PARALLEL BEAMS CO-EXTRACTION

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Abstract

Novel arrangement of the stripping foils in a negative ion cyclotron allows simultaneous parallel beams of small horizontal or vertical displacements to be extracted in the same beam line and delivered to the same target. One benefit of such an arrangement is the wider distribution of beam energy on the target, permitting much higher power deposition.

1 INTRODUCTION

The upper limit of beam energy deposited on a target is limited by the thermally hottest area on the target surface, usually the central peak of the typical Gaussian distribution. One way to increase the size of this area and reducing the energy density, and consequently the temperature, is to defocus the beam and trim it to the target shape by means of shadow collimators. Serious drawbacks of this technique, besides the obvious waste of available beam, are the activation of the collimators and their immediate areas as well as the increase in ambient radiation levels during operation. In normal production practices only about 10 % to 20% of the beam is allowed to be trimmed. Sophisticated focusing schemes involving multiply pole magnets to flatten the beam peak have been proposed, but their cost combined with the extra floor space needed and uncertainty of the results, limit their applications.

Similar arguments restrict the use of rotating or swept beams. In addition, the transient nature of those beams can produce high concentration of instantaneous stress, causing the premature failure of the target as a result of metal fatigue.

2 SINGLE BEAM TARGET

A typical energy profile on a target is shown in Fig.1. In this case, a 8kW beam is placed centrally on a 30mm by 80mm target. Targets of those dimensions are often used for isotope production. Energy density of 7.35MW/m² produces, in a well cooled target, a temperature of 104ºC. This value is used just as a reference point, but is, in fact, the upper limit for many target materials. Proportionally higher temperatures are generated by more intense beams. The Gaussian beam is shown truncated to a 80% rectangular shape from the original ellipse.

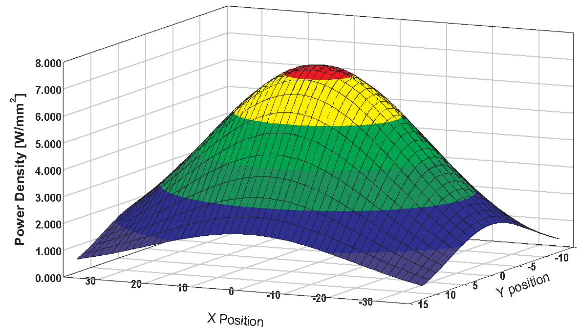

Figure1: Single beam distribution.

3 PARALLEL BEAMS CO-EXTRACTION

By stripping the electrons of a negative ion, its polarity is reversed. In a magnetic field such a particle will reverse its trajectory. Based on that phenomenon, stripping foils are used in a negative ion cyclotron to extract the beam from the machine. Since the beam is typically of a circular cross section, only part of the beam can be stripped by a foil smaller then the beam circle. Partial stripping was used in the past to extract several beams into separate beam lines. Popular arrangement in negative ion cyclotrons is to employ two diametrically opposed extractors, extracting into two beam lines.

However, by placing foil segments close to each other (in the order of few millimeters, or less) in one extractor, each segment covering a different area of the foil cross section, close parallel beams can be extracted into the same beam line. As an example, three such arrangements of dual foils are shown schematically in Fig. 2. In one arrangement the two segments are spaced horizontally, one above the other, to extract separately the top and bottom halves of the beam with an offset equal to the foil separation. Horizontally displaced segments extraction is feasible by placing a narrow foil, half the width of the beam cross section, in front of a solid foil to extract two, slightly different orbits. Probably the most feasible concept is shown in the lower setup. In this case we have two full size foils, one extended forward half the beam diameter and separated from the other by a small space. The shorter foil extracts a beam that will pass through the other foil on its way out.

Other arrangements are possible to achieve similar results, or more beams.

CP600, *Cyclotrons and Their Applications 2001, Sixteenth International Conference,* edited by F. Marti

