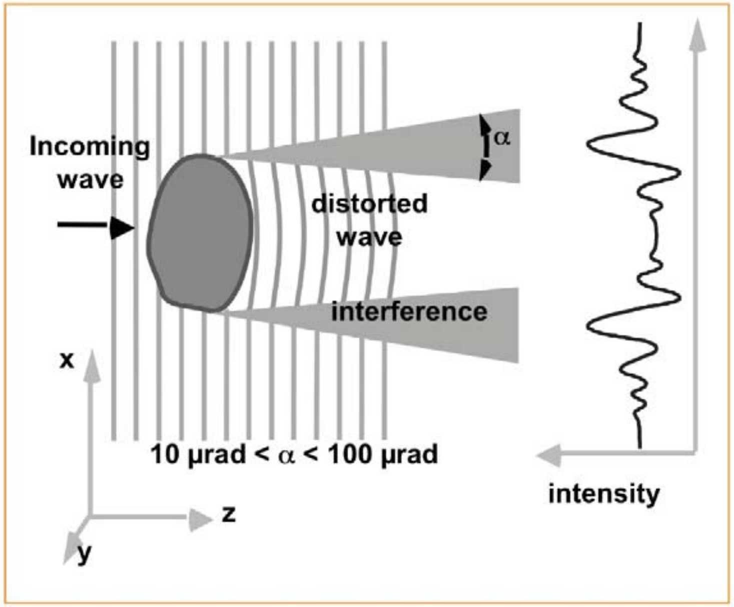
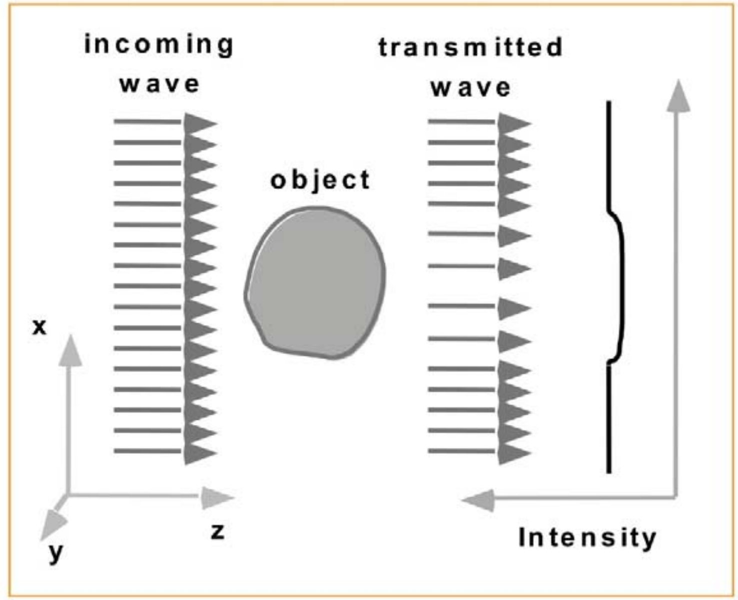
- Addressed area: carryon baggage inspection
- Problem solved: **practical** x-ray phase contrast imaging system
- Solved how? – **incoherent** implementation of XPCI
- Why should people care:
    - Delineation of all objects in a bag (differential phase)
    - Explosive discrimination potential (dark field)
    - Could combine both and “color-code” images

Phase Contrast vs. Conventional X-Ray Imaging





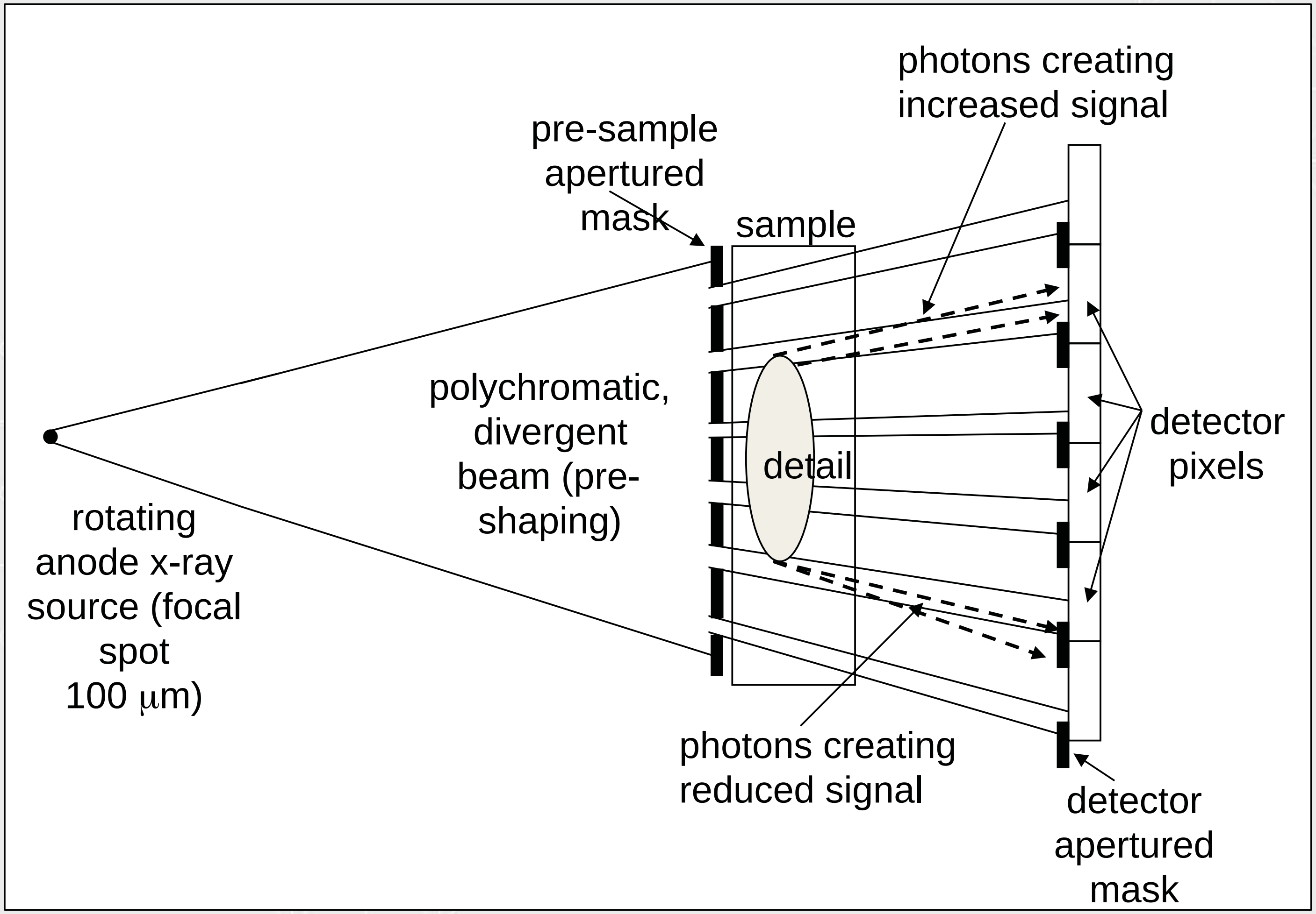
Refractive index: $n = 1 - \delta + i\beta$; $\delta >> \beta$ ->

