A SIMPLE METHOD FOR LARGE-CURRENT IRRADIATION OF A METAL TARGET IN THE CYCLOTRON

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Abstract

To produce a long-lived isotope Ho-163 the main probe of the cyclotron was modified and was used for irradiating a Dy-164 metal target inside the cyclotron with an intense proton beam of 20 MeV × 100 μA × 48 h. A design calculation of target cooling and a high-temperature bonding technique of target and cooling block are also mentioned.

Introduction

Recently a long-lived isotope Ho-163 is calling for attention because the electron-capture of this isotope might be utilized for determining the electron-neutrino mass[1]). For producing such an isotope irradiation of a cooled metal target by an intense beam within the cyclotron is effective, but an internal irradiation generally requires an elaborate and expensive facility. For the present purpose we modified and used the main (diagnostic) probe of the cyclotron; this rather simple method should be applicable for producing other radioisotopes.

Modification of the main probe

The modified part of the main probe is shown in Fig. 1. The main points of modification are: i) the water cooling channel has a form of sheet parallel to the cooling surface to which the target is bonded, and ii) the cooling block can be disconnected; this is essential for a high-temperature bonding and disbonding of the target in an induction furnace[2]). The most important parameters of the cooling block is the beam grazing angle θ and the conduction-layer thickness D. From test irradiations the former was chosen to be $\theta = 8.5°$, and the latter was determined to be D = 8 mm from a thermal design calculation mentioned below. An interlock system was newly added, which exhausts water in the cooling lines of the main probe in the event of vacuum failure of the cyclotron.

Thermal design of the cooling block

Thermal design calculation consists of i) thermal conduction in the Cu layer (D) as well as in the target and bonding metal, and ii) thermal transfer between the Cu wall and the cooling water. For an assumed proton beam of 20 MeV × 100 μA over a spot of 0.5 cm^2, a Dy metal target of 72 mg/cm^2, a brazing filler metal thickness of 0.05 mm, and cooling water of 11.6 ℓ/min over the cooling channel cross section of 22.5 × 2 mm^2 at a pressure of 4 atm the calculated temperatures are 580°C and 630°C at brazing-metal/Dy and Dy/vacuum interfaces, respectively (for the chosen value of D = 8 mm).

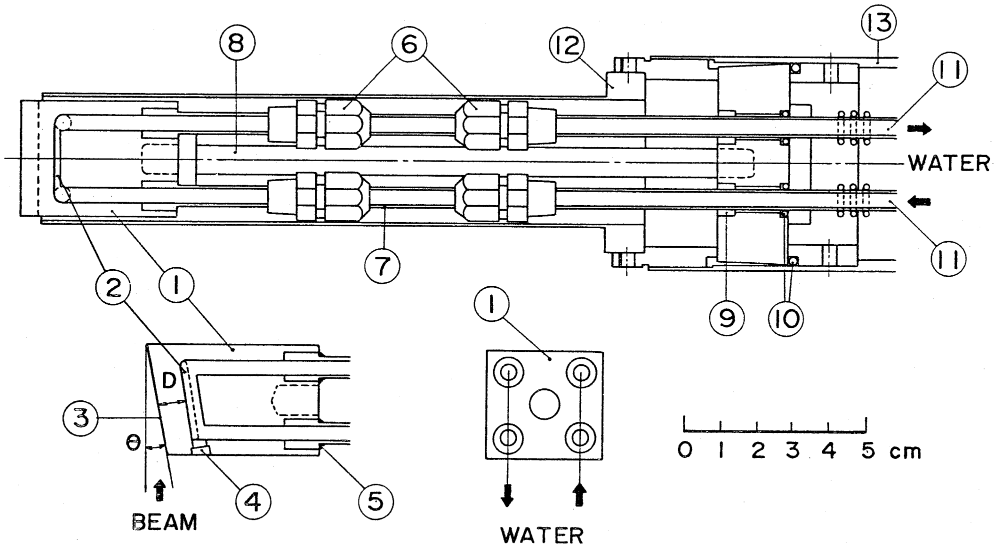

Fig. 1. Modified main probe for internal irradiation of a metal target: 1) Cooling block of Cu, 2) Cooling-water channel, 3) Cooling surface, 4) Plug, 5) Soldering (Paraflame), 6) Joints, 7) Flexible tube, 8) Mechanical support (SUS), 9) Insulating ring, 10) O rings, 11) Water inlet and outlet (Cu tubes), 12) RF shield, and 13) Main-probe stem.

Bonding of Dy metal and cooling block

Considering the high temperature expected at brazing-metal/Dy interface, we developed a high-temperature brazing technique using BAg-8 having solidus and liquidus of 780°C [2]. This technique should be applicable to various cases of large-current irradiation of metal targets.

Production of Ho-163

About 10 μg of Ho-163 was produced by the present method using the Dy-164(p,2n) reaction. The target was irradiated at R = 645 mm which is inner than the effective extraction radius of R_{ext} = 675 mm of the cyclotron. Thus the Dy MX-rays from Ho-163 were successfully observed[3].

References

1) A. De Rújula, Nucl. Phys. B188 (1981) 414.
2) K. Ishii et al., to be published in Nucl. Instr. Methods.
3) S. Yasumi et al., 1982 Int. Neutrino Conf., Balatonfüred, June, 1982.