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Scintillation imaging of air during proton and carbon-ion beam irradiations

Seiichi Yamamoto [a,*], Toshiyuki Toshito [b], Takashi Akagi [c], Tomohiro Yamashita [c], Masataka Komori [a]

[a] Radiological and Medical Laboratory Sciences, Nagoya University Graduate School of Medicine, Japan
[b] Department of Proton Therapy Physics, Nagoya Proton Therapy Center, Nagoya City West Medical Center, Japan
[c] Hyogo Ion Beam Medical Center, Japan

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ABSTRACT

We previously reported that the luminescence imaging of water during proton or carbon-ion irradiation is possible using a charge-coupled device (CCD) camera, and these luminescence images can be used for the range estimations for these therapies. In the images during these irradiations to water phantoms, we observed scintillation images in the air parts. We conducted analysis of these images during proton and carbon-ion irradiations to use them for beam width estimations. We set profiles on the air part of the luminescence images of water during 100.2 MeV proton and 241.5 MeV/n carbon-ion irradiations. We estimated the widths of the beams from the scintillation images and compared them with those by simulation results. We also estimated the intensity and light spectrum of the scintillation of air and compared with those of the luminescence of water. The estimated widths of the proton and carbon-ion beams from the scintillation images of air were almost the same as those measured with simulations. The intensities of the scintillation of air were 3% and 5% of those of the luminescence of water for the proton and carbon-ion beams, respectively. The light spectrum of the scintillation of air peaked around 350–450 nm while those of luminescence of water showed wide distribution which peaked 450–550 nm. We confirmed that scintillation imaging of air during proton and carbon-ion beam irradiations were possible. The scintillation imaging of air could be used for the width estimations of proton and carbon-ion beams.

1. Introduction

Measurements of dose distribution for proton or carbon-ion therapy are important because of the dose accumulation at the target [1,2]. Even though ionization chambers are routinely used to measure the dose distribution, a relatively long time is required for such measurements and a more efficient method is desired.

Recently, we successfully imaged the luminescence of water during proton or carbon-ion irradiations using a cooled charge-coupled device (CCD) camera. We also reported that the luminescence imaging of water can be used for the range estimation for these therapies [3,4]. In the images during these irradiations to water phantoms, we found the scintillations in the air part of the images. The scintillation images of air might be used for beam diameter measurements for proton or carbon-ion therapy.

For the previous works, the scintillation imaging results of X-ray and electron beams in air were reported [5]. Alpha-particle imaging in air was also conducted using a CCD camera [6,7]. In these imaging, nitrogen gas (N_2), which is a kind of gas scintillator in air, was excited by these radiations, and the distribution measurements of X-ray, electron beams or alpha particles in air were realized. Optical imaging is also used for both high energy photon and electron therapies to detect Cerenkov-light from water phantoms [8–10]. However, no optical imaging of air during proton or carbon-ion irradiation has been reported yet. Consequently, we conducted analysis of the air part of the images during proton and carbon-ion beam irradiations to the water phantoms and explored to use these data for beam width estimation. We also evaluated the intensities and light spectra of proton and carbon-ion beams in air and compared them with those for the luminescence of water.

2. Methods

2.1. Experimental setup for scintillation images of air during proton and carbon-ion irradiation

Fig. 1(A) shows a schematic drawing of our experimental setups for luminescence imaging during proton or carbon-ion irradiation.

* Corresponding author.
E-mail address: s-yama@met.nagoya-u.ac.jp (S. Yamamoto).

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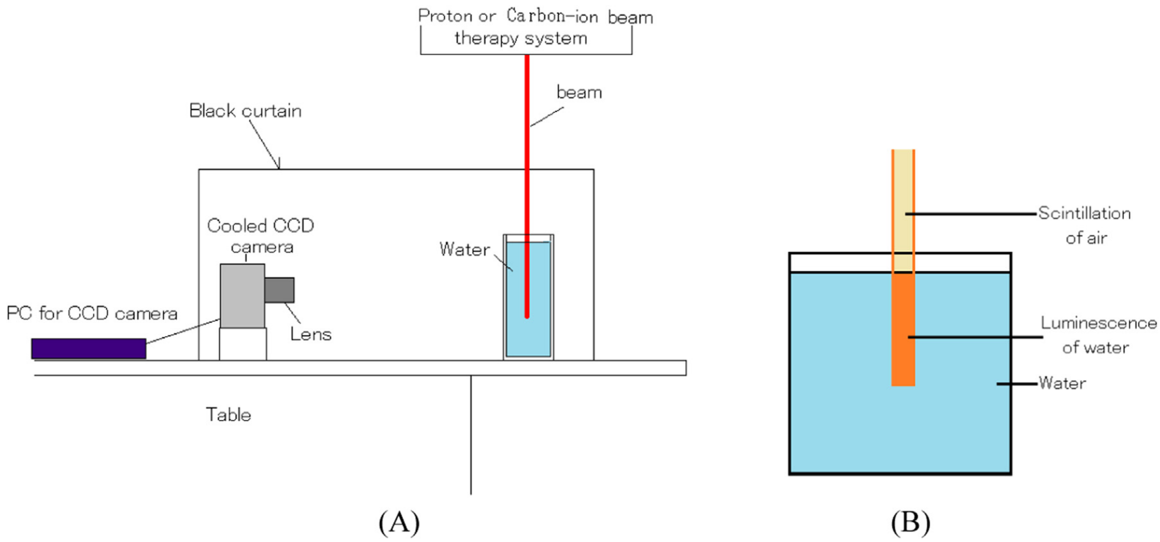

Fig. 1. Experimental setup for scintillation imaging of air during proton or carbon-ion irradiation: schematic drawing of experiments (A) and schematic drawing of scintillation in air (B).