phase contrast ($\Delta I/I_0 \sim 4\pi\delta\Delta z/\lambda$) >> absorption contrast ($\Delta I/I_0 \sim 4\pi\beta\Delta z/\lambda$)

Two possible approaches:
- **detect interference patterns**
- **detect angular deviations**

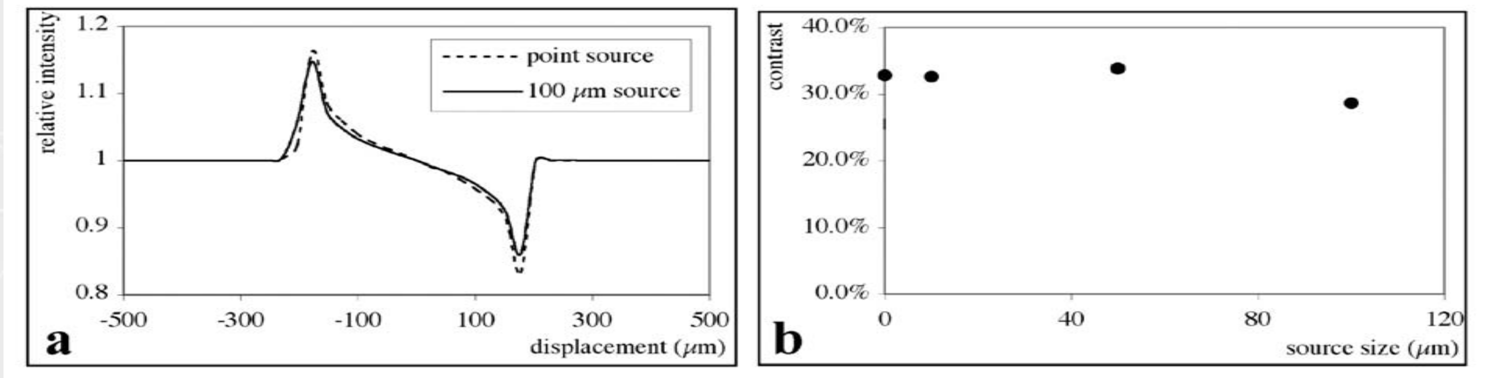
Coherent approaches suffer when transferred to conventional sources

THE METHOD CAN BE ADAPTED TO A DIVERGENT AND POLYCHROMATIC (=conventional) SOURCE



Olivo and Speller Appl. Phys. Lett. 91 (2007) 074106

Little loss of signal intensity for source sizes up to 100 μm



Which can be achieved with state-of-the-art mammo sources

Why?

1) Because we are only relying on refraction, which survives under relaxed coherence conditions;
2) Because we are use aperture pitches matching the pixel size, i.e. BIG: the projected source size remains < pitch, and therefore blurring does "not" occur.

