RADIATION SAFETY SYSTEM FOR PKUNIFTY PROJECT *

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Abstract

PKUNIFTY (Peking University Neutron Imaging FaciliTY) , which is based on a 2 MeV RFQ accelerator-driven compact neutron sourse with an expected fast-neutron yield of $2.9*10^{12}$n/s via the deuteron-beryllium reaction, has been operated this year. A radiation safety system for PKUNIFTY, that protects personnel from radiation hazards has been built and run since last year, is described. It consists of a shielding optimized with Monte-Carlo simulation, a dose interlock system, an alternative interlock with another 4.5MV tandem accelerator facility, and a video monitoring system. The dose of supervision area is less than 0.5μSv/h during beam operation.

INTRODUCTION

A thermal neutron imaging facility, Peking University Neutron Imaging FaciliTY (PKUNIFTY), which is based on a compact accelerator-driven neutron source, has been constructed and operated in Peking University this year[1]. A total view is shown in Fig.1. It consists of a D^+ ion injector, a 201.5 MHz mini-vane four-rod radio frequency quadruples (RFQ) accelerator and a high energy beam transport (HEBT). The accelerated D^+ ions are used to produce neutrons by D-Be reaction. The deuteron beam energy is designed as 2MeV and the rated average beam current is 4mA, which gives a fast neutron yield of $2.9*10^{12}$ n/cm2/s [2]. In addition, the Be(d,n) reaction gives a high γ yield.

The purpose of the radiation safety system of the PKUNIFTY is to protect personnel from neutron and γ radiation hazards. It consists of a shielding optimized with Monte-Carlo simulation, a dose interlock system, an alternative interlock with another 4.5MV tandem accelerator facility, and a video monitoring system. The dose interlock system protects operators from strong radiation. It prevents the application of high voltage power supply for the extraction of D+ ion source unless the door to interlocked area is closed and secure. The video monitoring system provides an additional safety measure. Operators in the control room can monitor the beam line area visually. When they find any exception of human accesses, they can shut down the facility manually.

This paper describes in detail the shielding design of PKUNIFTY, dose interlock system, and alternative interlock with another accelerator facility.

SHIELDING DESIGN

The RFQ accelerator and the target of PKUNIFTY were installed together in an existing neutron experiment hall, of which the wall is made of 1.5m thick concrete. And a lot of electronic devices of the accelerator were installed beside the beam line. The shielding should protect these devices from radiation damages. The reference [3] shows some ordinary electronic devices can work properly when the device's cumulative fast neutron flux below 10^{11}-10^{12} n/cm^2 and cumulative γ dose below 10^3 Gy. We designed the shield as summing our electronic devices can work in the similar situation.

Consider a simplified model, in which the moderator and reflector are surrounded by a layer of lead and a layer of boron doped PE, the ion beam tube and collimator are omitted, Monte-Carlo simulations of the shielding configuration indicate that an inner 8cm thick lead layer in conjunction with an outer 42cm thick boron doped PE layer is adequate for radiation protection. In this case the neutron flux will be attenuated by an order of magnitude of 10^{-9}, and the γ-ray dosage out side the shielding will be less than 1mSv/h. With 250 working days the dose is much lower than 1mSv, which is the dose limit for public

Figure 1: A total view of PKUNIFTY

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exposure in China.

To reduce the radiation leaked from the beam tube and collimator, some local shield were installed. Include a 8cm thick arc shape lead, a thinner beam tube at the beam waist, and a 20cm thick 80cm*80cm boron doped PE wall. The simulated neutron yield near the bean line is shown in Fig.2.

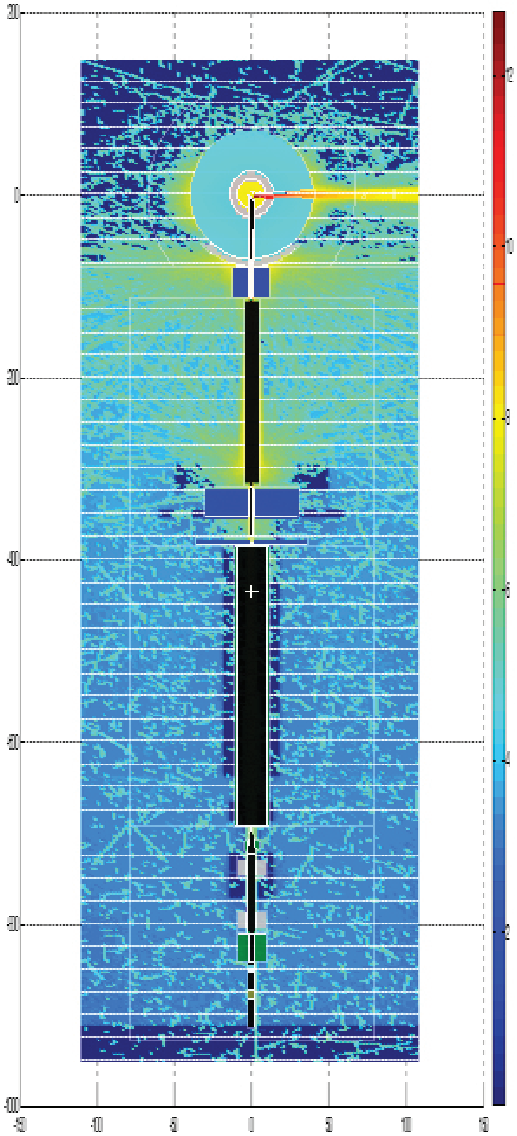

Figure 2: Neutron yield near the beam line.

