ELECTROSTATIC DEFLECTORS: NEW DESIGN FOR HIGH INTENSITY BEAM EXTRACTION

S. Passarello, M. Re, G. Gallo, D. Garufi, A. Grmek, G. Manno, E. Zappalà and G. Cuttone, INFN-LNS, Via S. Sofia, 62, Catania, Italy

Abstract

During the last years big effort was devoted to increase the electrostatic deflectors' reliability; this provided a better comprehension of the most significant effects concerning their working conditions. Deflectors were checked during the normal operation of the K800 Superconducting Cyclotron (CS) at LNS, at the operating pressure of 1 10^{-6} mbar and a magnetic field of 3.5 T, the maximum cathodes voltage was –60kV (120 kV/cm). The maximum extracted beam power was, up to now, 100 W; it is foreseen to extract up to 500 W. In this contribution we present the study, the tests and the design of a new water cooled electrostatic deflector. Particular effort was applied to optimise the beam extraction efficiency, the thermal dissipation, and the mechanical stability. In particularly we implemented new insulators, new anodised aluminium cathodes, new Ta septum, new voltage and water feedthroughs and a more efficient cooling system. All these improvements were performed to increase the mean time between failure and the beam current stability.

INTRODUCTION

During the last years the K800 Superconductive Cyclotron (CS) was also dedicated to deliver the beam for some new facility at LNS such as CATANA [1] and EXCYT [2] which were developed respectively for the proton treatment of the ocular melanoma, and the production of radioactive ion beam. This required a strong improvement on the accelerated beam quality in terms of current stability, medium time between failure, extraction efficiency and the maximum deflected beam current.

The electrostatic deflectors of the CS are the most critical elements of the extraction system. The last years' experience provided a deeper comprehension of the phenomena and parameters involved in the deflectors working condition [3, 4]. According to the new requirements we completely redesigned the two deflectors taking into account that only the first one needs the water cooling. In this work we present, the tests and the design of a new water-cooled electrostatic deflector.

WATER-COOLED DEFLECTOR

Housing and Liners

The previous version of the deflector housing was composed by three parts (see figure 1): the left side was Aluminium while the upper and lower part (named Liners) are made in OFHC copper. The Ta septum was not screwed to the liners, but it was free to move into a groove. Using the old deflector we were able to stably extract in October 2003 a beam power of 100 W. The new deflector was designed to improve the thermal exchange via water-cooling up to a power of 500 W (see figure 2). In this version, housing and liners are made in OFHC copper and the heat exchange is enhanced adopting two water-cooled bands positioned in contact with the septum. Water-cooled pipes have been vacuum brazed to ensure low outgassing rate during the CS operation. In this way the heat exchange surface was improved by a factor 100 compared with the old deflector.

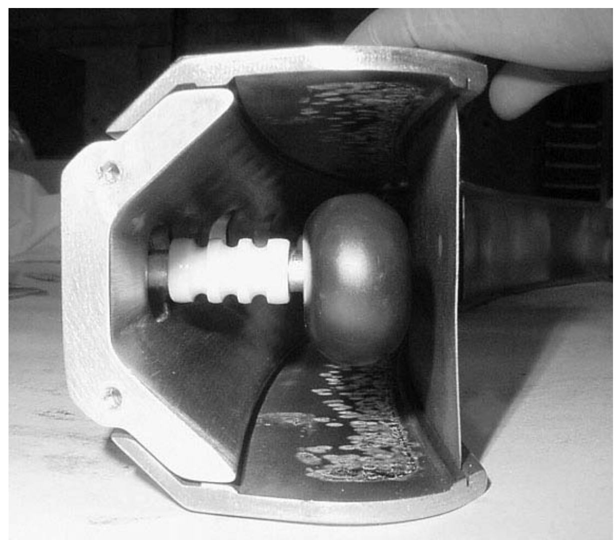

Figure 1: lateral view of the electrostatic deflector.

Figure 2: lateral view of the new water-cooled electrostatic deflector.

0-7803-8859-3/05/$20.00 ©2005 IEEE

Septum

Septum shape was redesigned: its length is about 40 cm, height is 50 mm while thickness is 0.3 mm, but the central part is reduced to a thickness of 0.1 mm. At the entrance side there is a "V"-notch [5] 5x42 mm that allow the impinging beam to dissipate its power on a longer path compared to the old septum, thus to avoid possible extreme temperature rising during the beam deflection (see Fig. 2).