Olivo and Speller Phys. Med. Biol. 52 (2007) 6555-73

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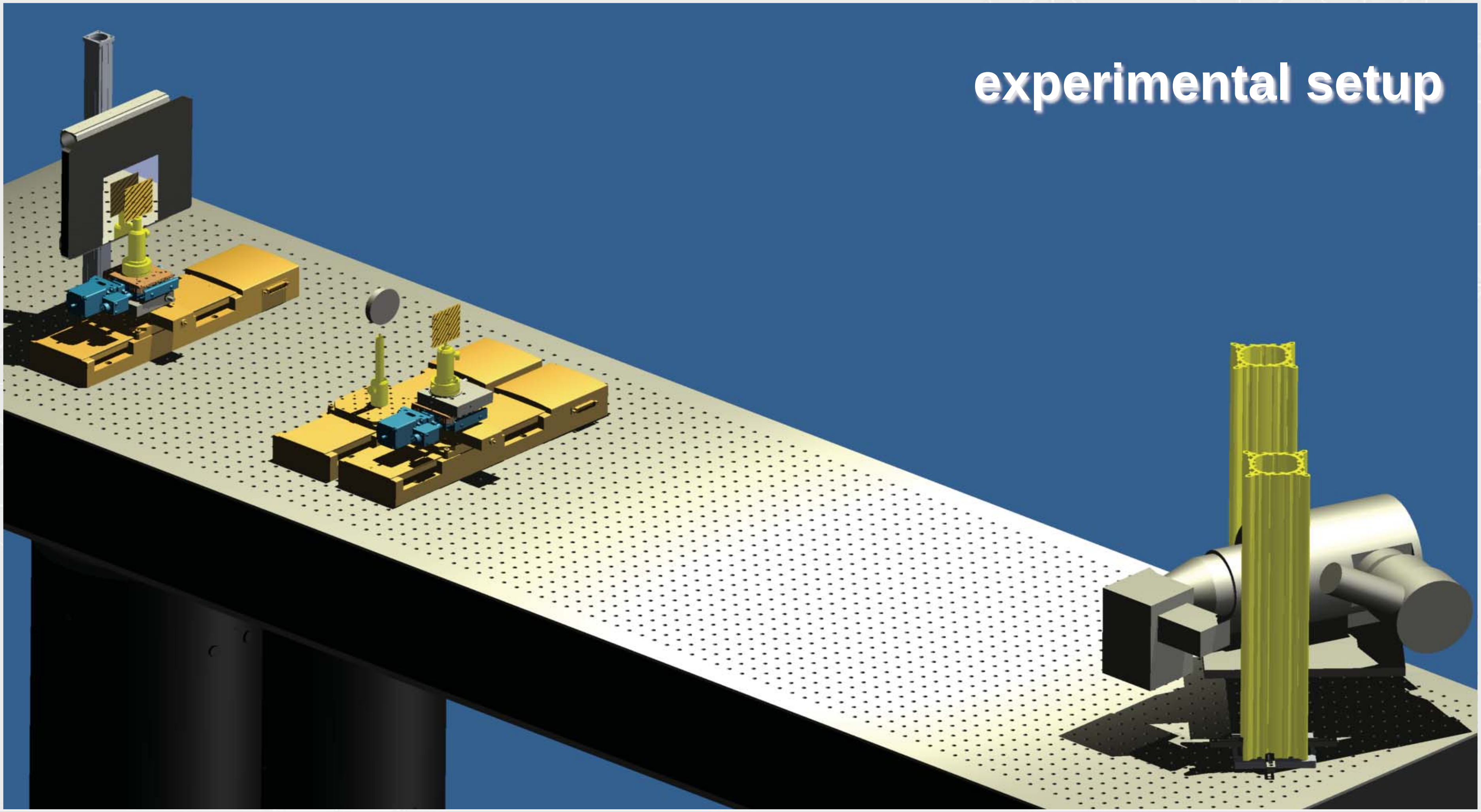
experimental setup



