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Micro-spot gamma ray source based on LWFA and its application in high resolution tomography

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The radiography of gamma-ray is one of the most important non-destructive testing in many fields. However, the spot size is always in millimeter scale for the generation of gamma-ray by conventional way, which becomes the limiting factor for the spatial resolution of radiography and tomography. As the development of laser wakefield acceleration (LWFA), the electron beam with small divergence and spot size can be generated easily in the experiment by tens of terawatt ultra-short laser pulse. Based on LWFA, high-energy micro-spot gamma-ray sources can be also produced from bremsstrahlung. With a spot size almost 20 times smaller than that of conventional gamma-ray sources, this method provides a breakthrough in spatial resolution for high-energy radiography.

Since 2012, we started our research on this subject[1]. From 2016, the properties and conditions of micro-spot gamma-ray source were detailed investigated on a 45TW commercial femtosecond laser system[2]. The high energy gamma-rays were generated from the bremsstrahlung of the energetic electron beams propagating in high Z materials. The experiment demonstrates that the spot size can be as small as about 40 μm, and the maximum yield per shot of the high energy X-ray can be up to 1.7×10^{10} photons. The photon energy spectra always obeyed the quasi-Maxwellian or exponential distribution, and was almost independent to the electron spectra. Typical results are shown in Fig.1 and Fig. 2.

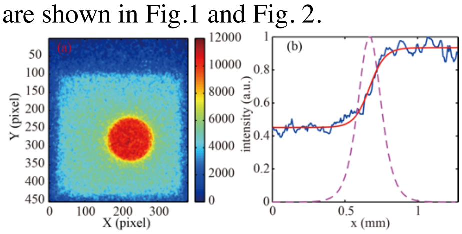

Figure 1. The penumbral image of the high energy X-ray and calculated spot size

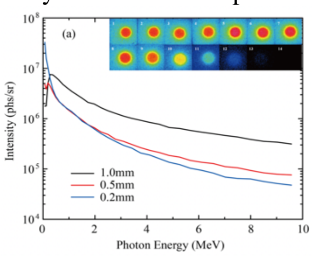

Figure 2. The energy spectrums with different target thickness and the inset of (a) is the raw images from FSS by one shot.

Using the micro-spot gamma-ray source, high-resolution radiography was demonstrated, which shows that the spatial resolution is better than 100μm, even after 100mm thickness stainless steel plate. Furthermore, a Computed Tomography was also demonstrated (shown in Fig. 3), which shows the resolution of reconstruction can reach 100 μm at 10% contrast.

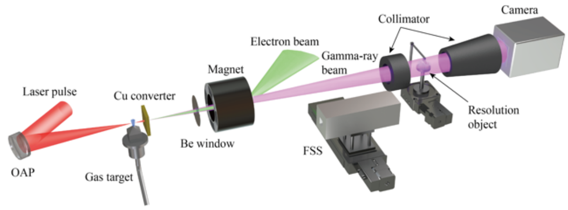

Figure 3. Experiment arrangement of CT experiment.

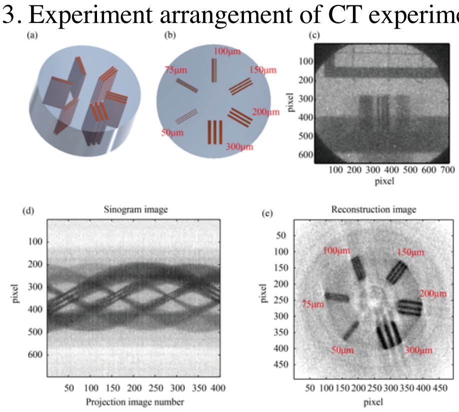

Figure 4. Spatial resolution object and CT imaging.

Our research results show that the laser driven micro-spot gamma-ray sources provide a prospective way to increase the spatial resolution in the high-energy high-resolution radiography for many non-destructive testing (NDT) application. Due to the advantage in spatial resolution, laser based high energy CT represents a large potential for many NDT applications.

References:

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