INSTITUTE OF PHYSICS PUBLISHING PHYSICS IN MEDICINE AND BIOLOGY

Phys. Med. Biol. **48** (2003) N59–N63 PII: S0031-9155(03)56541-1

NOTE

The direct measurement using an imaging plate for coincidence of radiation centre and laser position in external radiation therapy

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Received 22 November 2002
Published 29 January 2003
Online at stacks.iop.org/PMB/48/N59

Abstract

A new method of quality assurance has been studied to measure coincidence of the radiation centre and a patient-setup laser position on a transverse plane to the beam at the isocentre. This measurement is achieved by using an imaging plate (IP). When radiation is applied to an IP, the energy is stored as trapped electrons. The number of electrons is decreased by local laser exposure. As a result, the radiation field produced by external beam irradiation is recorded as 'positive' information and the position of the patient-setup laser is recorded as 'negative' on an IP. The advantages of this method are the direct measurement, short time and high resolution. These are required for daily and monthly quality checks. We confirmed the advantage of this method by an experiment using a proton beam.

1. Introduction

In external radiation therapy, the target is most commonly positioned in the desired location with the help of patient-setup lasers, which indicate the position of the isocentre. Therefore, it is very important to verify and control coincidence of the radiation centre and the laser position accurately. Many studies have been made on the quality assurance of this subject (Tsai *et al* 1999, Arjomandy and Altschuler 2000, Treuer *et al* 2000, Welsh *et al* 2002). In the previous works, some objects were located at the laser position to know the coincidence. These additional setup procedures produced a new measurement error. Falco *et al* (1999) developed a technique for the direct-setup alignment of a radiosurgical circular field from an isocentric linac to treatment room laser cross-hairs. But the laser cross-hairs were not superimposed in the radiosurgical field. A method realizing direct measurement of the coincidence of the radiation centre and the laser position has been required.

0031-9155/03/040059+05$30.00

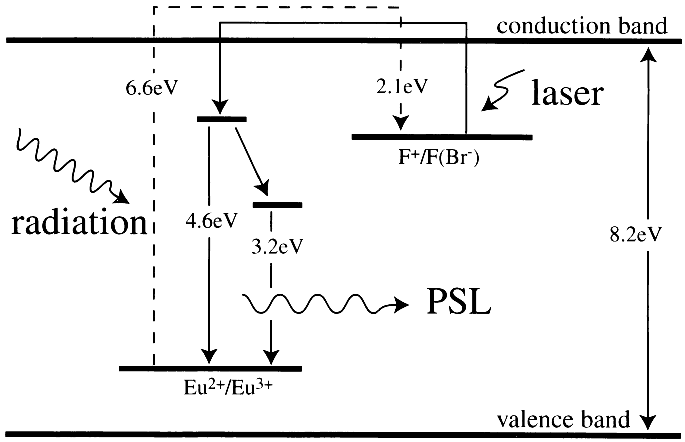

Figure 1. The energy level diagram and the PSL mechanism in BaFBr:Eu^{2+}. The dashed line shows the ionization and electron trapping process caused by radiation. The solid line shows the photoelectric effect and PSL process caused by the laser exposure.

We have tested a direct measurement by using an imaging plate (IP). IPs have been developed as an image-storing medium and are now widely used as detectors of two-dimensional images produced by ionizing radiation in medical, biological and physical fields. In recent years, it has been found that IPs are also applicable to a proton beam (Hayakawa *et al* 1996, Nohtomi *et al* 1999, 2000). An IP has a flexible polyester base coated with highly dispersed barium fluorohalide phosphor crystal BaFBr:Eu^{2+} (Iwabuchi *et al* 1994). Figure 1 shows the energy level diagram and photo-stimulated luminescence (PSL) process in BaFBr:Eu^{2+}. When radiation is applied to an IP, the energy is transferred to the phosphor crystals and is stored as trapped electrons. This means that electrons become trapped at 'F-centres' in the BaFBr matrix and holes become trapped at Eu^{2+} ions. The radiation image is temporarily stored in the IP. These F-centres have an absorption band at about 600 nm. The IP is read out by an image reader which scans the IP surface with a focused 633 nm He–Ne laser beam. The He–Ne laser releases the trapped electrons, which recombine with the holes trapped by Eu^{2+}, and photons at about 400 nm are released. This is known as the PSL phenomenon. The emitted PSL light is collected by a photomultiplier tube, and the tube output is recorded as time series of digital signals using an analogue-to-digital converter.

We expect that our patient-setup laser (635 nm) also releases the trapped electrons locally and this local reducing process can be applicable to record the laser position.

2. Materials and methods

The experiment was carried out at a treatment room in the Proton Medical Research Center (PMRC), University of Tsukuba. A proton beam with the energy of 200 MeV was produced by a synchrotron and it was passed through a dual-ring double-scatterer system to obtain a laterally uniform spatial distribution. As shown in figure 2, a brass collimator with 10 × 10 cm^2 aperture and thickness of 5 cm was mounted onto the gantry head. An IP with 20 × 25 cm^2 sensitive area (BAS III, Fuji film Co. Ltd) was placed on the transverse plane to the beam at the isocentre. The IP was irradiated with only 1 spill of proton beam and the two-dimensional dose distribution was recorded. After proton beam irradiation, the laser system LDTF163C06-2 (Takenaka Optonic Co. Ltd) was inserted on the beam line in the gantry head.