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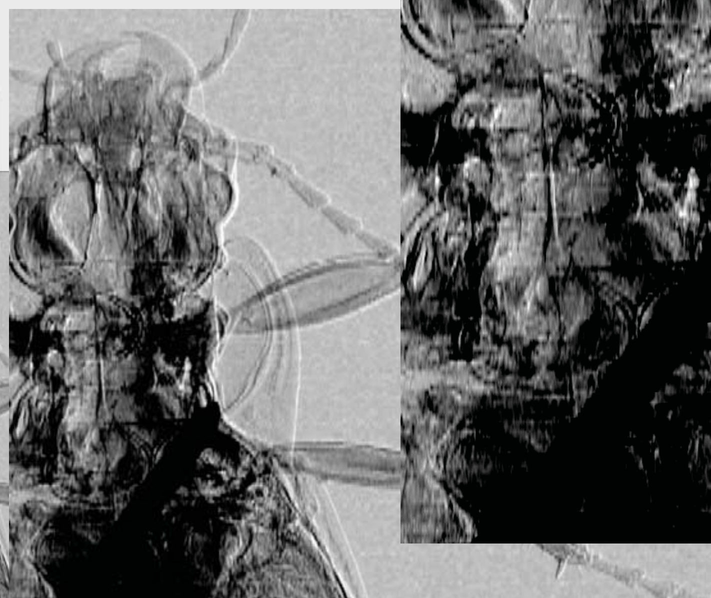
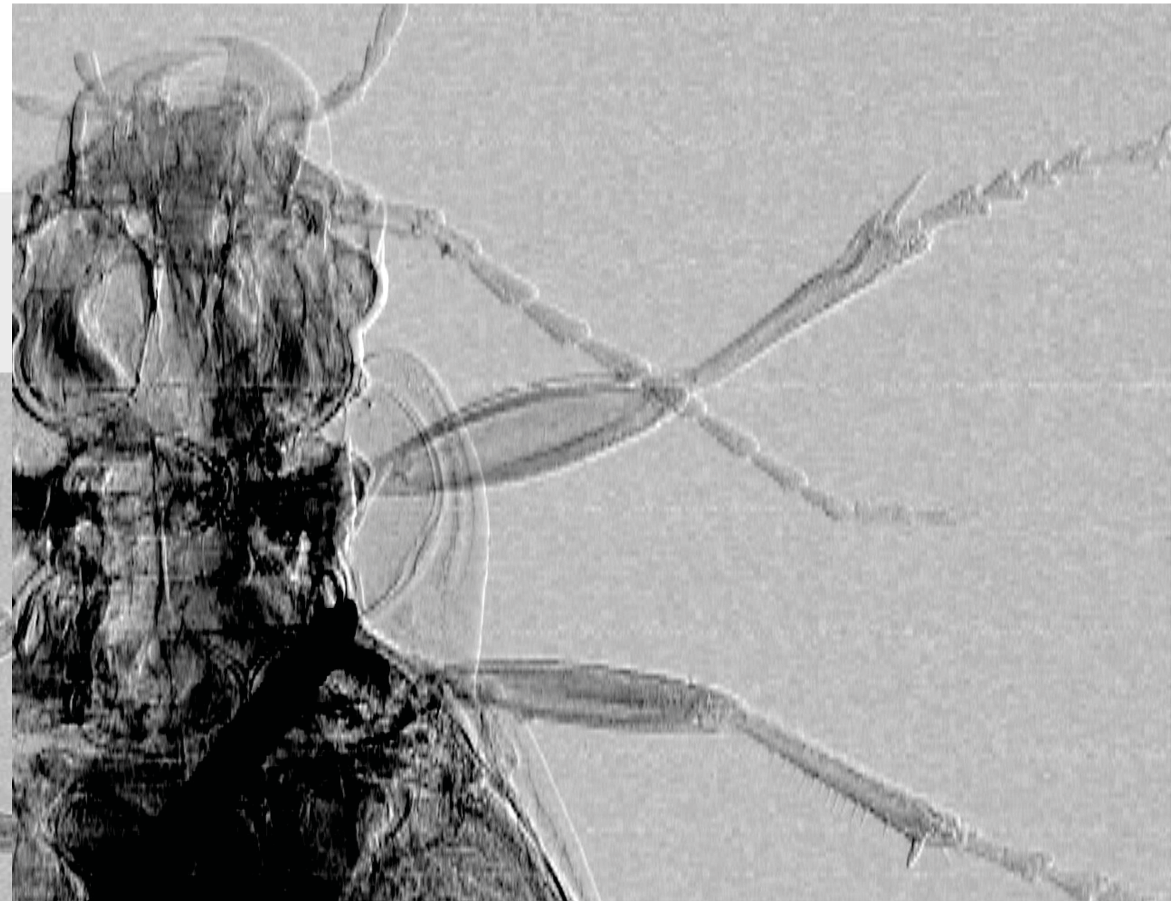
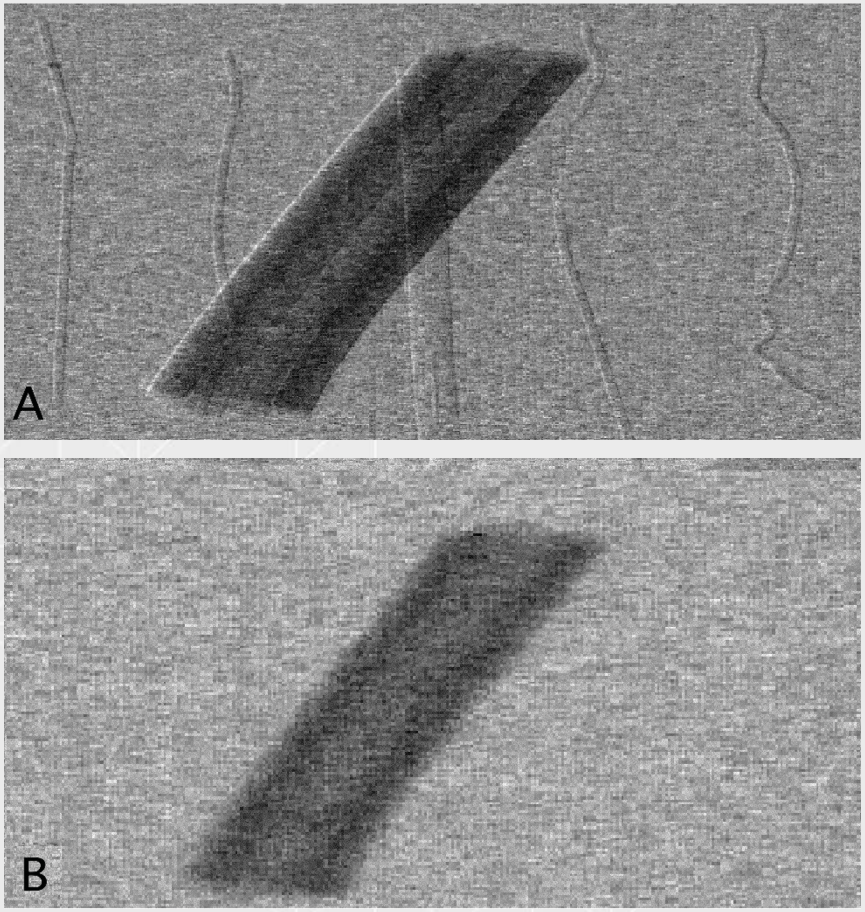
Preliminary results

