Fused CT imaging technique to improve 3D isotope-selective NRF-CT image

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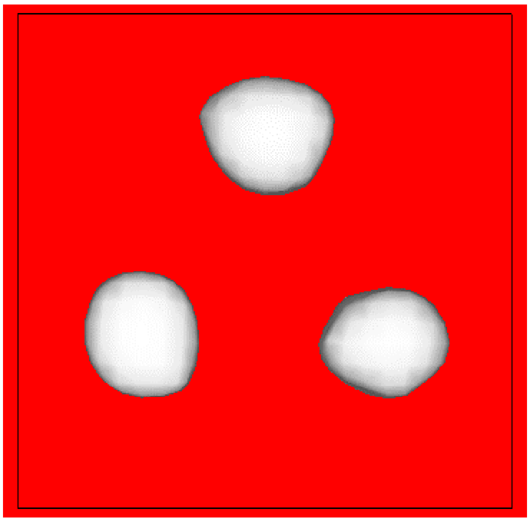
Abstract

CT imaging based on NRF transmission method has an advantage of isotope selectivity. Using an LCS gamma-ray beam in UVSOR, we demonstrated a 3D NRF-CT image with 4 mm pixel resolution for a sample containing 208Pb isotope. To improve the NRF-CT image quality, a fused visualization technique in combination with a gamma-CT image is introduced.

Keywords: Computed tomography (CT), Fused visualization (FV), laser Compton scattering gamma-ray beam (LCS), Nuclear Resonance Fluorescence (NRF)

1. Introduction

The combination of computed tomography (CT) and nuclear resonance fluorescence (NRF) transmission method has the isotope-selective imaging capacity to distinguish a specific isotope from a set of isotopes buried within the same sample. We experimentally obtained an isotope selective 3D NRF-CT image of enriched lead isotope (^{208}Pb) [1]. The NRF-CT imaging technique needs a long data acquisition time, approximately 48 hours, even with the obtained image resolution of 4-mm/pixel in the horizontal plane and 8 mm/pixel in the vertical plane for a cylindrical sample with a diameter of 25 mm and a height of 20 mm. Improving the NRF-CT image resolution is challenging with the current experimental condition. Therefore, we propose a numerical method to improve the NRF-CT image quality using the fusion visualization technique (FV) by combining the NRF-CT image with a gamma-CT image, which can quickly be obtained a better pixel resolution. Both images were measured at the beamline BL1U in UVSOR-III Synchrotron Radiation Facility under the same experimental condition except for the gamma-ray parameters. We used a laser Compton scattering gamma-ray beam (LCS) generated by the collision of a Tm-fiber laser system beam with a wavelength of 1.896 μm and the Synchrotron storage ring electrons beam with an energy of 746 MeV. With the typical 2.4-Watt average power of the laser system, we generated an LCS beam in 1 mmϕ and 7×10^6 photon/s flux intensity to obtain a 3D gamma-CT image in 1-mm pixel resolution. With the typical 36-Watt average power of the laser system, we generated an LCS beam in 2 mmϕ, 10^8 photon/s flux intensity, and a 5.528 MeV maximum energy to excite the $J^\pi = 1^-$ state at 5.512 MeV in ^{208}Pb to obtain a 3D NRF-CT. As the CT target, the enriched ^{208}Pb was implied in a cylinder aluminum holder together with a set of different objects, including enriched ^{206}Pb, Fe, Al, and an empty area. We employed the FV technique between the primary gamma-CT and the NRF-CT images, subtracting the atomic absorption component [1] to obtain a 3D FV NRF-CT. Movie 1 shows the fused CT-image of the CT target and clearly shows the locations of the ^{208}Pb rods. In contrast, the rods (^{206}Pb, Fe, Al, and air) were totally disappeared. The FV technique shows a significant advancement for using an isotope-selective CT imaging technique in practical applications in nuclear engineering field.



Movie 1. 3D FV NRF-CT image

References

[1] K. Ali, et al., Applied Sciences, vol. 11, no. 8, p. 3415, 10 April 2021.

Use this link to find the image on *vimeo* (https://vimeo.com/568768324)