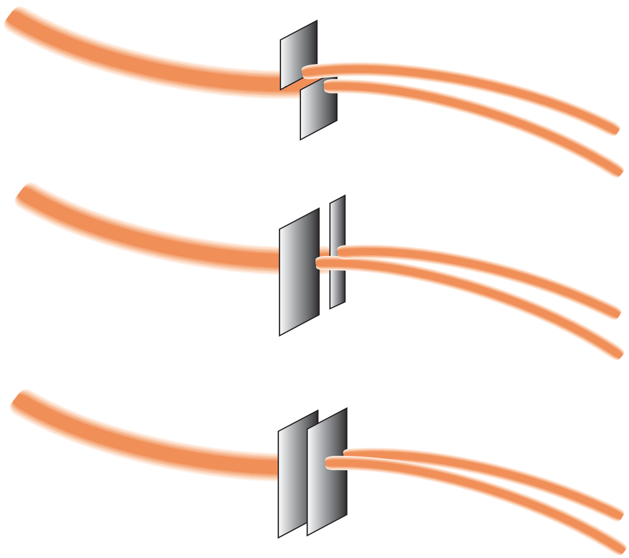

Figure 2: Multiple beam stripping foils

4 DUAL BEAM TARGET

The thermal distribution of two parallel beams, spaced 40mm (representing approximately 1.4mm extraction separation in a typical isotope production cyclotron like the TR30) on an identical target face to the previous example, is shown in Fig 3. The beams have an energy of 5kW each, to deliver a total of 10kW on target. As before, the combined beam shape was trimmed to deposit 80% of beam power on the target area. Highest beam concentration can be seen in the dual peak where the power density is 7.2 MW/m^2, slightly lower then the 7.35 MW/m^2 in the case of the single beam, but considering the higher total power on target, the peak temperature of 102ºC is comparable with the single 8kW beam.

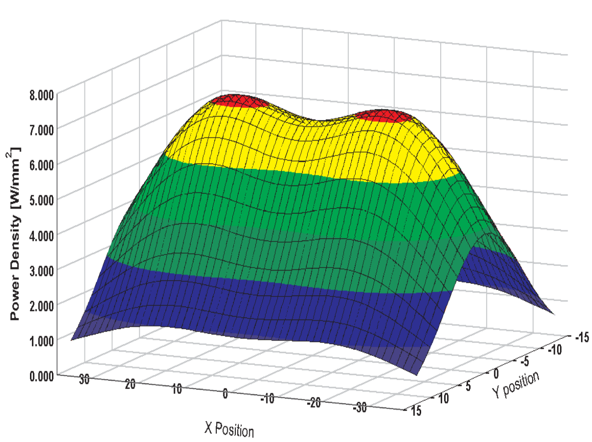

Figure3: Dual beam distribution

5 THERMAL ANALYSIS

The result of a thermal analysis of a typical, water-cooled target face is shown below. Only one quadrant of the symmetrical target is displayed. In both cases the water flow is 16 l/min, the target face material is silver.

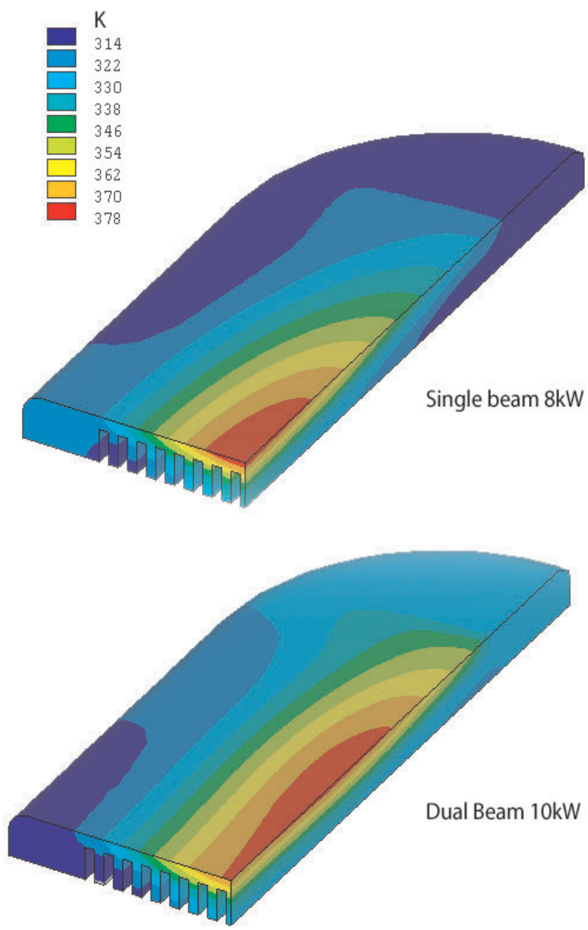

Figure4: Thermal FEA of target

6 CONCLUSION

With the ever increasing capabilities of the new generation of cyclotrons, especially in the area of isotope production, the targets are lagging behind in their ability to accept those beams. While optimized design, new alloys and cooling arrangements allow some increase in total power delivered to the target, we are reaching the limit of those refinements. The parallel beams co-extraction opens new possibilities to increase beam powers while maintaining low surface temperatures. Best of all, the mentioned above improvements in the target design can be implemented as well, to further increase the target capacity.

A patent application was filed for this process.

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