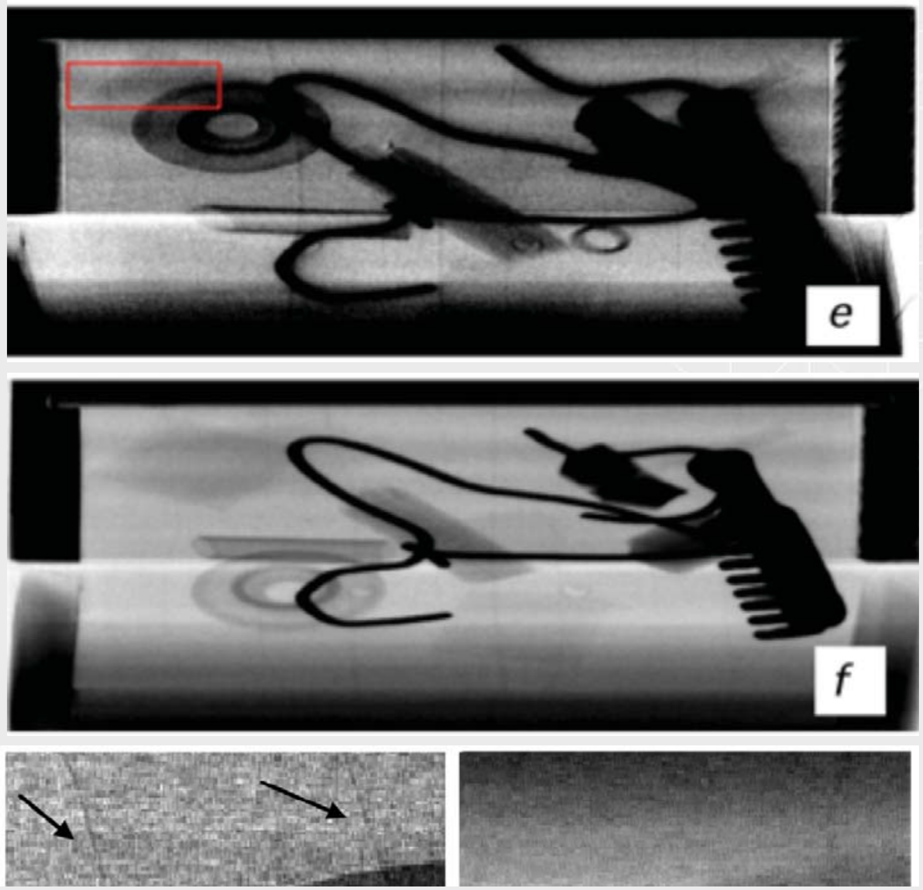




Differential phase used in previous project



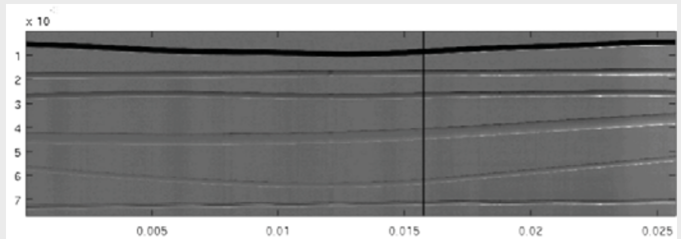
Olivo *et al* Appl. Opt. 50 (2011) 1765-9



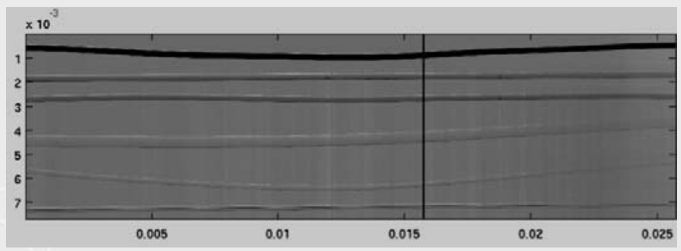
Ignatyev *et al* Materials 4 (2011) 1846-60

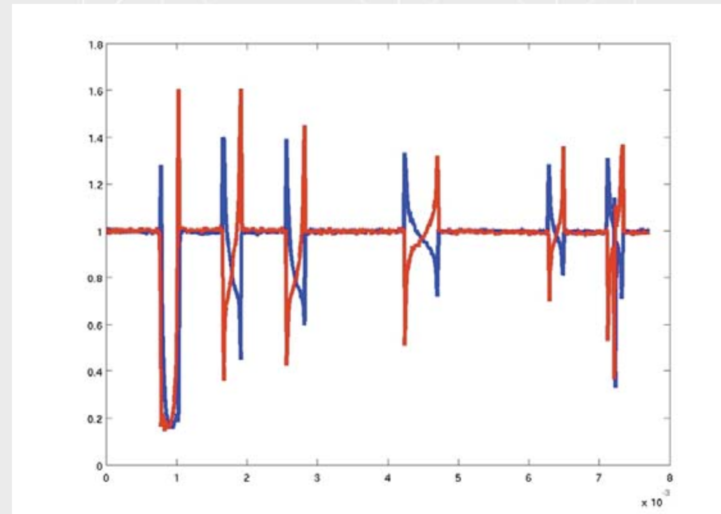
Quantitative phase contrast imaging

"SLOPE -"

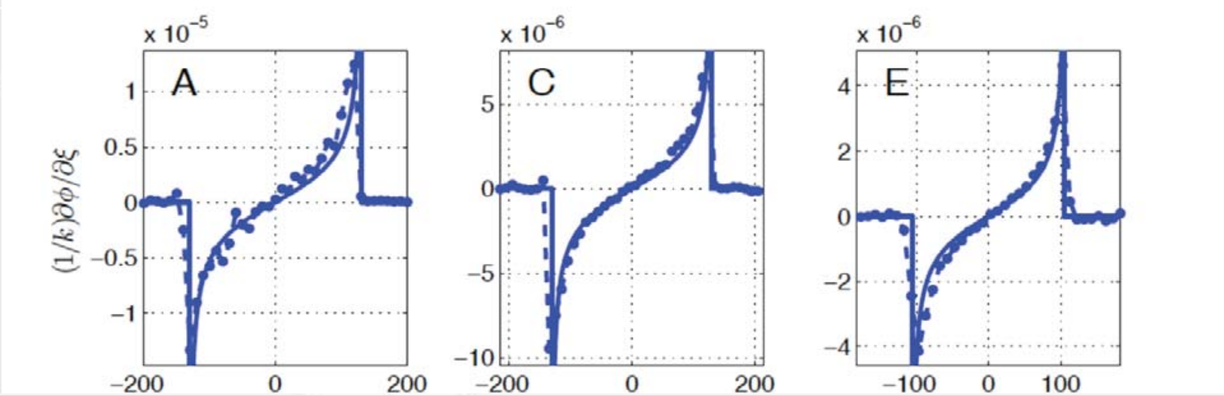


"SLOPE +"





