X-ray pink beam dynamic micro-CT at SSRF

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Summary: A pink beam based 25 Hz dynamic synchrotron radiation micro-CT method was successful developed using pink beam from test beamline at Shanghai Synchrotron Radiation Facility. The live ant results show the method is feasible to perform in-vivo four-dimensional study in biomedical and so on.

1. INTRODUCTION

X-ray micro-CT (μCT) is a non-destructive technique widely used for visualizing the morphology of samples, and for assessing quantitative information on their three-dimensional (3D) geometries and properties. With the availability of third generation synchrotron radiation (SR) facilities, the SR-μCT has evolved as an accepted and utilized technique for quantitative characterizing the 3D internal structure of samples in many research fields thanks to its superior advantages, such as high temporal and spatial resolution, phase-sensitive imaging and so on[1].

In recent years, fast SR-μCT has attracted more and more attentions and has been applied in many fields, such as investigating high temperature sintering processing of aluminum powder[2], scrutinising the compression of the air sac during respiration in a bell cricket[3], observing the bubble growth in hydrated basaltic melts[4] and so on. Although the monochromatic beam based dynamic CT can obtain quantitative information[5], but its time resolution is not high since the flux is quiet low. In order to reach high temporal resolution SR-μCT, white or pink beam is usually utilized since it has very high flux compare to monochromatic beam.

Here, a 25 Hz dynamic SR-μCT method was developed using the pink beam from test beamline at Shanghai Synchrotron Radiation Facility (SSRF). The key instruments are the Aerotek air bearing rotation stage and Photron FASTCAM SA-Z camera with in house developed high efficiency optics system. The results of plant stem and live ant will be present.

2. EXPERIMENTAL METHOD

The experimental instruments of dynamic SR-μCT consists of a in house developed shutter that can offer a minimum 30ms beam window, a 1mm Al filter, an Aerotech air bearing rotation stage that can reach maximum 4800°/s rotating speed, and a high-speed detector. The detector combines with a Photron FASTCAM SA-Z camera detector, which has pixel size of 20 μm and maximum frame-rate up to 120,000fps at 512 × 256 pixels, and an in house developed high efficiency optics system that has 8× magnification and coupling efficiency of 16.9%.

One live ant was used, it was settled in a ventilated plastic container at a normoxic state and at room temperature. The size of the ant is about 1 mm × 3.5 mm. During the dynamic SR-μCT experiment, the rotating speed is 4500°/s and frame rate is 8000fps for live ant sample that result in 320 projections/CT and 25 Hz CT. The sample-to-detector distance was 33.5 cm and 1mm Al filter is used for both samples.

Data were processed using the PITRE software that is a free software package for phase-sensitive X-ray image processing and tomography reconstruction[6]. For the live ant sample, a single distance phase retrieval[7,8] was performed for all the recording projections before the slice reconstruction using FBP algorithm. The reconstructed slices were 8-bit grey-scale, in which the materials with the highest refractive index were displayed as white and the lowest refractive index as black. The 3D rendering was made by Dragonfly 3.6 (Object Research Systems Inc, Canada), in which the 3D images were displayed as stacks of 2D image slices.

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3. RESULTS

Figure 1 shows the 3D rendering images of live ant at 0s, 0.16s and 0.32s during experiment respectively, the ant has nice and smooth contour even for the fast-moving position such legs at the middle left of each picture, it means the 25Hz CT time resolution is fine for perform *in-vivo* four-dimensional study of insect like live ant.

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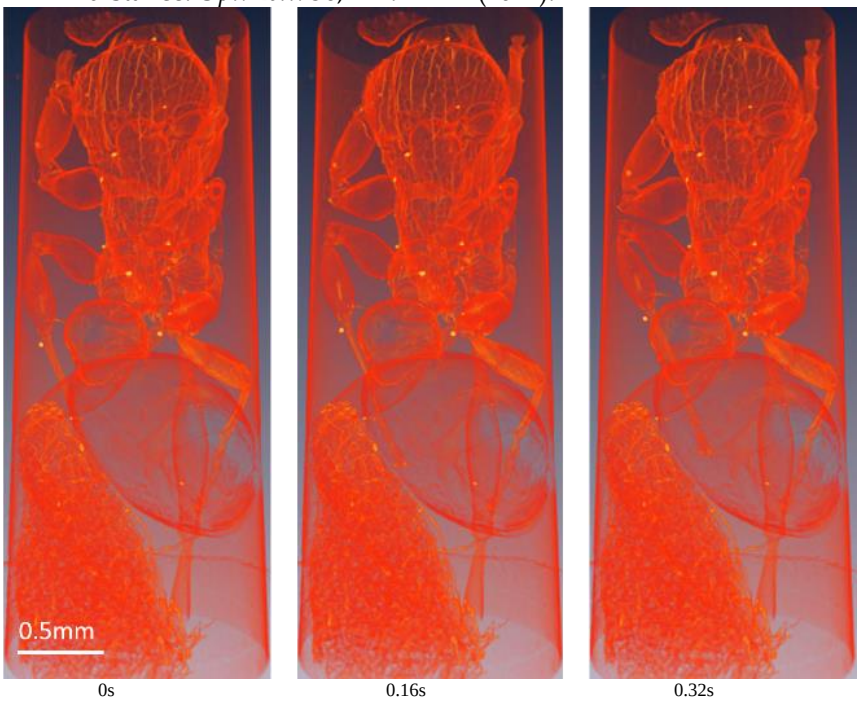

Figure 1. The 3D rendering images of live ant at different time.