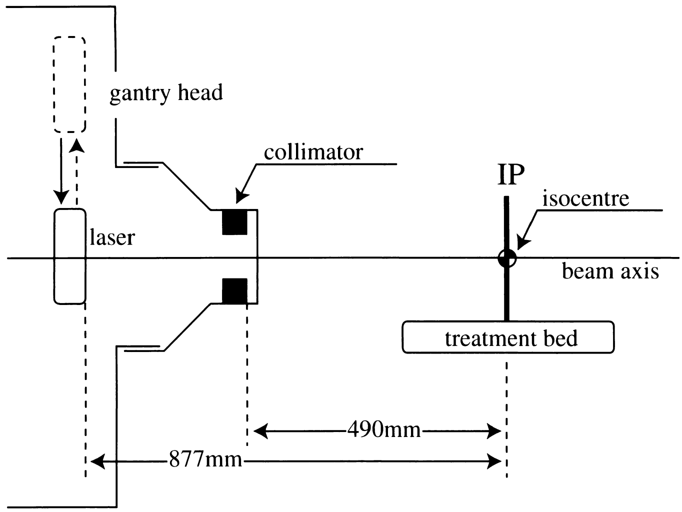

Figure 2. Illustration of the experimental setup. After proton beam irradiation, the laser system was inserted on the beam line in the gantry head and then the IP was exposed to the cross-hairs laser with a wavelength of 635 nm for about 20 s.

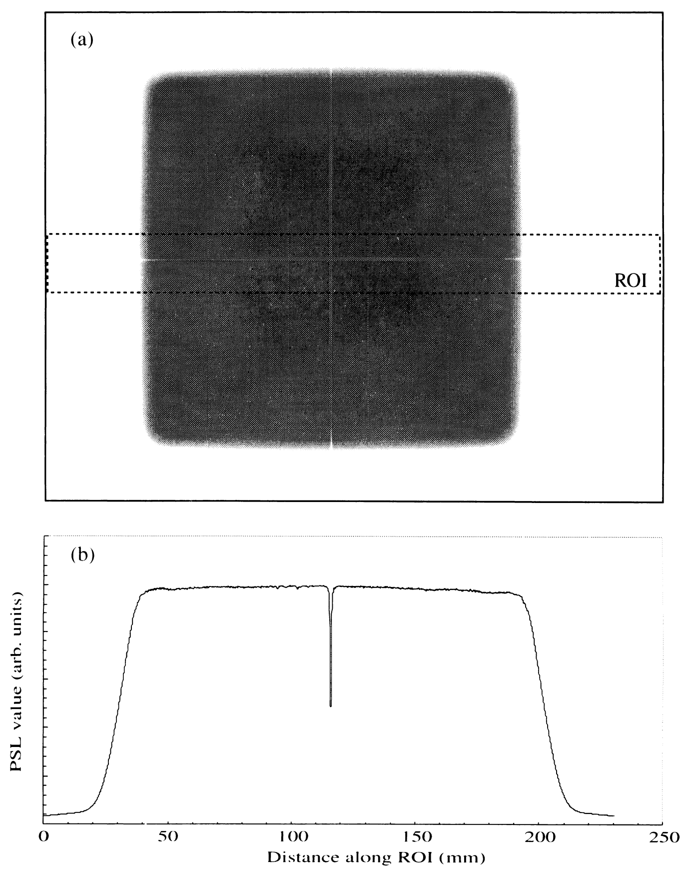

Figure 3. Two-dimensional image of the IP (a), and the profile along the horizontal ROI (b).

Then the IP was exposed to the cross-hairs laser with a wavelength of 635 nm and 0.1 mW power for about 20 s. These operations were performed in a darkened ambience in order to avoid light exposure reducing PSL signals. The IP was not covered to enable laser exposure. The stored image was read out by BAS2000-II (Fuji Film Co. Ltd) with 100 μm resolution. The total time of this experiment was about 10 min.

3. Results and discussion

The image obtained by the IP is shown in figure 3(a). It is obvious that the radiation field and the laser cross-hairs are superimposed in the same IP directly. Figure 3(b) shows the horizontal profile along the ROI. According to our expectation, PSL signals are decreased at cross-hairs laser positions. The radiation field produced by proton beam irradiation is recorded as ‘positive’ information and the laser position is recorded as ‘negative’ on an IP. In order to calculate the radiation centre, we assumed the intermediate point between both of the half height points of dose distribution as the radiation centre. It is found that the deviations of the radiation centre from the intersection of the laser cross-hairs are 0.15 mm horizontally and 0.05 mm vertically, separately. The influence of IP displacement on the result can be ignored because the relation between the radiation field and the laser position does not depend on the IP displacement. As a consequence, an easy and short time setup is achieved.

4. Conclusions

We have succeeded in the direct measurement for coincidence of the dose distribution and the laser position by using an IP. The IP has the advantages of wide dynamic range, linear response and high sensitivity. Also, the IP has sensitivity for various kinds of beams such as ultraviolet, x-ray, electron, proton, other heavy ions and neutron. In our method, an easy setup is introduced without an additional object located at the laser position to know the coincidence. The time taken for this measurement is less than 10 min. The laser intersection is clearly superimposed as reduced PSL signals in the radiation field on the IP. These are required for daily and monthly quality checks. This technique can be used to align the radiation beam with the laser intersection with excellent accuracy. In addition, this method is available not only for a particular geometric field but also for the actual treatment field. Thus, this method has the potential to become widely available and is useful in standardizing quality assurance methods in various external radiation therapies.

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