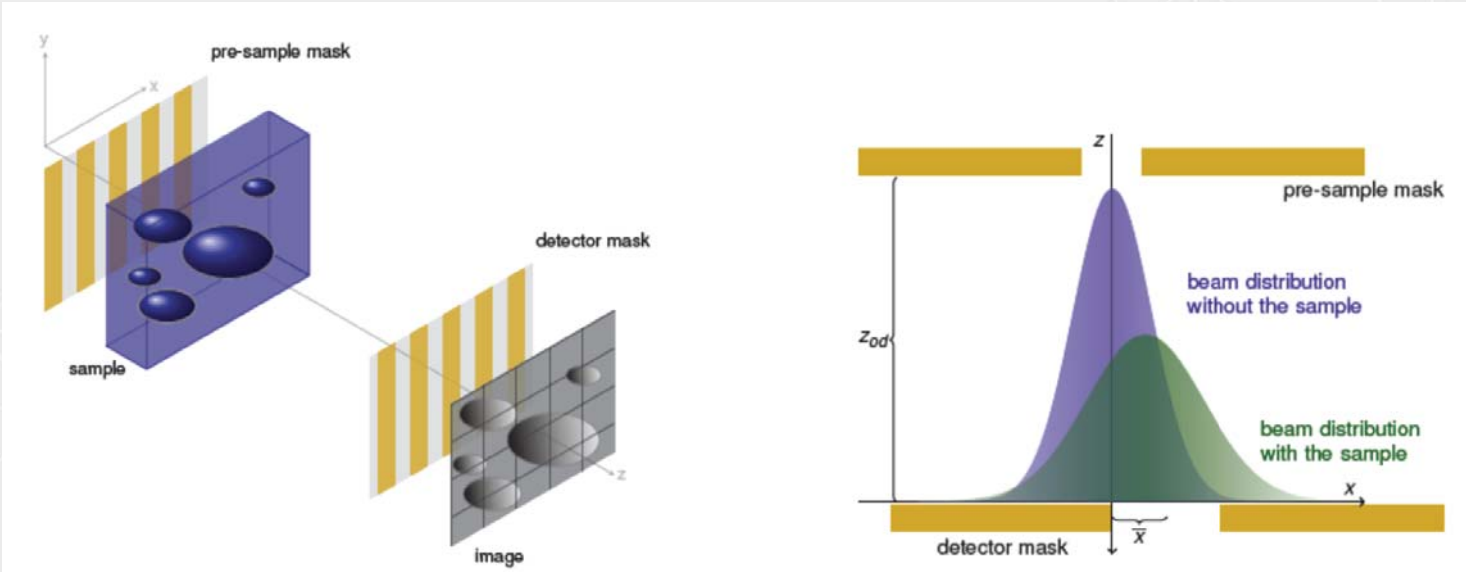
Titanium Aluminum PEEK

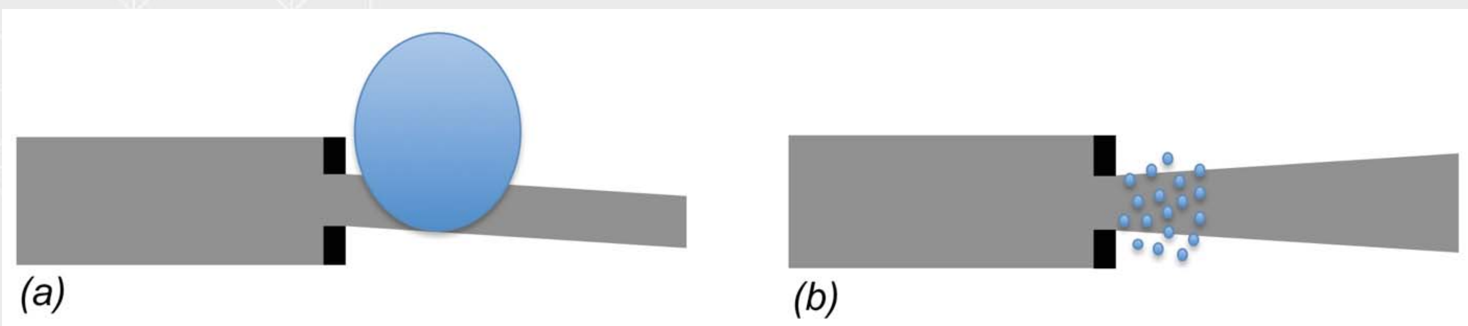


Highly precise retrieval, for both high and low Z materials, up to high gradients where other methods break down

