Proton Radiography with CR-39 by Using the Protons from High Power Femto-second Laser System

Chang Il Choi [a], Dong Hoon Lee [a], Byoung Hwi Kang [a], Il Woo Choi [b],
Do-Kyeong Ko [b], Jongmin Lee [b], Yong Kyun Kim [a*]
[a] *Department of Nuclear Engineering, Hanyang University, Seoul 133-791, Korea*
[b] *Femto Science Laboratory, Advanced Photonics Research Institute, GIST, Gwangju 500-712, Korea*
[*] *Corresponding author: ykkim4@hanyang.ac.kr*

1. Introduction

Proton radiography techniques are useful to obtain a high quality image of a thin object, because protons travel straight in matter. Generation of the high energy proton using conventional accelerator costs high and requires large accelerating facility. But proton radiography using high power femto-second(10^{-15} second) laser has been interested, because it can generate high energy protons at lower price than the conventional accelerator like a cyclotron.

For this study, we used the CR-39 SSNTD (Solid State Nuclear Track Detector) as the proton radiography screen.[1] Commonly, CR-39 is used to detect the tracks of energetic charged particles. Incident energetic charged particles left latent tracks in the CR-39, in the form of broken molecular chains and free radicals.[2] These latent tracks show high chemical reactivity. After chemical etching with the caustic alkali solution such as NaOH or KOH, tracks are appeared to forms of hole.[3]

If protons with various energies enter the two targets with another thickness, number of protons passed through the target per unit area is different each other. Using this feature of protons, we can a proton radiographic image with CR-39. We studied proton radiography with CR-39 by using energetic protons from high power femto-second laser and evaluated potentiality of femto-second laser as new energetic proton generator for radiography.

2. Methods and Results

2.1 Experimental Setup and Methods

Phantoms were manufactured to evaluate the quality of obtained image. We obtained the 1.8 MeV proton ranges in Mylar and polyethylene by using TRIM code simulation (range in Mylar: 49.6 ㎛, range in polyethylene: 60.6 ㎛) to determine the phantom thickness. A step wedge phantom was made of Mylar film with 13μm thickness and two character phantoms were made of polyethylene plate with 0.5mm thickness (all protons stop inside the polyethylene).

CR-39 plate, manufactured by Fukuvi Chemical Industry, with 1000 ㎛ thickness was employed. CR-39 pieces which were posted the phantoms are placed inside the vacuum chamber. The 100TW high power femto-second titanium sapphire laser system which has been installed at GIST(Gwangju Institute of Science and Technology) was used for generating protons. The laser generated by this system has energy with 1.4J, pulse width with 40fs, output of power with 35TW, and maximum of proton energy was 1.8MeV.[4]

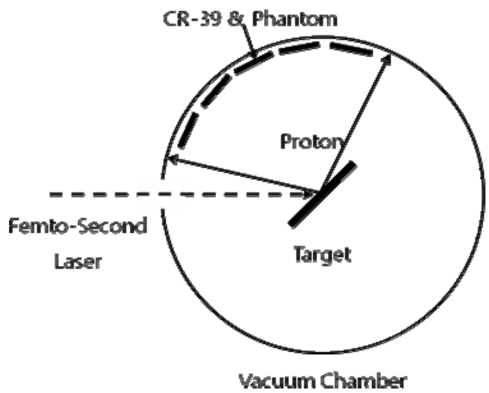

Fig. 1 CR-39 and the phantoms inside the vacuum chamber

After bombarding a phantom with protons having maximum energy of 1.8MeV, CR-39 was etched in 7 N NaOH solution at 70℃ for 4 hours.[2,3] We obtained digital images by using Olympus BX60M optical microscope and Olympus AcquCAM II digital camera.[5]

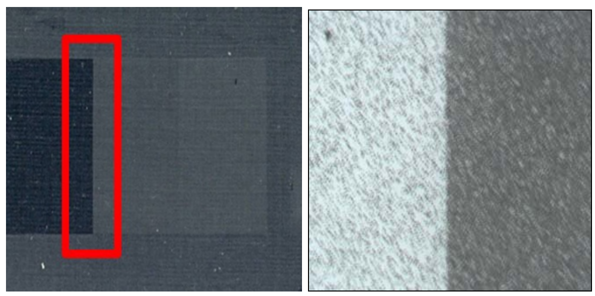

Fig. 2 Image of CR-39 after chemical etching (left) and digital image at boundary of 39 ㎛ Mylar region and 26 ㎛ Mylar region (right)

Grey scale value of obtained images was acquired by using the XCAP imaging software. We obtained ESF(Edge Spread Function) and LSF(Line Spread Function) by analyzing grey scale values.[6] Finally MTF(Modulation Transfer Function) was acquired from FFT(Fast Fourier Transform) method.

2.2 Results

We obtained various LSFs in various light intensity of microscope.

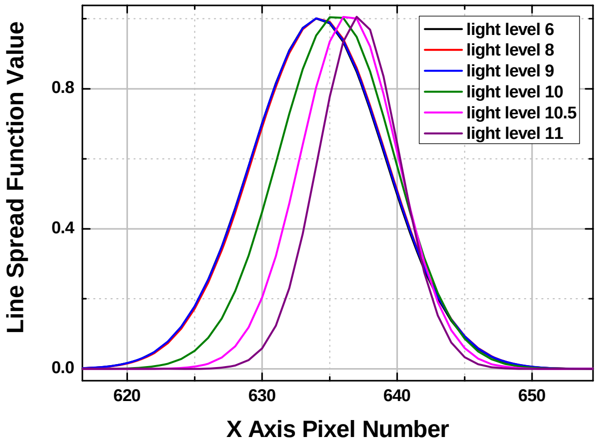

Fig. 3 Line spread functions under various light intensity conditions

When light intensity of microscope was so high, images were distorted and X axis pixel number of LSF peak point were shifted. Under suitable light intensity conditions, LSF curve are approximately coincident.

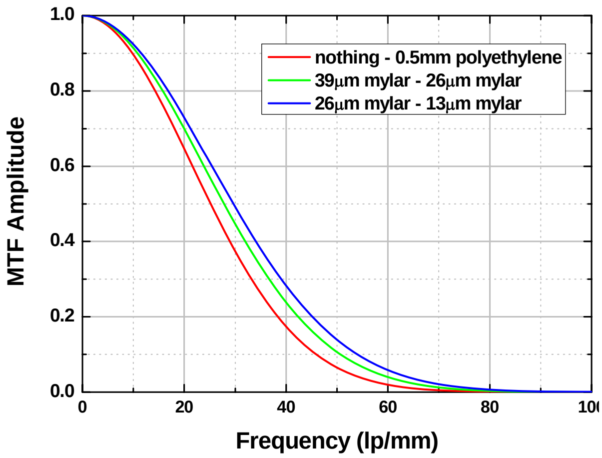

Fig. 4 Modulation transfer functions of various phantoms

We analyzed MTF curve and obtained spatial resolution of images as 9.3 ㎛, 9.8 ㎛, 10.9 ㎛.

3. Conclusions

We performed proton radiography experiment by using CR-39 and high power femto-second laser system at first in Korea. CR-39 plates with posted phantoms were irradiated by protons having maximum energy of 1.8MeV and were etched by NaOH solution. After proper etching, we obtained digital images by using microscope and analyzed images by using Origin and XCAP programs. We could obtain proton radiography images with higher spatial resolutions(9.3 ㎛, 9.8 ㎛, 10.9 ㎛) than X-ray radiography images.

Acknowledgements

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