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journal or publication title	Physics in Medicine and Biology
volume	48
number	4
page range	N1-N5
year	2003-01
その他のタイトル	QA by IP for external radiation therapy
URL	http://hdl.handle.net/2241/00146112

doi: <https://doi.org/10.1088/0031-9155/48/4/401>

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

Short title: *QA by IP for external radiation therapy*

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Abstract

A new method of quality assurance has been studied to measure coincidence of the radiation center and a patient-setup laser position on a transverse plane to the beam at the isocenter. This measurement is achieved by using an imaging plate (IP). When a 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” one 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 proton beam.

1. Introduction

In external radiation therapy, the target is most commonly positioned in the desired location with help of patient-setup lasers, which indicate the position of the isocenter. Therefore, it is very important to verify and control coincidence of the radiation center and the laser position accurately. Many studies have been made on the quality assurance of this subject (Tsai *et al.* 1996, Arjomandy *et al.* 2000, Treuer *et al.* 2000, Welsh *et al.* 2002). In the previous works, some objects were located on 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 radiosurgical circular field from an isocentric linac to treatment room laser cross-hairs. But the laser cross-hairs did not superimposed in the radiosurgical field. A method realizing direct measurement of the coincidence of the radiation center and the laser position has been required.

We have tested a direct measurement by using an imaging plate (IP). An IP has been developed as

an image storing medium and is now widely used as detectors of two-dimensional images produced by ionizing radiation in medical, biological and physical fields. In recent years, it found that an IP is also applicable to a proton beam (Hayakawa *et al.* 1996, Nohtomi *et al.* 1999 and 2000). An IP has a flexible polyester base coated with highly dispersed barium fluorohalide phosphor crystal BaFBr:Eu²⁺ (Iwabuchi *et al.* 1994). Figure 1 shows the energy level diagram and photo-stimulated luminescence (PSL) process in BaFBr:Eu²⁺. When a 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 to 'F-centers' in the BaFBr matrix and holes become trapped to Eu²⁺ ions. The radiation image is temporarily stored in the IP. These F-centers have an absorption band at about 600nm. The IP is read out by an image reader which scans the IP surface with a focused 633nm He-Ne laser beam. The He-Ne laser releases the trapped electrons and recombine with the holes trapped by Eu²⁺, and photons at about 400nm are released. This is known as 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 with an analog-to-digital converter.

We expected that our patient-setup laser (635nm) 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 energy of 200MeV was produced by a synchrotron and it passed through a dual-ring double-scatterer system to obtain a laterally uniform spatial distribution. As shown by figure 2, a brass collimator with 10x10cm² aperture and thickness of 5cm was mounted onto the gantry head. An IP with 20x25cm² sensitive area (BAS III, Fuji film Co. Ltd.) was placed on the transverse plane to the beam at the isocenter. The IP was irradiated 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. Then the IP was exposed to the cross-hairs laser with wavelength of 635nm and 0.1mW power for about 20 seconds. These operations were performed in a darkened ambience in order to avoid light exposure reducing PSL signals. The IP was not covered to enable us laser exposure. The stored image was read out by BAS2000-II (Fuji film Co. Ltd.) with 100μm resolution. The total time of this experiment was about 10 minutes.

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” one on an IP. In order to calculate the radiation center, we assumed the intermediate point between both of half height points of dose distribution as the radiation center. It is found that the deviations of radiation center from the intersection of the laser cross-hairs are 0.15mm in horizontal and 0.05mm in vertical separately. The influence of IP’s displacement on the result can be ignored because the relation between the radiation field and the laser position does not depend on the IP’s displacement. As a consequence, the 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 advantage such as wide dynamic range, linear response, and high-sensitivity. And the IP has sensitivity for various kinds of beams such as ultraviolet-ray, X-ray, electron, proton, other heavy-ions and neutron. In our method, an easy setup is introduced without an additional object located on the laser position to know the coincidence. The taking time for this measurement is less than 10 minutes. The laser intersection is obviously 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 to the laser intersection with excellent accuracy. In addition, this method is available not only for the 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 method in various external radiation therapy.