Munro *et al* Opt. Exp. 21 (2013) 647-61

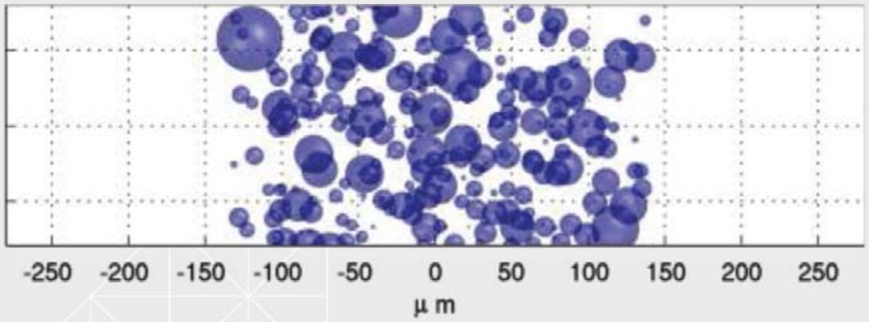
Three-shot DARK FIELD IMAGING retrieval

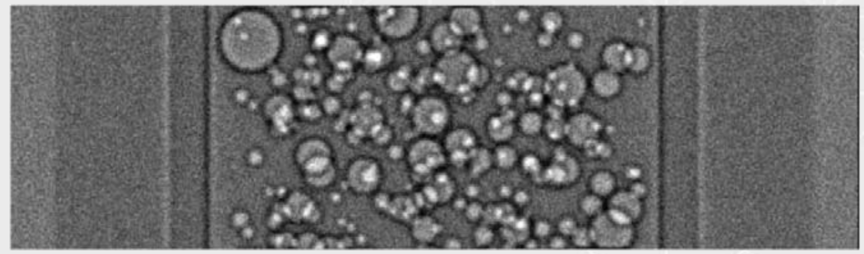




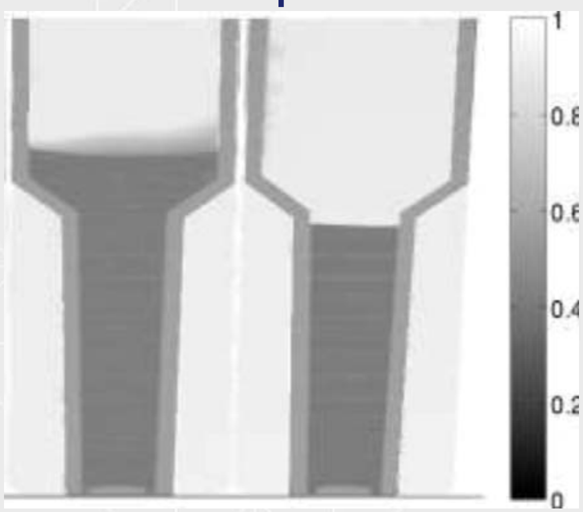
Endrizzi *et al*, Appl. Phys. Lett. 104 (2014) 024106

Example of what images might look like: microbubbles - a new concept of “phase-based” x-ray contrast agent



