論文 / 著書情報
Article / Book Information

題目(和文)	前立腺がん治療用注射針型陽子線励起X線源の線量分布の評価方法の開発
Title(English)	Development of evaluation method of the dose distribution of a syringe-needle type proton-induced X-ray source for prostate cancer brachytherapy
著者(和文)	胡宇超
Author(English)	Yuchao Hu
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Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
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論 文 要 旨

THESIS SUMMARY

専攻： Department of	原子核工学　　　専攻	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of　（　工学　）
学生氏名： Student's Name	胡 宇超	指導教員（主）： Academic Supervisor(main)	小栗 慶之
		指導教員（副）： Academic Supervisor(sub)	

要旨（英文 800 語程度）
Thesis Summary (approx.800 English Words)

This thesis is titled "Development of evaluation method of the dose distribution of a syringe-needle type proton-induced X-ray source for prostate cancer brachytherapy", and consists of four chapters.

The first chapter, "Introduction" gave the necessary backgrounds of this research. The first part described the current status of prostate cancer therapy, including the diagnostics (PSA and Gleason score) and the treatments. The methods of treatment can be categorized into three groups: hormonal therapy, surgical prostatectomy and radiotherapy. The radiotherapy consists of two types of approaches depending on the position of the radiation source: external beam irradiation and brachytherapy. Compared with the external beam irradiation, the brachytherapy has an advantage that the damage to the normal tissues is low due to the internal irradiation. However, it also has some risks such as the loss of the "seed" sources and the exposure of the surgical staff and caregivers. On the other hand, although the temporary implantation method with the technique of remote afterloading can avoid such risks, the usage of high-energy gamma-ray sources restricts the application of this method to tumors with small sizes. Thus there is an issue that the choice of implantation method is limited by the type of the radiation source based on radioisotopes. To overcome this difficulty, we have proposed a new radiotherapeutic method based on a compact proton accelerator. The concept of this method is to insert a syringe needle attached to the accelerator into the tumor, instead of inserting radioactive "seed" sources. The proton beam from the accelerator is transported inside the needle and impinges on a metal target at the end of the needle to induce characteristic X-rays of the target atom. This X-ray can be used to irradiate cancer cells. The energy of the X-ray is variable by changing the atomic species of the metal target. In addition, the dose rate, i.e. the X-ray intensity, can be adjusted by the incident proton beam current while keeping the energy constant. As a result, the customization of X-ray energy and dose rate is possible to fit various types of tumor. As a similar device, there exists an electron-accelerator-based interoperative irradiation system. However, being different from electron-induced X-rays, the proton-induced X-ray (PIXE) has high monochromaticity, which is an advantage of this syringe-needle type source for better defining the irradiation volume. On the other hand, the main issue needed to be investigated is the uncertainty of the dose distribution around the needle type source. Thus the purpose of this research is to develop appropriate

experimental and calcuational methods to quantitatively evaluate the dose distribution.

The second chapter, "Experimental and calculational methods" described all the methods used in this work. Firstly, the basic experimental setups including the tandem electrostatic accelerator and its beam-line components were explained. This explanation was followed by the description of the principle of the calculational methods. In this research, two types of Monte Carlo simulation toolkits were used: PHITS and Geant4. The properties of these numerical tools, especially the treatment of PIXE were explained. In the third part of this chapter, four separate studies operated in this research were explained in detail. The first was measurement of the intensity of the X-ray emission by using a detector set at various positions against the syringe needle source. The intensity data could represent the dose distribution at the measured points. The second experiment was a direct observation of the X-ray emission using liquid scintillator and a high sensitivity CCD camera. The third was a combined method, in which the experimentally measured data of the proton beam emittance using "pepper-pot" method was inputted to a Geant4 simulation program to calculate the dose distribution around the syringe needle. The fourth one was an improvement of the second and the third experiments focusing on the evaluation of the absolute dose under the experimental condition.

In the third chapter, "Results and discussion", the results of each work explained in the previous chapter were exhibited and discussed. The first was the result of the measurement of X-rays at multiple angles, including the X-ray energy spectrum and normalized X-ray angular distribution. In the liquid scintillator imaging experiment, the images of scintillation light induced by the PIXE source were shown. The results of the beam emittance measurement experiment consist of the photograph of a Mylar film showing the "burn spots" and the emittance ellipse data calculated from the spot sizes and positions. 3D views of X-ray distribution around the syringe needle generated by the improved Geant4 program with the measured beam emittance data were presented. The last is the results of the improved beam emittance measurement and liquid scintillator imaging experiment, from which the absolute dose rate under the experimental condition was obtained.

The last chapter, "Conclusions", gave a summary of the investigations above. Some conclusions such as the high monochromaticity of the X-ray and the effectiveness of the experimental and calculational methods for evaluating the dose distribution and dose rate could be obtained. The issue of the low dose rate under the current setup was discussed and the possible improvement ways were proposed.