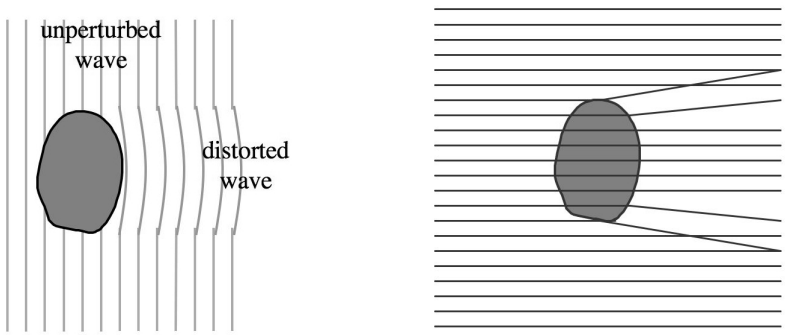
**Working principle of the AXIm XPCI method**

The interaction of x-rays with matter can, to first approximation, be described through the complex refractive index $n$:

$$n = 1 - \delta + i\beta$$

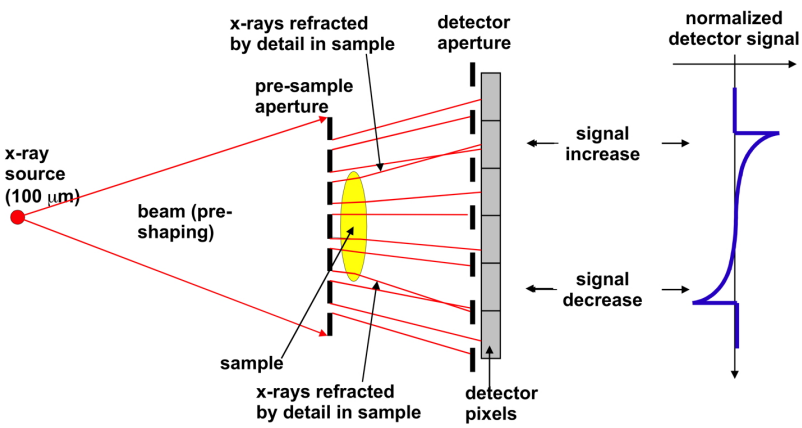
Conventional x-ray imaging only exploits the imaginary part $\beta$, responsible for attenuation, while the unit decrement of the real part $\delta$, responsible for phase effects, is discarded. However, for most materials $\delta$ is much larger than $\beta$ - often up to 1000 times larger.




This means that also an object opposing little or no attenuation to x-rays will phase shift the x-ray beam, creating a distortion of the x-ray wave front, as can be seen on the left hand side of the above figure. This is what happens in the more realistic "wave optics" description of the phenomenon.

However there is a significantly simplified description that makes this more easily understandable on an intuitive level – ray-optics. In this approximated representation, x-rays travel along straight lines which are orthogonal to the wave front. Hence a wave front distortion translates into a small change in the direction of x-rays, as depicted on the right hand side of the above figure. This is x-ray refraction: indeed, refraction happens for x-ray as it does for visible light, only at much smaller angles.

The drawing on the right hand side of the above figure is a vast exaggeration of the phenomenon: in truth, typical x-ray refraction angles are on the order of the microradian: the angle subtended by 1 mm placed 1 km away. The challenge is therefore being able to develop a lab-based system that can pick up such small deviation angles.




The way our method does this is schematized in the above drawing. We use two masks – one before the sample, one in contact with the detector. The first one splits the beam in a plurality of individual "beamlets", the second creates insensitive regions between adjacent pixels of an x-ray detector. The two masks are slightly misaligned, such that every beamlet hits the edge of an aperture on the detector

mask. In this way, a minimal movement of each beam due to refraction will translate into a difference in the number of x-rays detected by the corresponding pixel. In the configuration depicted above, a upward and downward deflections lead to an increased and decreased number of counts, respectively. By means of this simple mechanism, phase changes that are invisible to a conventional imaging system are translated into intensity changes, which are instead detected.