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Figures

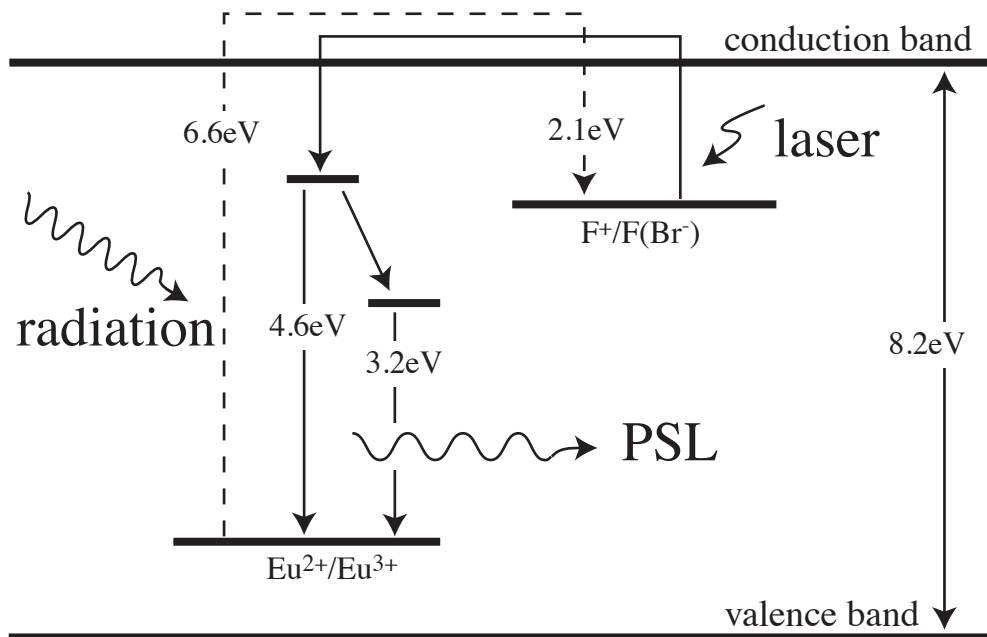


Figure 1. The energy level diagram and the PSL mechanism in BaFBr:Eu²⁺. The dashed line shows ionization and electron trapping process caused by radiation. The solid line shows photoelectric effect and PSL process caused by the laser exposure.

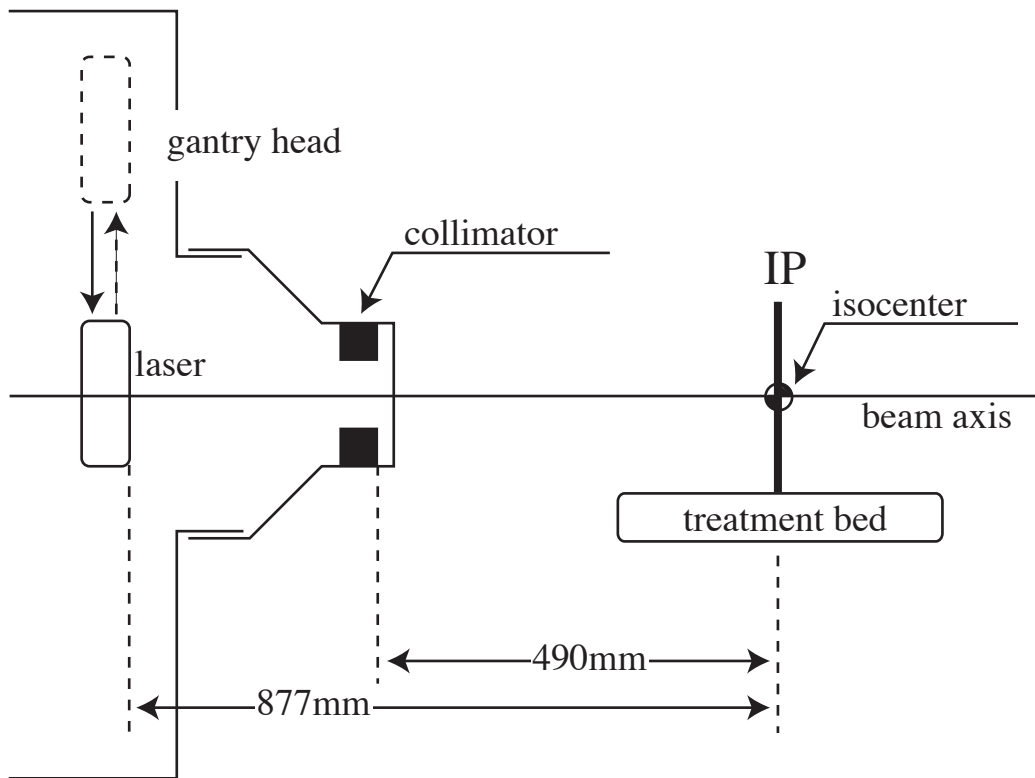


Figure 2. Illustrate of the experiment setup. After proton beam irradiation, the laser system was inserted on the beam line in the gantry head and then the IP was exposed to the cross-hairs laser with wavelength of 635nm for about 20 seconds.