Septum is made on tantalum (Ta), other candidate is tungsten (W). Actually, W seems to be a better material with respect to Ta : higher melting temperature (3410 Vs. 2996 °C), lower vapour pressure (5 10^{-6} mbar Vs. 5 10^{-5} mbar at 2500°C), lower thermal expansion coefficient (4.5E-6 Vs. 6.5E-6 1/K), higher thermal conductivity (173 Vs. 57.5 W/mK); moreover : higher Young Modulus (411 Vs. 186 GPa) , i.e. lower deformation by mechanical charge. By the other hand Ta has two main advantages : lower density (16.6 Vs. 19.3 g/cm3), i.e. longer beam path and therefore lower power density released by the beam; but what more appealing: Ta is easier to conform with the machinery. Nevertheless it is foreseen to test in the next future also a W septum.

We performed also some ANSYS thermal simulation of a simplified model of the deflector. In figure 3 we report the temperature distribution for a beam dissipation of 100 W. The beam trajectory is slightly misaligned with the symmetry axis. The maximum temperature is 1007 K, while by removing the two water-cooled bands, the temperature rise up to 1479 K.

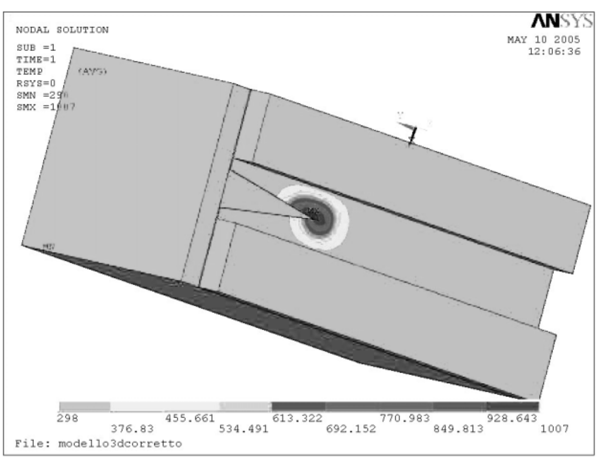

Figure 3: ANSYS simulation of the water-cooled deflector: beam dissipation = 100W.

Insulators

We replaced the old Macor insulator with new ones made on glazed alumina (99% purity) , ended by Stainless Steel connections.

By using these new insulators we experimented a lower total dark current, but this could be also due to the contemporary adoption of new electrodes. By theoretical considerations we can affirm that the glazing will saturate surface defects, grain boundary defects and the dandling bonds of its polycrystalline structure. These defects are responsible for the electron emission and surface conduction by avalanche. For that reasons we believe that the glazing enhance the performances of the insulators

These new insulators exhibit longer duration and reduced the high voltage conditioning time. In the next future it is foreseen to test also some AlN electrical insulators which are thermally conductive.

Electrodes

In a previous deflector version the electrodes (cathodes) were made of Ti alloy. Last years' tests confirmed that the best cathodes material is the hard-anodized aluminium electrodes; this anodization treatment was first applied at the K 1200 deflectors of the Michigan State University where they have been successfully tested. By means of these new electrodes we achieved very good results in terms of beam stability and accelerator reliability [6].

100 kV HV Feedthrough

Since previous high voltage feedthroughs contain some plastic parts they were not able to dissipate high thermal power. Therefore a new feedthrough was designed.

It consists of copper cup brazed on a ceramic insulator tube (see Fig.4), this contains a high voltage cable and a dry N_2 gas tube for cooling.

The differential pressure from the atmosphere to the CS vacuum chamber provide the needed force to assure a good electrical contact between the copper cup and the cathode. A pneumatic device which is automatic controlled, will stably keep the force at 50N to prevent any overpressure damage. In this way the feedthrough is able to follow the deflector during its movements.

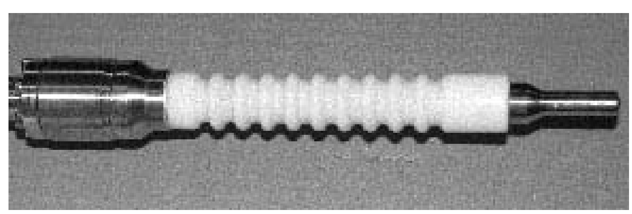

Figure 4: HV Ceramic feedthrough.

Water Feedthrough

The old water cooling system was not adequate to dissipate a beam power up to 500 W. Therefore we developed a dedicated water feedthrough supporting a higher water flow and which is easier to remove during the deflector exchange procedure. The cooling system provide water only to the first deflector (named E1) where the main part of the beam power is released.

The water feedthrough consists of a 12 mm coaxial tube for water inlet and outlet (see Fig.5) with a double seal connection, the system is movable by an automatic device similar to the one used for the high voltage feedthrough.

