Radiation Issue Occurred During an Ion Source Commissioning

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Abstract: Radiation is an important issue, which should be carefully treated during the design and commissioning of an ion source. Measurement results show that X-ray comes up around the ceramics column of an extraction system when the source is powered up to 30 kV. The X-ray dose increases greatly when a beam was extracted. Inserting the ceramic column into a metal vacuum box is a good way to block X-ray emission for those cases. Moreover, this makes the online test of an intense H+ ion beam with energy up to 100 keV possible. However, for deuteron ion source commissioning, neutron and gamma-ray radiations become a serious topic. In this paper, we will describe the design of the extraction system and the radiation doses of neutrons and gamma-rays measured at different D+ beam energy during our 2.45 GHz deuteron electron cyclotron resonance (ECR) ion source commissioning for PKUNIFTY (PeKing University Neutron Imaging FaciliTY) project at Peking University.

**RADIATION FROM PROTON ION SOURCE**

During the process of being accelerated, the H+ (or H2+, H3+) ions may collide with residual gas or electrodes in the extraction column, thus liberating electrons which are accelerated toward the opposite direction. These back streaming electrons upon striking the extraction electrodes and components of the ion source will produce bremsstrahlung.

During the experiments, X-ray arises when the voltage is increased up to 30 kV even with no proton beam output, because of the electrons produced by the field-emission.

Comparison experiments between two different structures of the extraction system

(a) Extraction system without X-ray shielding.

(b) Extraction system with X-ray shielding (extraction column inserted into diagnostic chamber).

The X-ray dose increased rapidly up to 1.13 μSv/h from 0.1 μSv/h with the same voltage of 50 kV when a proton beam of 57 mA was extracted with a duty factor of 1/6 (166 Hz, 1 ms).

The X-ray emission outside the vacuum chamber decreases to background level with this new structure, which makes it possible to test an intense H+ beam on-site even with the voltage up to 100 kV.

In addition, inserting the extraction system into the diagnostic chamber (Fig. (b)) can efficiently shorten the first drift space in LEBT, which will effectively reduce the beam loss due to the beam divergence and emittance growth.

**RADIATION FROM DEUTERON ION SOURCE**

A 2.45 GHz PMECR deuteron ion source haven been developed for PKUNIFTY project at Peking University.

Although the Coulomb barrier of stopping materials for neutron production in direct deuteron induced reactions contributes significantly for D+ energy of ~MeV, significant neutron fields have been experimentally observed even at very low energy due to the d, D reaction.

The neutron emission increases only when energy is above 40 keV. The gamma-ray emission only increases slightly from 0.09 μSv/h to 0.3 μSv/h. The neutron emission increases rapidly as both the beam energy and beam intensity increase. A maximum neutron dose of 14.1 μSv/h with D+ of 46 mA/50 kV (peak current).

The neutron emission increases only when energy is higher than 15 keV and reaches a saturated level of about 8 μSv/h·mA with energy above 40 keV. The Gamma-ray emission increases rapidly as soon as the energy reaches up to 40 keV.

Just after deuteron beam turned off, the neutron emission goes immediately down to 0, while the gamma-ray emission goes down to background level after 10 min.

**CONCLUSION**

Radiation studies on the proton and deuteron ion source have been performed at PKU. The optimized design of inserting the extraction column into the vacuum chamber was adopted and the X-ray emission has been shielded effectively in that way. In particular, the neutron and gamma-ray radiation as functions of beam energy are exposed. These experimental results obtained during the ion source commissioning will be great helpful for the design of radiation protection.