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Uc_x target developments for the ALTO and the SPIRAL 2 projects

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Abstract

The ALTO project (Accélérateur Linéaire auprès du Tandem d'Orsay) will provide an electron beam available at IPN Orsay at the end of 2005. The maximum energy will be 50 MeV with a maximum average intensity of 10 μA. It will be used for photofission in UC_x targets. With the same target as that already used on the PARRNE set up it will be possible using ALTO to induce up to 10^{11} fissions/s instead of 10^9 previously obtained with the 26 MeV/1 μA deuteron beam. Several ion sources will be adapted on the set up: ISOLDE FEBIAD type, surface ionization, laser,…. Moreover the electron beam could be used for other applications. Calculation about fission, energy deposition and dose rate will be presented, as well as the target–ion source adaptation on the PARRNE facility. For the SPIRAL 2 project planned at GANIL for 2008, the fission of ^{238}U in uranium carbide target will be induced by a neutron flow created by bombarding a carbon converter with a 40 MeV high intensity deuteron beam. The target has been designed to reach more than 10^{13} fissions/s with a good release time. Calculation and technical considerations used to optimize the target design are detailed. One of main difficulties for this target is to maintain it at high temperature (more than 2000 °C) during 3 months. A tantalum oven has been studied and a prototype is under test at IPN Orsay. Some R&D studies on a high density target are in progress in collaboration with PNPI Gatchina and INFN Legnaro.

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1. The UC_x targets

UC_x targets already used at IPN Orsay on the PARRNe set up are made using the Isolde method [1]. Same kinds of targets are considered for the SPIRAL 2 project with fast neutrons and for the ALTO project with gammas. Such a type of thick target is an assembly of disks about 1 mm thick composed of a mixing of uranium carbide and graphite. These disks are obtained by compressing a mix of uranium oxide and graphite powders. The carbonation is made by heating up to 2000 °C under vacuum to make the reaction: $UO_2 + 6C \rightarrow UC_2 + 2C + 2CO\uparrow$ or $UO_2 + 6C \rightarrow UC + 3C + 2CO\uparrow$. The graphite allows limiting the carbide grain size for minimizing diffusion paths. The structure of a target is a mix of carbon graphite and 20–30 μm uranium carbide grains. During irradiation, targets are heated up to 2200 °C.

2. The ALTO project

The PARRNe program (Production d'Atomes Radio-actifs Riches en Neutrons) at IPN Orsay is dedicated to the development of n-rich isotope beams by the ISOL (Isotope Separator On-Line) method. The PARRNe set up has already enabled R&D studies on UC_x targets for the

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SPIRAL 2 project, using the 26 MeV/1 μA deuteron beam, delivered by the Tandem, to produce fast neutrons [2]. Physics experiments were also performed [3]. An electron accelerator connected with the PARRNe separator is being constructed [4]. Its characteristics are expected to be the following: the maximum energy will be 50 MeV with a maximum average intensity of 10 μA. The repetition rate will be 100 Hz with an impulsion current duration between 2 ns and 2 μs. The maximum emittance has been estimated at 6 π mm mrad at 50 MeV. With the same target already used on the on-line isotope separator PARRNe, we could induce about 100 times more fission with the electron beam. Using the PARRNe set up, about five photofission experiments of 3 weeks of irradiation per year should be possible. Several ion sources will be adapted on the separator: ISOLDE FEBIAD type, surface ionization, laser,.... The use of the deuteron beam will remain possible for the R&D studies for the SPIRAL 2 project.

3. The ALTO target

The production of the target is estimated using the FICEL code [5,6]. Due to the absorption of photons in the target the production does not increase proportionally with the target density. The case of a conical shaped target has been also studied. It has been shown that a conical target three times larger with the same density would produce only 30% more fission events than the cylindrical one.

We will use an assembly of about 90 disks of 14 mm diameter, 1 mm thick and in some cases with a small spacing between each disk. The estimated production is 10^{11} fission events per second. For such a target, 350 W of the 500 W incident beam will be absorbed in the target, 150 W being re-emitted out of the target as photon radiation.

3.1. The case of a converter

The production has also been estimated when a tungsten plate, called "converter" is introduced in the electron beam way before it hits the target to produce gamma-rays. In this case a part of the fission events is due to the photons emitted from the converter. Another part is due to bremsstrahlung radiations produced in the target by the electrons which pass through the converter and hit the target (Fig. 1).

These results proved the production is better without converter. Nevertheless, a converter could be useful to reduce the energy deposited in the target. In fact if the converter thickness is equal to the range of electrons, no electrons will hit the target and only the energy due to photon absorption will be deposited in the target. The results given in Table 1 show that the converter would reduce the production by a factor 4 while the energy deposited would be reduced by a factor 8.

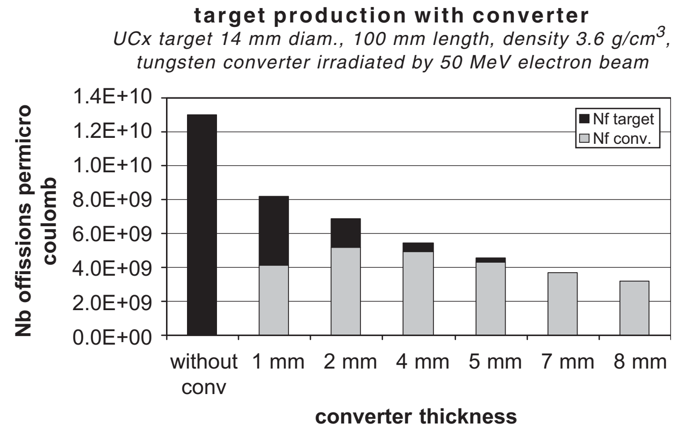

Fig. 1. Fission produced in the target with various converter thicknesses. In black: fission induced by photons produced in the target. In gray: fission induced by photons produced in the converter. The converter is in direct contact with the target.

Table 1
Production and energy deposited in the target without converter and with an 8 mm tungsten converter (range of 50 MeV electrons in W is 8 mm)

	Nb of fission per μC	Energy deposition (MeV)
Without converter	1.3×10^{10}	35
Converter W 8 mm	0.32×10^{10}	4.2

4. The SPIRAL 2 target

For the SPIRAL 2 project the specification is to reach 10^{13} fissions/s in the case of UC_x target using a 40 MeV/5 mA deuteron beam with a rotating carbon converter [7]. The production of a target irradiated by fast neutrons is estimated using the FICNER code [8]. Thanks to this code one can see the effect of geometrical parameters onto the production. Fig. 2 illustrates the spatial fission distribution in the target.

For the SPIRAL 2 project a target diameter 80 mm, length 80 mm, at about 40 mm from the entrance of the converter has been designed (Fig. 3). A conical target would not be better for the production than a cylindrical one with the same volume. Due to fast neutron angular distribution, it is not necessary to make a too long target. Moreover, this kind of target geometry is supposed to be better for effusion than a longer one with a smaller diameter.

The target has to work at a temperature higher than 2000 °C in order to allow an efficient release of the produced radioactive elements. The power deposited inside the target by the fission reactions is about 500 W for 1.6×10^{13} f/s. A 10 kW extra heating must be added in order to reach convenient temperatures. A tantalum oven prototype is under test. The UC_x disks will be in a graphite container surrounded by a tantalum foil to avoid reaction between carbon and the oven. The main difficulty is to