Popular summary

Since the discovery of x-rays they have allowed us to see inside objects without the need to destroy, cut or damage them. This has been useful in many ways, foremost in the field of medicine where you can take images of the skeleton or other parts without the need of surgery. This works on the principle that x-rays penetrate objects more easily than visible light and it can penetrate deeper in skin for example. Denser objects are still harder to penetrate however, such as bone, and this leaves a shadow as fewer x-rays penetrate it. This also limits the technique in a way because it only allows you to see objects that are very dense compared to the surroundings, a bone surrounded by tissue for example. As such, it is not possible to see, say a tendon surrounded by tissue as they absorb about equal amounts of x-rays. This is where the technique of phase-contrast imaging comes in. It does not rely on how much x-rays the object absorbs, instead it relies on the difference in refractive index. As an example, say you have a piece of glass in water, both the glass and the water absorb about the same amount of x-rays so the glass would be hard to distinguish. But the refractive index of water compared to that of glass is quite different and taking phase-contrast images you would clearly be able to see the difference. This means that this technique has many useful applications but the problem is that it requires the source of the x-rays to be incredibly small, a few micrometers, and at the same time you need a lot of x-rays. This means that you either have to go to a synchrotron, which is very expensive and not always available, or use a microfocus x-ray tube that produces less x-rays.

In recent years a new type of particle accelerator has begun to catch the interest of a lot of researchers, called laser wakefield acceleration (LWFA). This uses a plasma to accelerate particles, usually electrons, over a very short distance. As a comparison, the linear accelerator at the MAX IV Laboratory accelerates electrons over 300 m, LWFA can reach the same energy over a distance of about 9 cm. The electrons emit x-rays when accelerated and this generates a very small x-ray source and was determined during this thesis to be 2.5 micrometers, which makes it suitable for phase-contrast imaging.

By rotating the object, taking images at different angles, one can reconstruct the full object in 3D even though the images are only 2D. Combining this with phase-contrast imaging makes it possible to create 3D images of small objects with little absorption. These 3D models can then be analyzed, such as cutting through different parts, rotating them, looking on the inside etc and this is demonstrated using a small fly in this thesis. Developing LWFA x-ray sources further could one day allow for phase-contrast imaging of for example blood vessels or tendons at medical facilities with very short exposure times compared to microfocus x-ray tubes. It would allow imaging of different low absorbing samples that usually require a synchrotron at much smaller and cheaper facilities.