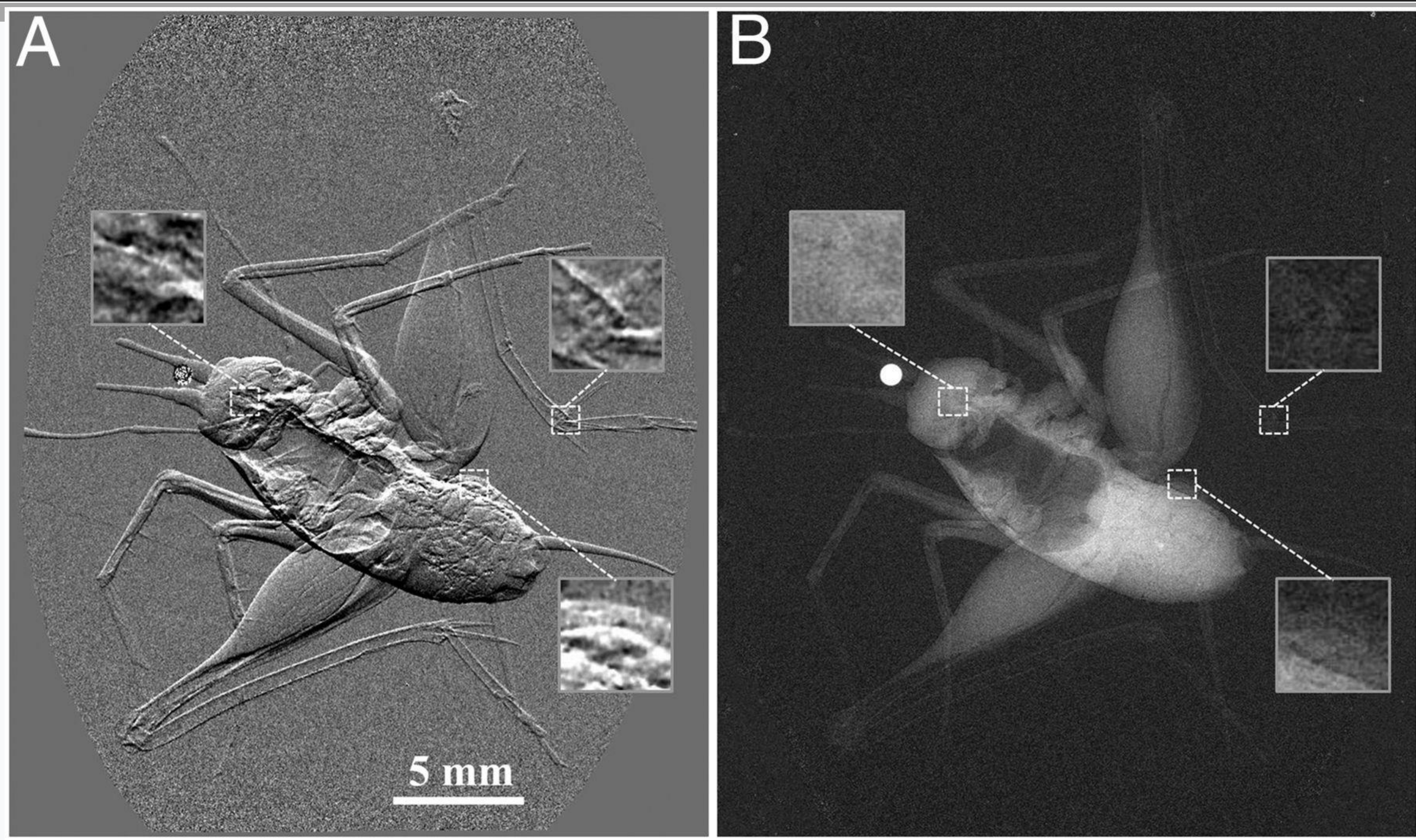
FUSION-BASED ALGORITHM FOR X-RAY PHASE CONTRAST IMAGING TECHNIQUES

Master student, Technician at XIL:
Rășinar Cezara-Diana

nuclear physics
X-ray Imaging Laboratory

Phase Contrast Imaging

- ➢ Promising refraction-based X-ray imaging technique
- ➢ Improved visibility for soft tissue
- ➢ Potential to reduce the radiation dose
- ➢ Enables the visualization of three types of contrast images