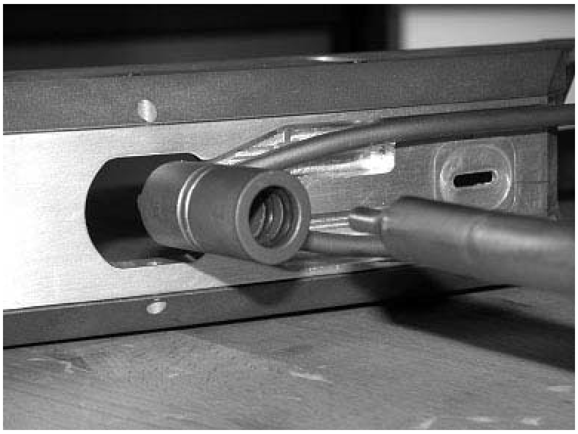

Figure 5: Water feedthrough.

Deflector Dismounting and Replacing.

When high intensity beams will be routinely accelerated by the CS, the high radioactive level will require a remote exchange procedure for the deflectors. In order to meet these requirements we developed a dedicated device and we modified the deflector moving bar system (see Fig. 6). In this way the remote handling of the deflectors is achievable.

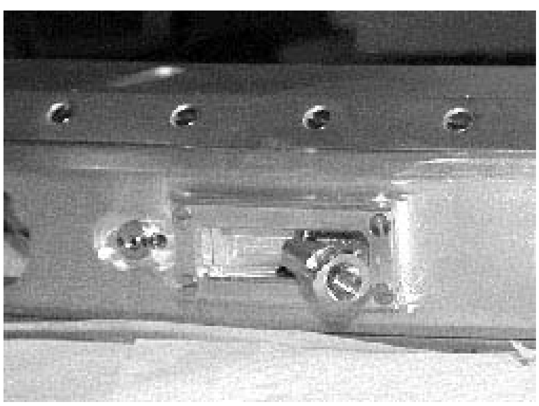

Figure 6: A view of the 'hook' connection.

Rotary feedthroughs are dedicated to remotely disconnect the moving bars from the deflector hook placed on the housing. The water-cooling system is empted and the water feedthrough is removed from its position. In this way the deflector lies untied on the median plane of the CS accelerator. At this step a special device (see Fig. 7) is dedicated to remove the deflector from its location and to save it in a Pb shielded chamber. The same device of figure 7 will restore the operating conditions by placing a new deflector that will be remotely connected to the moving bars and to the water- and H.V. feedthroughs.

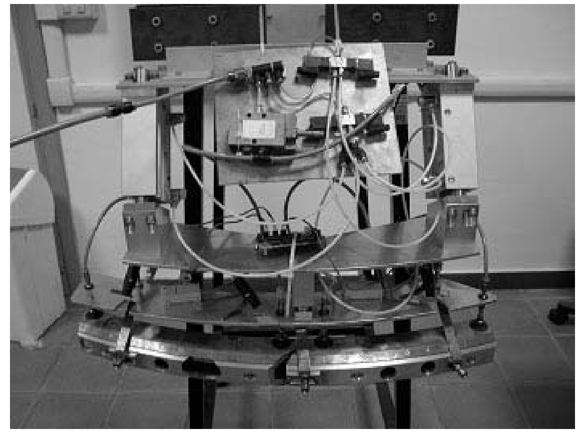

Figure 7: Special device for the remote handling of the CS deflectors.

Heat Exchange Off-Line Test

The new deflector (E1) was tested off-line in a test bench under vacuum. The heat was provided by two electrical heater of 500 W each, they were applied on the septum while the heater-, housing- and septum-temperature were monitored.

We estimated that nearly the 50% of the heat was dissipated by thermal irradiation from the heater, while the remaining 50% was transmitted by thermal conduction to the septum over a contact area of about 2 cm^2. In this experimental conditions the septum temperature at about 2 cm from the heaters raised to 200 °C while the housing temperature raised only to 52 °C.

After the test the deflector did not show any visible damage, therefore it was installed into the CS.

CONCLUSIONS

According to test performed "on-line" into the cyclotron and "off-line" in test bench, we believe that this deflector is able to extract from the CS a beam power up to 500 W.

Further development and investigations will concern a new tungsten septum and some AlN insulators.

REFERENCES

[1] G.A.P. Cirrone; G. Cuttone et al., IEEE Transaction on Nuclear Science **51**(3), (2004) p.860.

[2] G. Cuttone et al., LNS Report 2003, (2004), 138

[3] M.Re, G. Cuttone, S. Passarello, E. Zappalà. Atti del XVI Congresso dell'Associazione Italiana del Vuoto, p. 95, (2002).

[4] M. Re, G. Sarta, E. Zappalà, G. Cuttone Proc. Of XVII International. Conf. AIV, (2004).

[5] S. Alfredon, F. Marti et al. AIP Conf. Proc. **600**(1), (2001) p. 133.

[6] D. Rifuggiato, LNS Activity Report 2003, (2004), 158