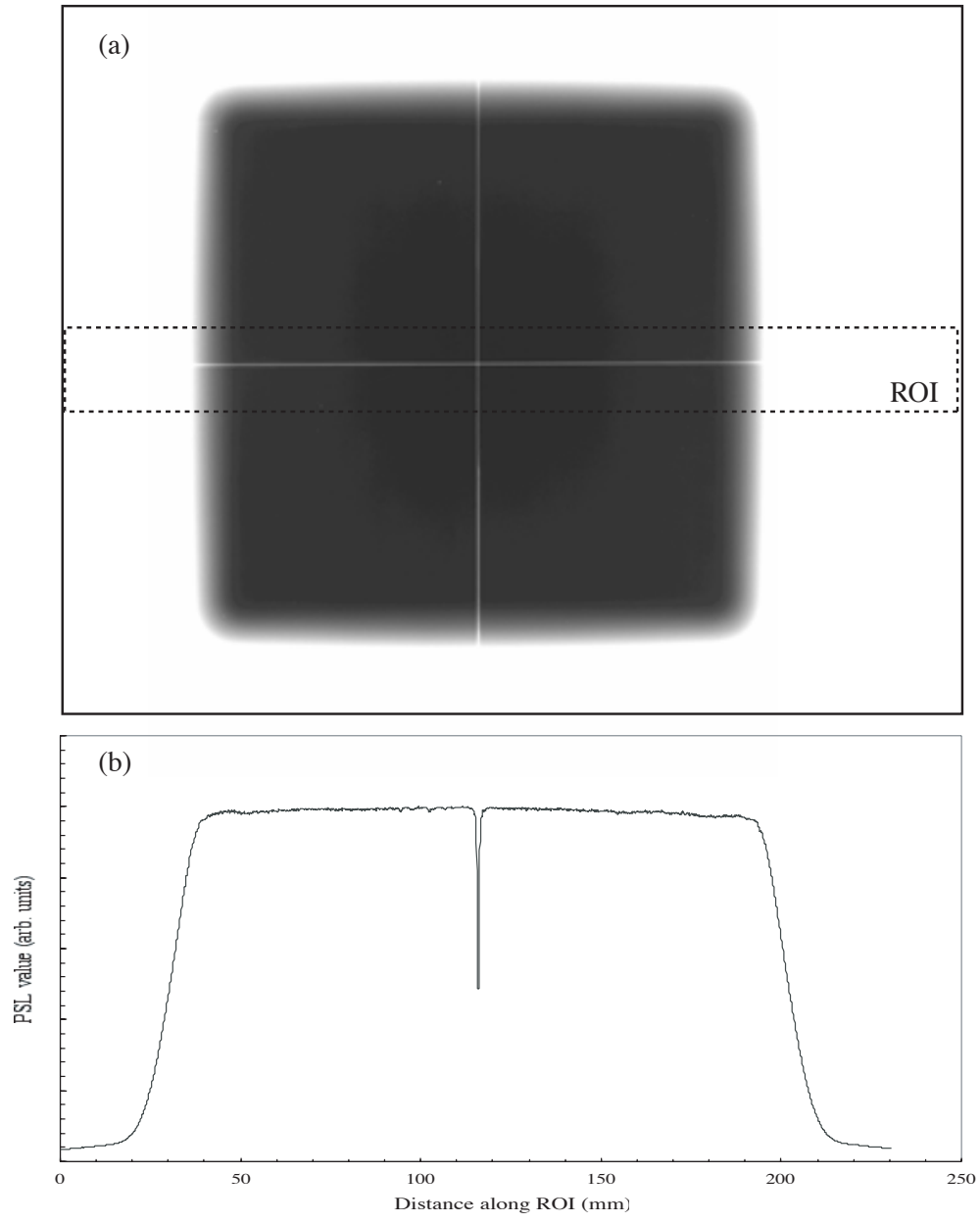


Figure 3. Two-dimensional image of IP (a), and the profile along the horizontal ROI (b).