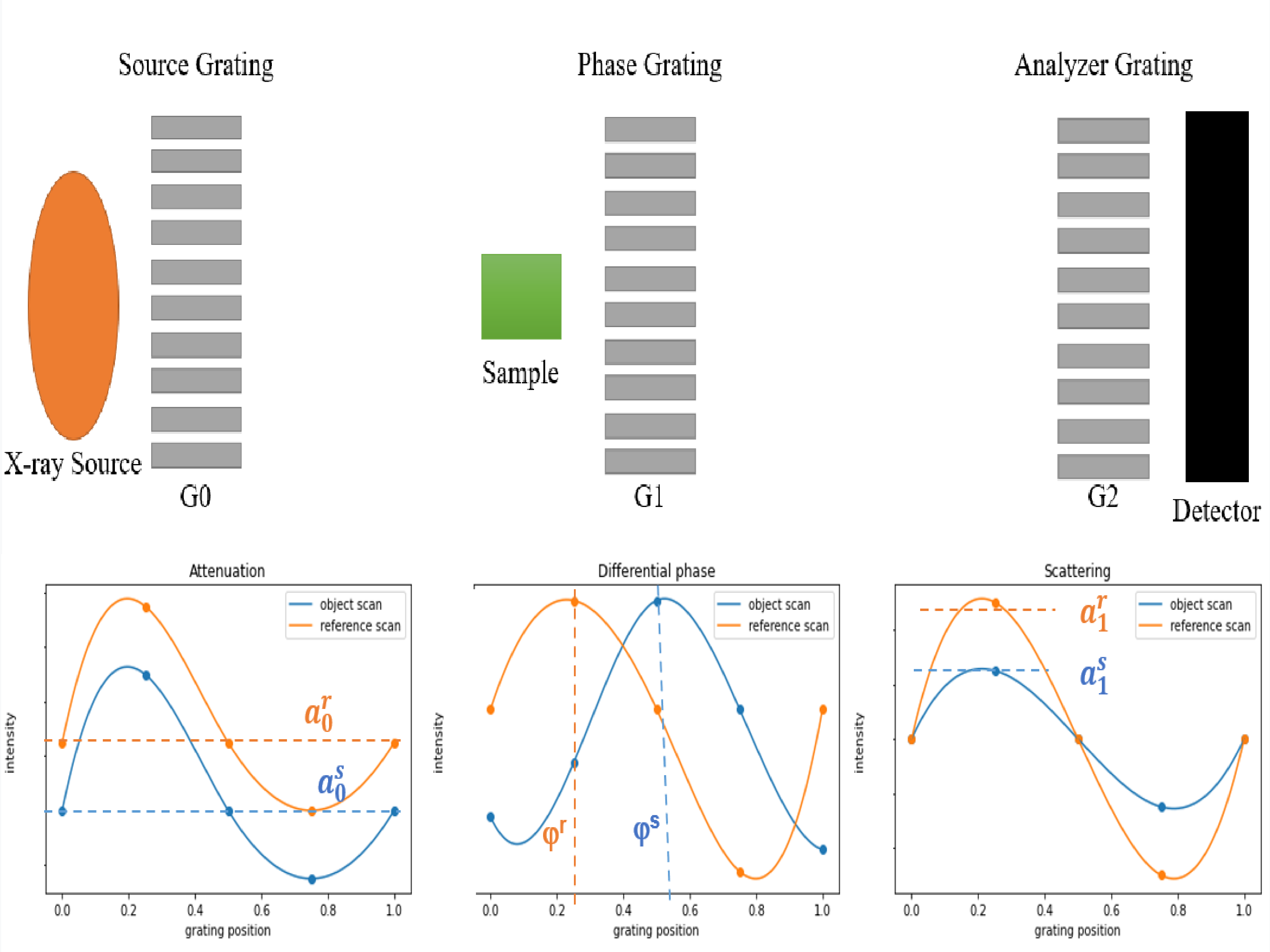


Houxun Miao et al. 2013 [1]

