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Performance of a slow positron beam using a hybrid lens design

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Abstract

The University of Hong Kong positron beam employs conventional magnetic field transport to the target, but has a special hybrid lens design around the positron moderator that allows the beam to be focused to millimeter spot sizes at the target. The good focusing capabilities of the beam are made possible by extracting work-function positrons from the moderator in a magnetic field free region using a conventional Soa lens thus minimizing beam canonical angular momentum. An Einzel lens is used to focus the positrons into the magnetic funnel at the end of transportation magnetic field while at the same time bringing up the beam energy to the intermediate value of 7.5 keV. The beam is $\boldsymbol{E} \times \boldsymbol{B}$ filtered at this intermediate energy. The final beam energy is obtained by floating the Soa–Einzel system, $\boldsymbol{E} \times \boldsymbol{B}$ filter and flight tube, and accelerating the positrons just before the target. External beam steering saddle coils fine tune the position, and the magnetic field around the target chamber is adjusted so as to keep one of the beam foci always on the target. The system is fully computer controlled. Variable energy-Doppler broadened annihilation radiation (VEDBAR) data for a GaN sample are shown which demonstrate the performance of the positron beam system.

Keywords: Focusing; Positron beam; Hybrid lens; *S*-parameter imaging

1. Introduction

Slow positron beams have proven increasingly useful instruments for material defect analysis at surfaces and interfaces [1]. Defect studies of small dimension samples with millimeter or sub-millimeter dimension, however, require a positron beam with equal or smaller diameter. The Hong Kong University (HKU) slow positron beam system was designed for this purpose [2]. The beam's hybrid lens design allows for sub-millimeter focusing at the target. The term 'hybrid' refers to the combination of magnetic fields and electrostatic lenses that in conjunction guide the particles from the moderator to the target. The basic principles behind the focusing of the beam have been described elsewhere [2]. Successful preliminary beam focusing at the primary gun energy of 7.5 keV has already been demonstrated [3]. In this

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paper, we report on the upgraded variable energy version of the beam in which an acceleration (or deceleration) stage has been inserted before the target in order to allow variation of beam energy. The performance of the HKU slow positron beam facility with respect to its ability to take standard variable energy-Doppler broadened annihilation radiation (VEDBAR) spectra is also reported. Moreover, the sub-millimeter focusing of the beam has allowed us to construct a real time *S*-parameter imaging system that is helpful in locating top surface metallizations [4] and a brief report is also made on this system.

2. System design

A schematic diagram of the primary gun section of the HKU positron beam is shown in Fig. 1. Positrons are emitted from the 50 mCi ^{22}Na source, which is placed behind a 4 mm diameter 12-layers transmission mode tungsten mesh moderator that had been annealed ex situ at 1800 °C [5]. An electrically insulated oil cooled solenoid is used to provide a reverse magnetic field for cancelling the magnetic field supplied by the large field coils that surround the positron beam system. This coil which has a diameter of 5.6 cm and a length of 20 cm carries a current of 18 A so that at its center, the magnetic field from the external field coils is exactly cancelled. The coil comprises two layers so that both the electrical and coolant connections can be made from the rear of the assembly. The coil is made from oxygen free high purity (OFHC) copper tube with external and internal diameters of 3.0 mm and 1.5 mm, respectively. Electrical insulation of the coil is provided by a layer of teflon sleeving. Transformer oil is forced through the tube with 10 bar of pressure producing a flow of $\sim 2\ cm^3\ s^{-1}$ so as to maintain the coil at close to room temperature. Positrons ejected from the moderator surface in the magnetic field free region are first extracted and focused using a modified Soa immersion lens [6]. This is followed directly by a grided Einzel lens [7] that both accelerates and focuses the positrons into the magnetic funnel that is produced as the compensating field of the oil cooled solenoid terminates. A beam focus is produced just down

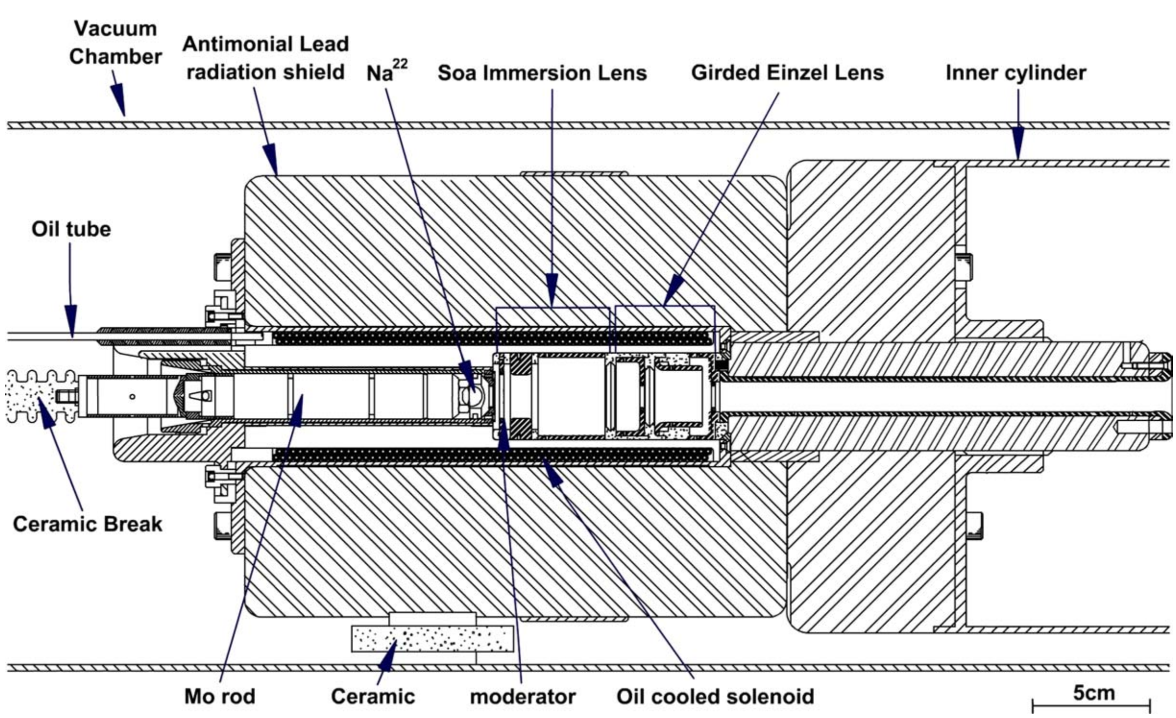

Fig. 1. Primary gun section of the HKU positron beam system.