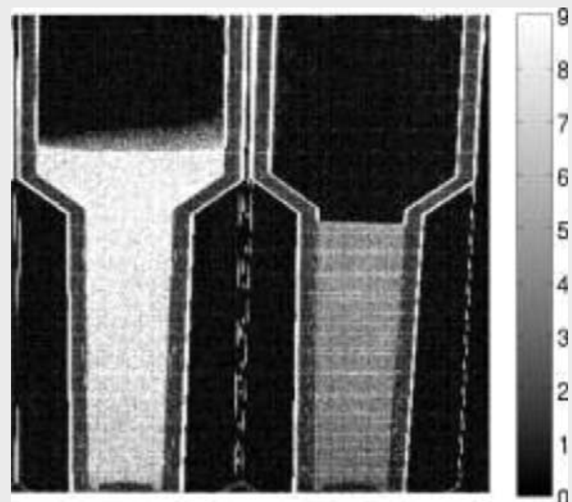


absorption



bubbles no bubbles

dark field



bubbles no bubbles

Millard et al. Appl. Phys. Lett. 103 (2013) 114105

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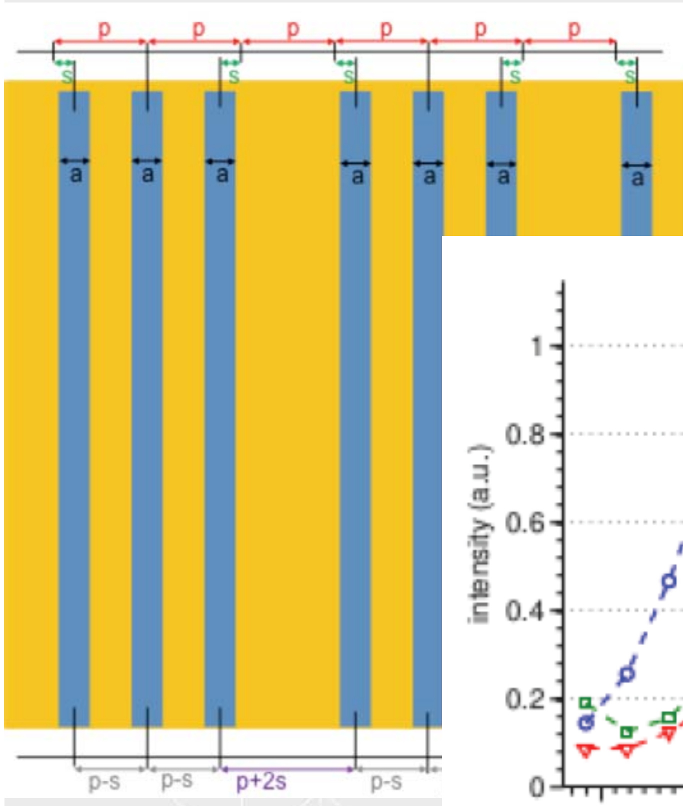
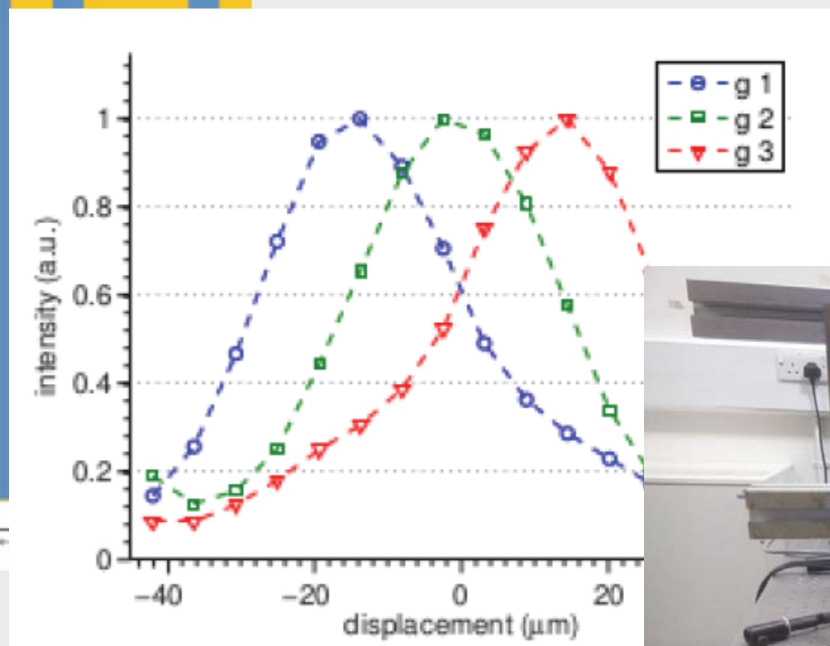
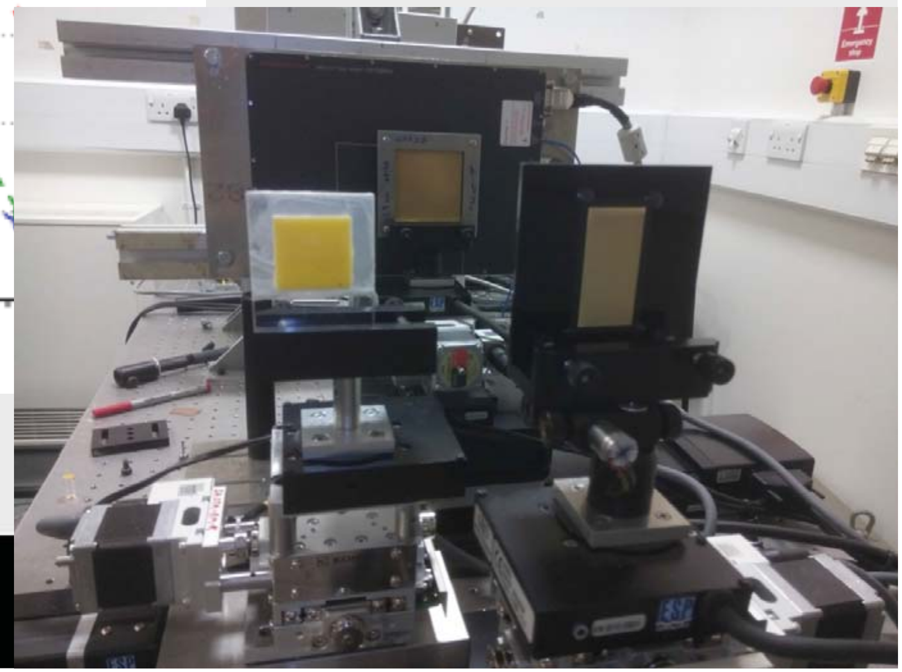
Avoid having to collect multiple frames: "asymmetric" mask + scanned acquisition







Endrizzi et al, Sci. Rep. 6 (2016) 25466

- We have tested the dark field method on explosive vs. benign materials on a range of samples and demonstrated that discrimination is possible;

- We have repeated all the above measurements with the asymmetric masks-based scanning method (all components of the imaging system kept still, three outoput images obtained simply through sample scanning) and obtained exactly the same results as with the “static” system requiring three input images (paper in preparation)

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UPSCALING: 20 cm masks (largest in the world as far as we know) obtained by tiling 3 smaller masks; no inherent issue in tiling more.

Energies up to 100 kVp, further increase possible

Scan speeds of several cm/s with lab system, can be esily increased.

First tests extremely

-> IT CAN MAKE PHASE CONTRAST HAPPEN

unpublished

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Conclusions:

Edge-illumination XPCi is a NON-INTERFEROMETRIC, TOTALLY INCOHERENT, QUANTITATIVE x-ray phase contrast method working with conventional sources which:

allows the use of fully divergent, fully polychromatic x-ray sources with focal spots of up to at least 100 μm - with no additional collimation/aperturing

requires aperture pitches of the order of ~50-100 μm - therefore making fabrication, alignment and scale-up (masks are available up to 30 cm) easier.

has been described both by wave & geometrical optics (but for source sizes like the ones we use they give the same results) and **robust phase and dark-field retrieval was achieved.**

Applications are underway in various areas including security, where we have built a large-area, high x-ray energy (100 kVp) demonstrator: the next step is to test it on real bags containing a mixture of explosive, non-threat materials and cluttering objects.