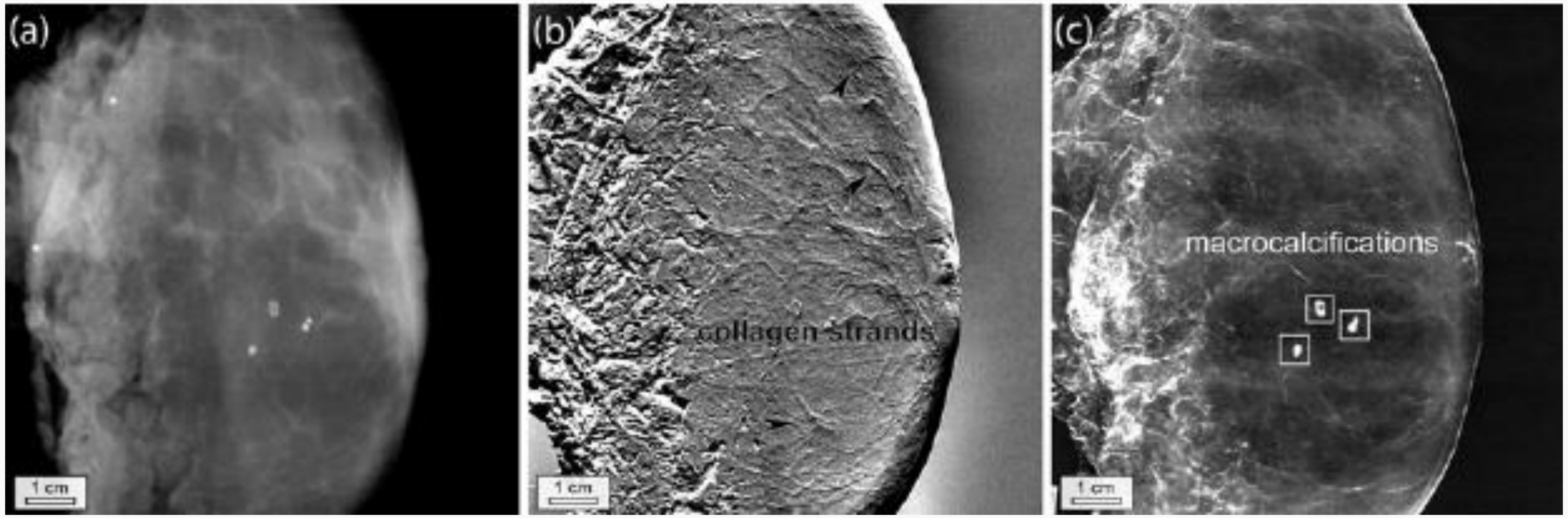
Grating Interferometry Technique

➢ **Talbot-Lau Interferometer set-up, consisting of 3 micro-periodic gratings, an X-ray source and a detector.**

➢ **Principle of attenuation, differential phase and scattering computing, for each pixel.**



Phase stepping method



Wen et al [2]

Attenuation

$$T = \frac{a_0^s}{a_0^r}$$

Phase contrast Imaging

$$\Delta\varphi_x = \frac{\lambda d}{p_2}\frac{\partial\phi}{\partial x}$$

Dark-field

$$D_x = \frac{V^s}{V^r}$$

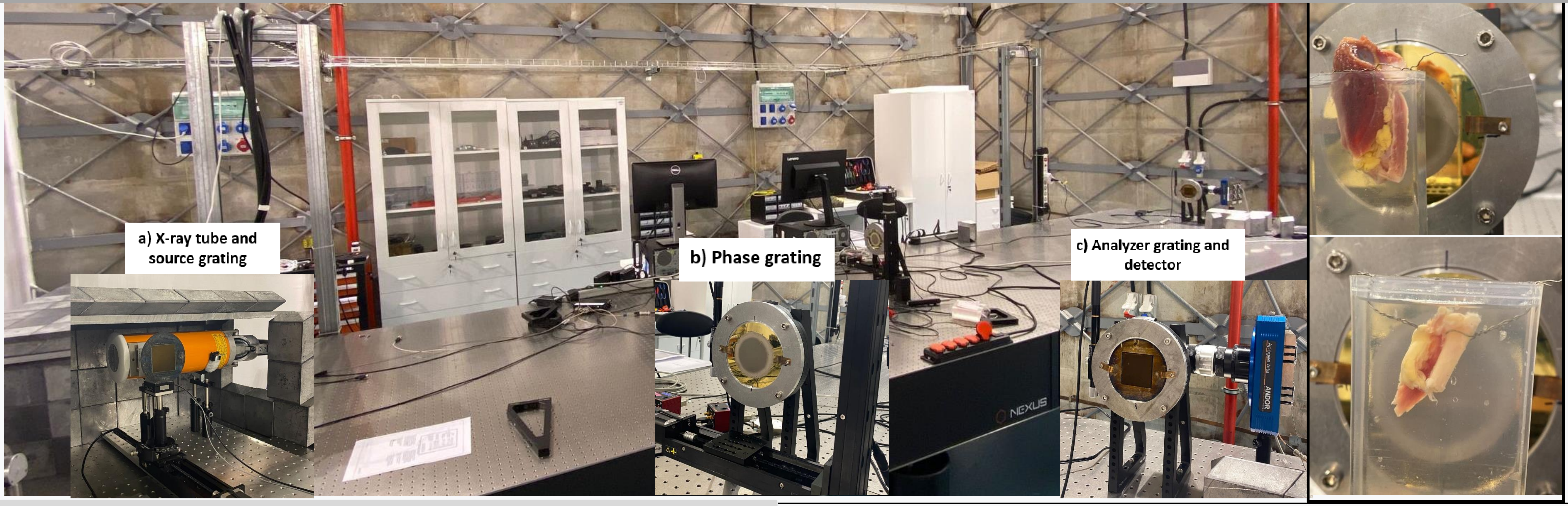
What if we find a method to merge just the meaningful information in one single image?

