Developments in X-Ray Imaging in Micron Sized Samples

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Since the discovery of X-rays in 1895 by Wilhelm Rontgen, x-ray imaging has become a consistent method used to produce images of material that does not contain a consistent density or composition (i.e. Human body, the Earth). Dr. Carolyn MacDonald and Dr. Tianxi Sun, a pair of researchers at the University of Albany are leading advancements through 2013 in x-ray imaging methods by obtaining high resolution images of small sample sizes by using confocal polycapillary x-ray optics. The two researchers combined their knowledge of x-ray imaging and optics and established an experiment where they were able to reproduce a magnified image of their sample. The researchers hope they can create a consistent way to generate high quality images of samples on the micron scale. If so, this development could be extremely significant toward real world applications in various professions, specifically the healthcare professions.

X-ray imaging research will always be important in our modern day society. Our healthcare system will always be in need of greater technology, better equipment to help enhance care provided. Border control services specifically airports, also will always be in need of greater equipment. Due to actions in the past, border security and safety has become an extremely important issue in all countries. As our modern day society, our understanding and need for smaller items is becoming more essential. As our science is expanding toward nanotechnology such as carbon nanotubes, if our research could provide x-ray imaging on that level of length, the results found could be huge moving forward.

The pair of researchers used a technique called focusing x-ray optics, which is a common application in x-ray imaging. To perform focusing x-ray optics, our researchers can find the focus by reflecting x-rays from an x-ray source through a parabolic mirror followed by a hyperbolic mirror. The focus will be the point where all our reflected x-rays will converge to. Our researchers then placed the sample, which would be on the size of micrometers, a small displacement to the right of our focus. If our researchers placed our sample on our focus point, our divergent beams would overlap and our image will appear completely blurred. As the x-ray beam diverges from the focus through the sample, a collimating optic is then used to help guide our x-rays to the detector. In doing this, our researchers are able to achieve an enlarged image of the sample on our detector by confocal polycapillary optics.

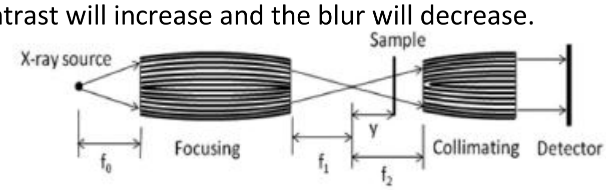
The confocal nature of our setup is generated by the displacement of our optics. A confocal setup occurs when the focus of the first optic is the source of the second optic, the focus of the second optic is the source of the third optic and so on. The polycapillary optic in our setup is composed of many small monocapillaries; each capillary will collect x-rays and by total reflection pass them onto our detector. Our researchers will use a polycapillary optic to collect our x-rays because they are able to collect x-rays in a wide energy band from large divergent angles.

Mathematically, we are able to show total magnification of our optic system. By looking at the separate magnifications of our focusing and collimating optics and were able to find our total magnification.

$$M_{total} = M_f M_c; \qquad M_{total} = \left(\frac{f_2}{y}\right)\left(\frac{D_{input}}{D_{output}}\right)$$

where D_{input} and D_{output} are the diameters of our collimating optics.

Magnification of our system will also affect our system`s contrast and blur effects. Blur is what causing our images to look distorted while contrast helps our image to look more clear and sharp. Were able to define the relationship between blur and contrast; if the distance from the collimating lenses to our detector is decreased, contrast will increase and the blur will decrease.



Our pair of researchers executed their experiment with use of an Oxford Microfocus Mo x–ray tube as their x-ray source and Fuji computed radiography plate (pixel size of about 50 micrometres) as their detector. Their setup contained a 105 mm focusing optic that was placed 50 mm in front of our x-ray source in confocal series with a 70 mm collimating optic. Using specific parameters, they were able to find the total magnification of our object as 5X. Using a resolution phantom, our researchers examined the intensity and the contrast of our optic system. They were able to deduce that the intensity of our contrast shown on the resolution phantom could be modelled by a Gaussian distribution. They also found when using an addition of an Nb filter, our x-ray beam will become more monochromatic and enhances the contrast of our object. With an increase of contrast, we will also see an increase of intensity of our object. Our researchers concluded that the contrast of their optic system is defined by $C = e^{-\frac{\left(\frac{2\pi}{\Lambda}\right)^2 (1.3\theta_C(f_2-y))^2}{2}}$. With their system parameters they found that our critical angle of divergence as $\theta_c = 1.7mrad$ and the contrast as 69%. Much of the loss contrast was contributed to the system`s geometrical blur. They found that if they move the object away from the focus point the blur would be reduced, however the magnification would decrease.

Next steps in this field would be to generate a greater magnified image on our detector, and to create a series of focusing and collimating optics that are specially designed for x-ray imaging. Our researchers were able to deduce that the level of magnification can be displayed in terms of its geometrical blurring. Future work should attempt to reduce the amount of blurring that occurs from the divergence of our x-ray beams. Change and addition to our setup will also be important moving forward; using a smaller resolution phantom would provide our system with a greater magnification. Likewise, if our altered our optics to contain a larger input diameter and a smaller output diameter our system will obtain a greater magnification of our image. The next step in this field would be to achieve a consistent way to produce high resolution, highly magnified images that show samples on the size of micrometers. These images would provide extremely useful in our healthcare professions, security and safety professions, research professions and various other fields (i.e. x-ray photography).

RSS Feed paragraph

Researchers at the University of Albany are making breakthroughs in X-ray imaging technology. Dr. MacDonald and Dr. Sun are using the properties of optics with x-ray imaging to find image quality of samples on the micron size. Our researchers are focused on finding a way to consistently produce high quality images with a high contrast, high magnification and a reduced blur.

Interview with Dr. MacDonald

1. Can you briefly explain your path through school/career? To your position now at the University of Albany.

2. What about x-ray imaging interests and motivates you?

3. What other research areas are you interested in.

4. Can you explain more in detail about how the resolution phantom?

5. How small can the small sample be (millimeters?, micrometers?)

6. Can could we apply this to real world scenarios.

7. You stated in the paper, that the focusing and collimating optic were not designed for x-ray imaging. Can you explain more in detail why this is?

8. What will the future hold for small sample size x-ray imaging?