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A New Target Concept for Production of Slow Positrons *

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Abstract

Slow positrons in the energy range up to a few keV are useful for material sciences and surface studies. The Advanced Photon Source (APS) linear accelerator (linac) was designed to produce 8-mA of 450-MeV positrons. A 200-MeV, 1.7-Ampere electron beam impinges on a 7-mm-thick (2 radiation lengths) tungsten target, resulting in bremsstrahlung pair production of electrons and positrons. The existing target was optimized for high energy positron production, and most slow positrons produced by the electron-gamma shower remain trapped inside. The linac could also be used to produce slow positrons, and a modified target could increase the low energy positron yield. Use of a multilayer or segmented target reduces self-absorption by the target, and thus more fully utilizes the incident beam power for slow positron production. A slow positron yield of 10^9/sec is expected from the existing incident electron beam. Multilayer targets could probably be used by other accelerator-based slow positron sources to improve slow positron yield without increasing the incident beam power. Two variations of a multilayer target concept are presented and discussed in this paper.

I. Introduction

High energy and low energy (slow) positrons are generally produced using the same type of target [1, 2, 3, 4]. High energy electrons impinge on a single block of heavy metal such as tungsten or tantalum which is two to three radiation lengths thick. If high energy positrons are desired, a pulsed solenoid is placed just downstream of the target to capture positrons of the desired energy. If slow positrons are desired, an annealed tungsten vane system is used as a moderator to thermalize the positrons. The slow positrons are then extracted from the moderator, reaccelerated to a certain energy, time modulated, and transported to the user's location.

Positron production yield is proportional to the beam power absorbed by the target, but the incident high energy electron beam loses only part of its energy in passing through a target of 2 or 3 radiation lengths. Increasing the target thickness would absorb more of the incident beam power, but would increase the number of positrons trapped inside the target. A 200-MeV electron beam passing through a 2-radiation-length-thick target still exits the target at about 80 MeV, and can still be used to produce more positrons. We feel it is possible to use a multilayer target instead of a single thick block target to improve slow positron production. Segmentation of the target effectively increases the absorbed incident beam power and reduces positron reabsorption. Simulation results using the electromagnetic shower program EGS4 [5, 6, 7] indicate that slow positron yields can be increased one order of magnitude without increasing the incident beam power if a segmented target is used in place of a solid block. Positrons produced in each zone of a multilayer target must still be moderated and collected, which is beyond the scope of this paper.

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II. Single Block Target

EGS4 [5, 6, 7] was used to simulate electron-positron pair production from a single block tungsten target. The incident beam energy was fixed at 200 MeV, and the target thickness was varied from 1 to 5 radiation lengths (3.5, 7.0, 10.5, 14.0, and 17.5 mm). Figure 1 shows the total positron yield as a function of energy for different target thicknesses. The maximum yield for a single block target occurs at 2 radiation lengths. The yield of 8-MeV positrons is higher with a 10.5-mm-thick target; however, the transverse positron distribution after the target is also a function of target thickness, increasing from 1 mm at 1 radiation length to 6 mm at 5 radiation lengths as shown in Figure 2. The diameter of the positron distribution from a 10.5-mm target is almost a factor of 2 larger than for a 7-mm target. Fast positrons are captured by a pulsed solenoidal coil just downstream of the target, and since its axial field decreases rapidly away from the axis, the capture efficiency for fast positrons decreases with increasing spot size. We have used the 2-radiation-length target as the optimum thickness for fast positron production at 200 MeV [3, 4], and we compare multilayer target results to it.

III. Multilayer Target

The transverse distribution of the positrons may not be as stringent a factor in slow positron production as in high energy positron production. A multilayer or segmented target will be more efficient for slow positron production, since we can more fully utilize the incident beam power. Use of multiple thin layers will also reduce positron reabsorption by the target. Two multilayer target concepts have been simulated to date. The target material was tungsten in both simulations, and the incident beam energy was fixed at 200 MeV. The shower output from the first target layer becomes the incident beam for the second target layer, and so on.

A. Five-Layer Target

We first simulated a five-layer target. Each tungsten layer was 3.5 mm thick, and layers were separated by 6.5 mm of vacuum. The total length of the target was