- Complementary information, provided by the three signals of an ablated breast recorded with a conventional X-ray tube source. [2]

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \cdot 100$$

where I_{max}, I_{min} - maximum and minimum values of the intensity pattern produced by the phase grating in each detector pixel

Experimental set-up

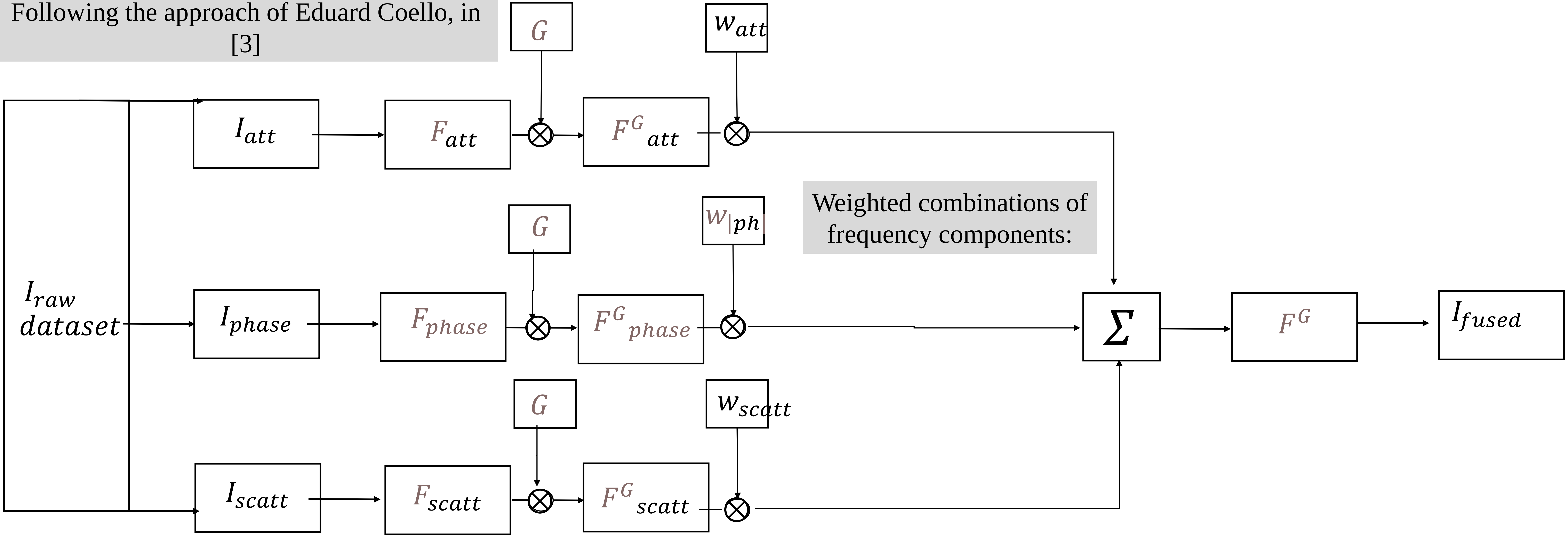


5.66 m Long Talbot-Lau Interferometer, consisting of 2.4 µm period gratings, within X-ray Imaging Laboratory from ELI-NP