DOSE INTERLOCK SYSTEM

The dose interlock system prevents access by anyone (including operators) into the hall while effective dose equivalent above 5 μSv/hour[4]. Radiation monitoring is accomplished by two dual monitors, for neutrons and for γ/X-rays. The neutron detector consists of a ^{3}He chamber placed in the middle of a polyethylene sphere. The γ/X-ray detector is Geiger-Muller type. One dual detector is attached to the wall at a height of 1.4 m and near the Be target. The other is movable and can be placed any interest point. The display unit is in the control room. It has all detectors dose rate displays and digital signal alarms.

The dose interlock system uses Programmable Logic Controllers (PLC) as the basis of the system. It includes two emergency-stop buttons placed in the hall and in the control room respectively, two patrol switches, warning lights, and two proximity switches on the wall and doors of the hall. The schematic of interlock system is shown in Fig.3.

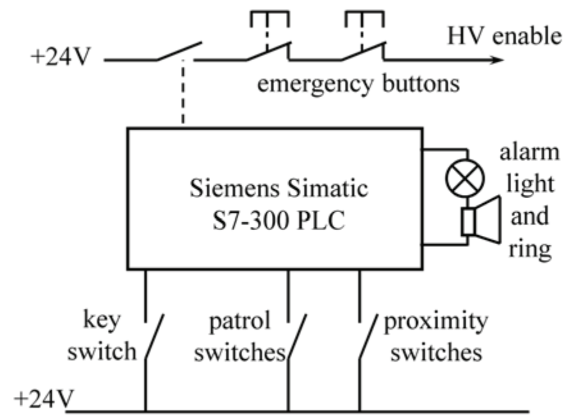

Figure 3: Schematic of interlock system.

The operation procedure of PKUNIFTY requires that the hall is patrolled and the doors are closed before to turn on the Glassman high voltage power supply for the extraction of D+ ion source. The warning lights will work when the dose rate is above the limit and digital alarm signals are sent to PLC by the dose rate display unit.

If any door of the hall is opened while the beam is enabled, the interlock system will ring a sound alarm and shut down the Glassman high voltage power supply immediately. If this happens, the patrol switches will be reinitialized, operators must patrol the hall again before the HV power supply can be activated.

The emergency-stop buttons are non-powered normal-connect switches installed in enable signal circuit of the HV power supply in series. If they are pressed down, the power supply will be shut down directly without PLC process.

A video monitoring system installed in the hall of the facility provides an additional safety measure. Users in the control room can monitor the whole hall visually. When they find any exception of equipments or human accesses, they can shut down the facility manually by pressing the emergency button in the control room.

ALTERNATIVE INTERLOCK

In the neutron experiment hall, there is another 4.5MV tandem accelerator facility, which can also produce neutrons. Only one facility can work at any time is necessary. We set interlock buttons and status indicators

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in each control room. A circuit diagram of the interlock system appears in Fig.4.

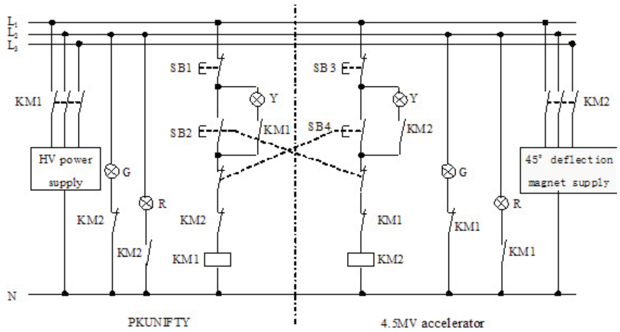

Figure 4: Circuit diagram for interlock with 4.5 MV accelerator.

There are two interlock buttons each, start button (SB2, SB4) and stop button (SB1, SB2). The green, yellow, red light means enable, working, disable respectively.

When the start button of PKUNIFTY is pressed, the yellow indicator will light, and the HV power supply for the extraction of D^+ ion source will be available. In the same time, the red indicator of 4.5MV accelerator will be on, the start button will be disable, and the power supply of 45 degree deflection magnet, which can deflect the high energy proton beam into the neutron experiment hall, can not work for the ac contactor is been disconnected.

When the start button of 4.5MV accelerator is pressed, the yellow indicator will light, and the ac contactor will be connect. But the HV power supply of PKUNIFTY will be disabling and the red indicator will be on.

Before the beam operates, either PKUNIFTY or 4.5MV tandem accelerator facility, a patrol of the neutron experiment hall is necessary.

SUMMARY

The radiation safety interlocks system of PKUNIFTY is presented. A shielding optimized with Monte-Carlo simulation protects devices installed beside the beam line from radiation damages. A dose interlock system prevents access into the hall area while effective dose equivalent above the limit. An interlock with 4.5MV accelerator makes sure there is only one working facility in the hall at any time.

The construction of PKUNIFTY has been completed this year. Some preliminary tests show that the shielding is adequate for radiation protection. The effective dose equivalent of neutron and γ-ray around the neutron experiment hall is less than 0.5 μSv/hour when PKUNIFTY was working at a 0.4mA average beam current.

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