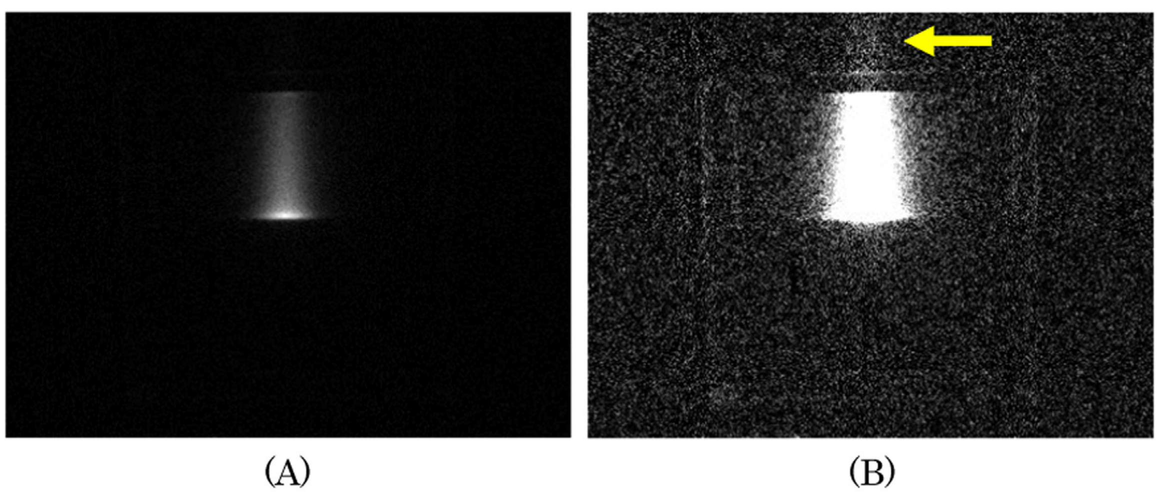

Fig. 2. CCD camera image of water phantom during 100.2 MeV proton irradiation displayed with maximum intensity of 2000 (A), and same image displayed with maximum intensity of 200 (B). Arrow shows scintillation of air part.

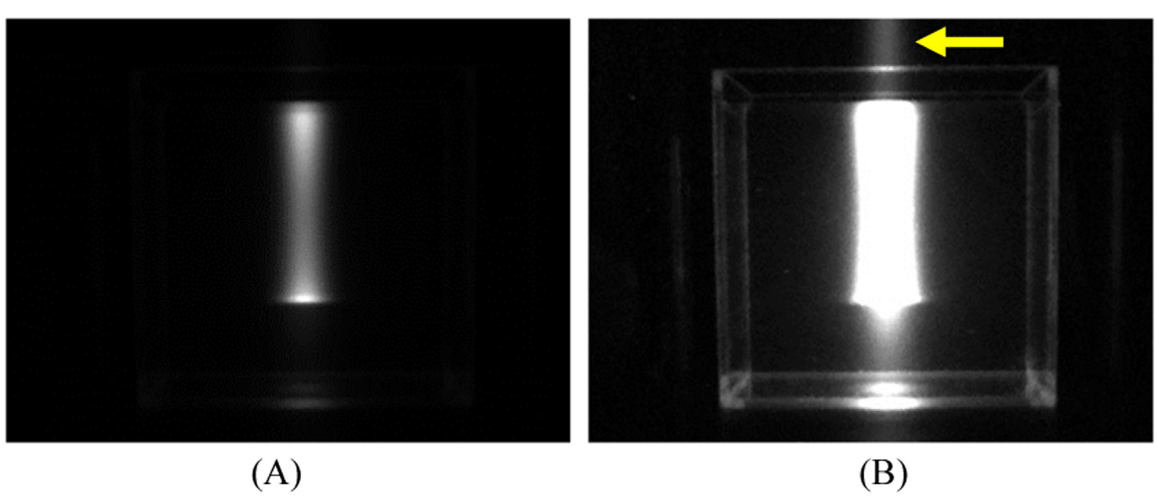

Fig. 3. CCD camera image of water phantom during 241.5 MeV/n energy carbon-ion irradiation displayed with maximum intensity of 50,000 (A), and same image displayed with maximum intensity of 5000 (B). Arrow shows scintillation of air part.