Angular Sensitivity	0.82 µradians
Fringe Visibility	15%
Mean Energy	30 keV

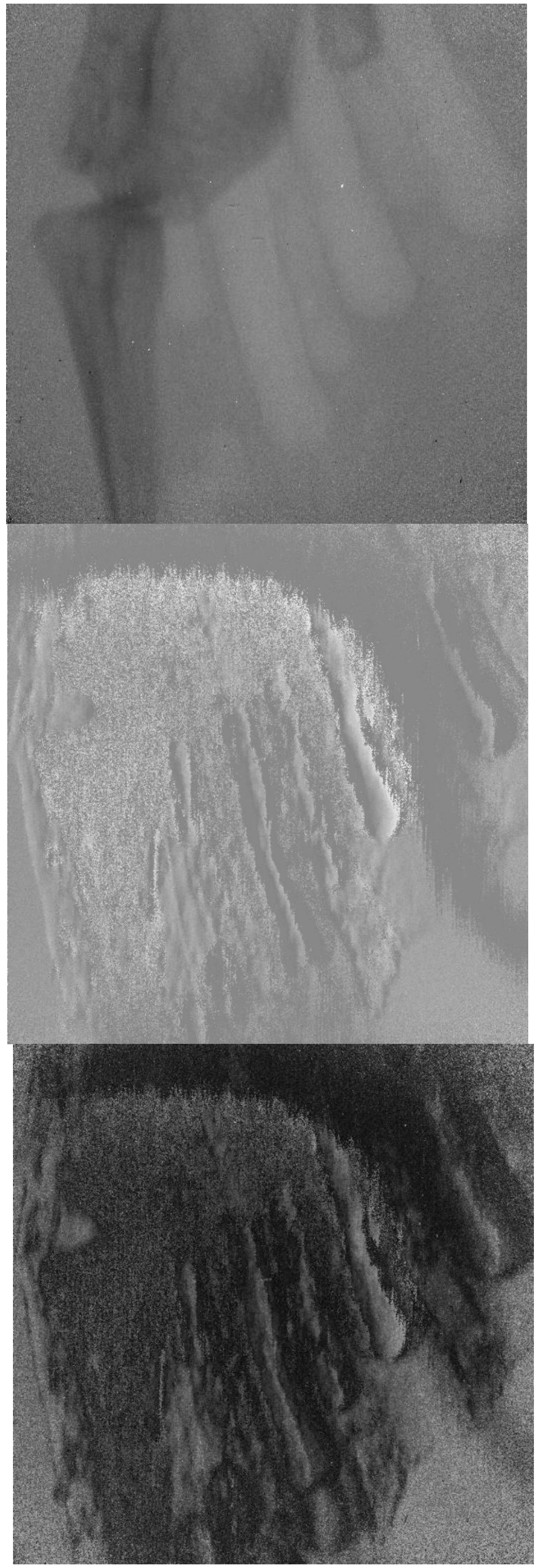
Image Fusion Algorithm

Following the approach of Eduard Coello, in [3]



Weighted combinations of frequency components:

Apply 2D TFD , and compute Gaussian function

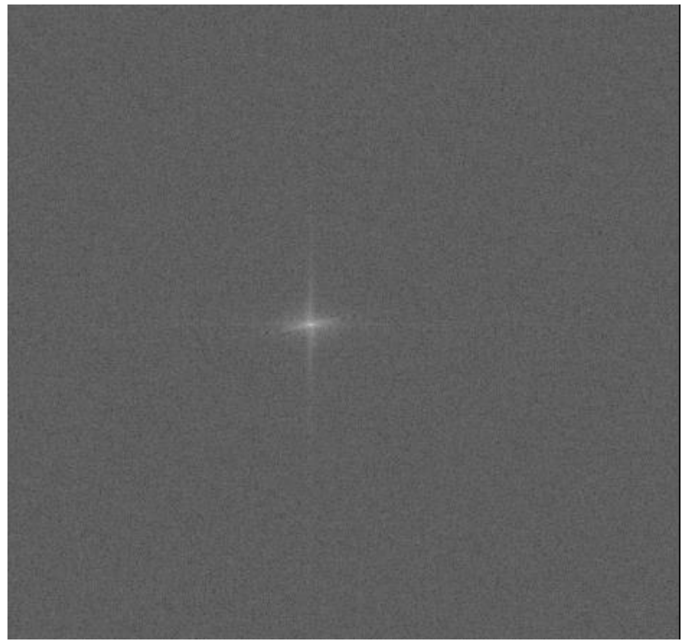


$$F_{att}(u,v) = F\{I_{att}(x,y)\},$$

$$F_{|phase|}(u,v) = F\{I_{|phase|}(x,y)\}$$

$$F_{scatt}(u,v) = F\{I_{scatt}(x,y)\}$$

2DFT

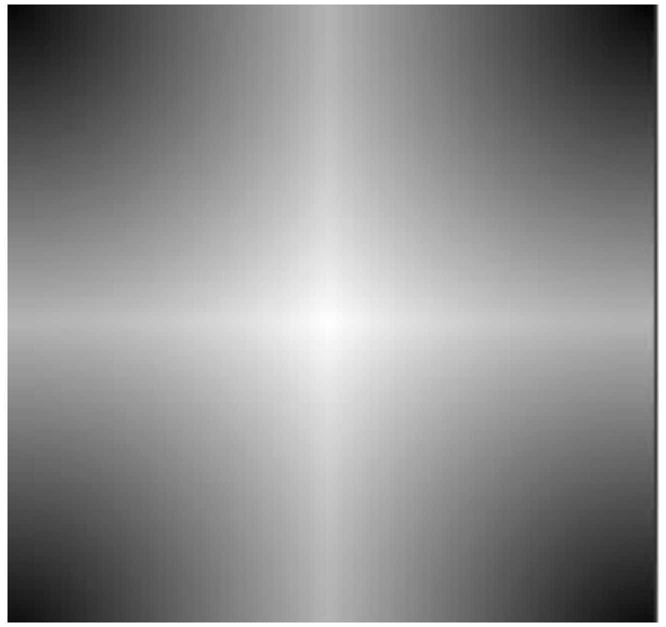


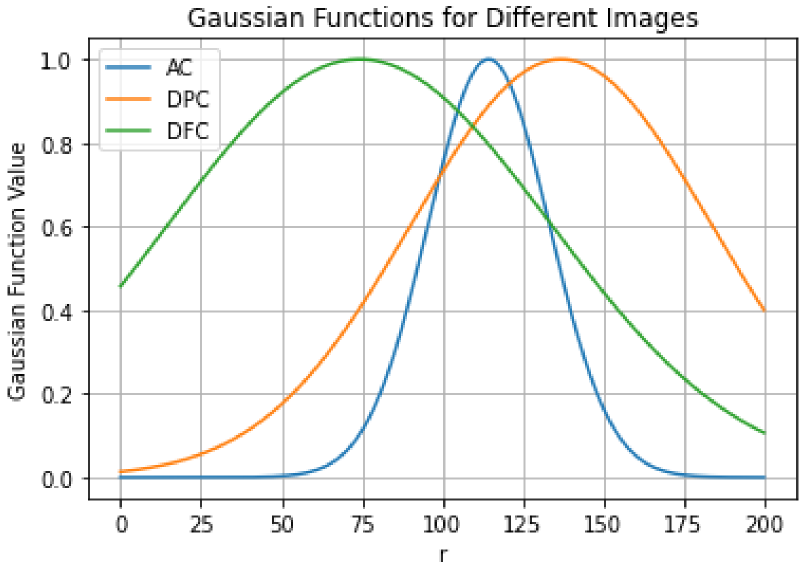
Frequency domain:

$$r(u,v) = \sqrt{(u^2 + v^2)}$$

$$G(\mu,\sigma,r) = exp(-\frac{(r-\mu)^2}{2\sigma^2})$$

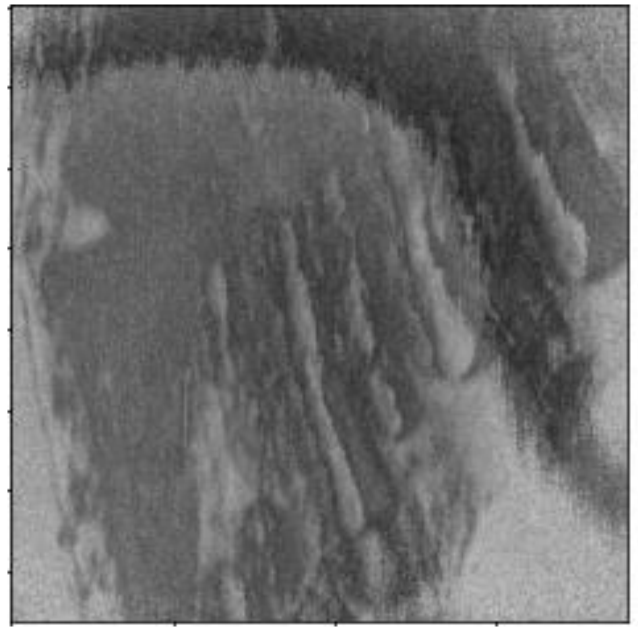
2D *Gaussian*





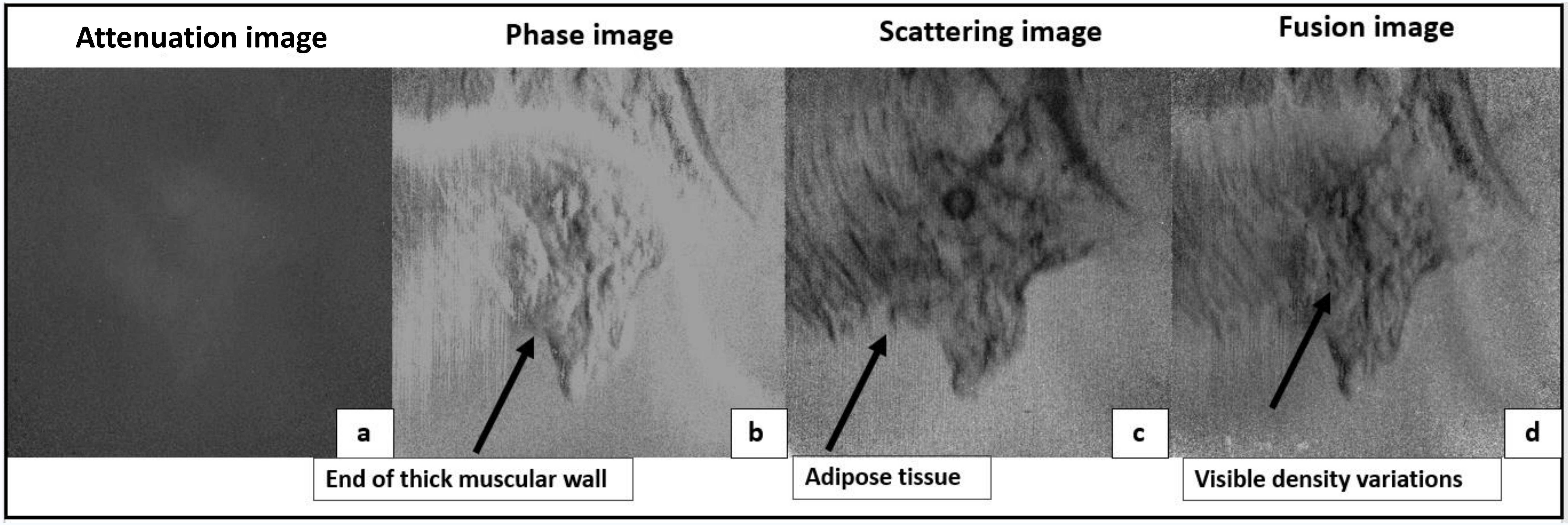
$\mathbf{F}\mathbf{G} \equiv w_{att}\mathbf{F}_{att}\mathbf{G} + w_{phase}\mathbf{F}_{phase}\mathbf{G} + w_{scatt}\mathbf{F}_{scatt}\mathbf{G}$

Σ



- where w_{att}, w_{phase} and w_{scatt} are corresponding weights
- the assignment of the constants depends on the nature of the investigated tissue

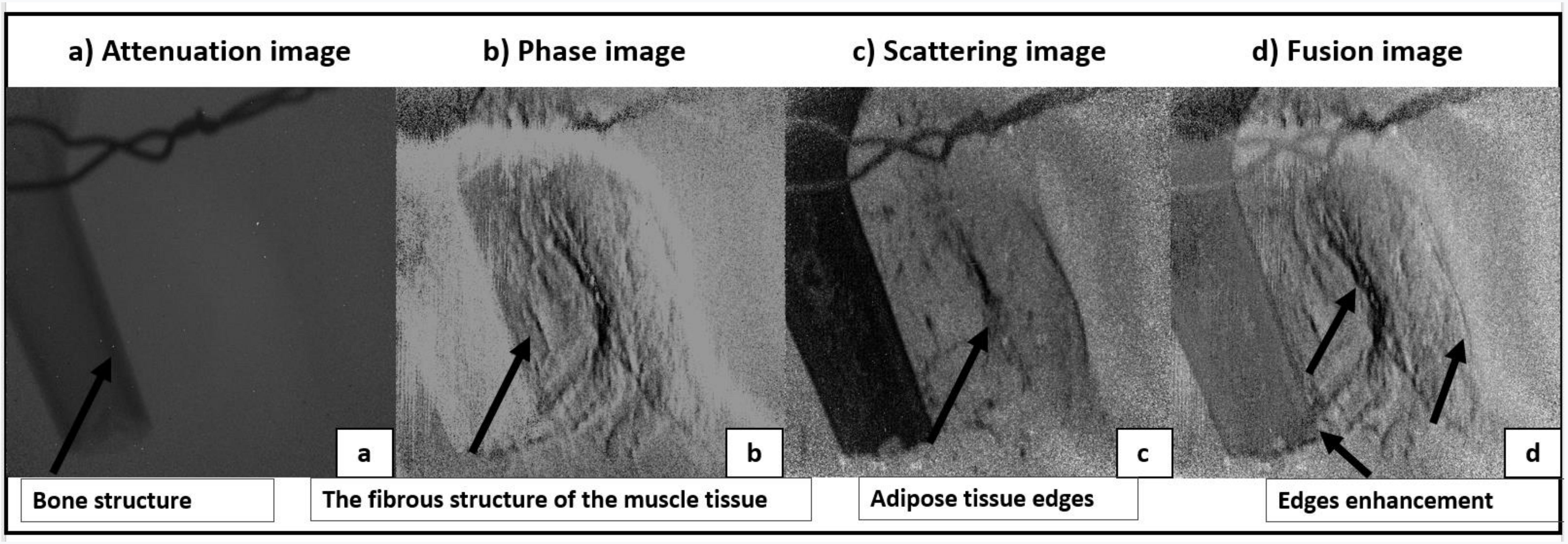
Results



Experimental results for a chicken gizzard. a. attenuation image; b. differential phase contrast image; c. scattering image; d. fusion image (with the weighting constants set as follows: w_{att} =1, w_{phase} =3 ,and w_{scatt} = 6)

- **the fiber-like texture of the thick muscle is preserved**
- **small density variations in the adipose and muscular tissue**
- **sharpness increase**
- **noise reduction**

Results



Experimental results for three different types of tissue: bone, muscle, and adipose matter.
a. attenuation image; b. differential phase contrast image; c. scattering image; d. fusion image (with the weighting constants set as follows: $w_{att} = 1$, $w_{phase} = 5$, and $w_{scatt} = 4$)

- ➢ **small differences in density variations**
- ➢ **feature enhancement**
- ➢ **better margin delineation**

Conclusions

- a new approach, improving the visualization of complex objects, composed of different types of tissues
- Talbot-Lau Interferometer with an ultrahigh sensitivity of 0.82 μrad was employed
- two objects, consisting of different types of tissue, have been investigated
- phase-stepping method for image processing: three contrast images: attenuation, phase and scattering
- significant improvements in merging the individual content of each signal with different percentages
- edge and feature enhancement, and better visualization of structural characteristics of tissue, noise reduction

THANK YOU

eli
nuclear physics

XIL
X-ray Imaging Laboratory

Bibliography

- *Eduardo Coello, "Fourier domain image fusion for differential X-ray phase-contrast breast imaging", Eur. J. Radiol., vol. 89, pp. 27–32, Apr. 2017.*
- *Wen H, Miao H, Bennett EE, Adamo NM, Chen L. Flexible retrospective phase stepping in x-ray scatter correction and phase contrast imaging using structured illumination. PLoS One. 2013 Oct 31;8(10):e78276. doi: 10.1371/journal.pone.0078276. PMID: 24205177; PMCID: PMC3814970.*
- *Auweter SD, Herzen J, Willner M, Grandl S, Scherer K, Bamberg F, Reiser MF, Pfeiffer F, Hellerhoff K. X-ray phase-contrast imaging of the breast--advances towards clinical implementation. Br J Radiol. 2014 Feb;87(1034):20130606. doi: 10.1259/bjr.20130606. PMID: 24452106; PMCID: PMC4064551.*