4 The Slow Positron Facility

4-1 Overview

The Slow Positron Facility, equipped with a dedicated 55 MeV linac, provides a high intensity, pulsed slow positron beam. It operates in a short-pulse mode (width 10 ns) and a long-pulse mode (width 1 μs), at frequencies of up to 50 Hz.

4-2 Increase in the Beam Intensity by Modification of the Slow Positron Production Unit

The converter/moderator assembly for the slow positron beam production has been replaced. The main modifications are: (i) 25 μm-thick W foils of sizes 4.8 mm × 21 mm and 4.8 mm × 29 mm were set in lattices. (ii) Two sets of lattices were assembled. (iii) The Ta converter, W moderator lattices, and extraction grid were electrically isolated from each other, and connected to a cascade voltage supply (up to 35 kV + up to 10 V × 3). The floating voltage was formerly applied by a 9 V dry cell only to the extraction grid.

The converter and the frame for the moderator are made of Ta as before. Figure 1 shows the new assembly. The slow positrons are extracted in the direction perpendicular to the linac beam, out of the lattice face.

The moderators were annealed after the W strips were set in the lattices. They were encased in covered boxes of 50 μm-thick W foil, and the boxes were irradiated on the covering lids with the beam of an electron beam welder. The annealing temperature was elevated to around 2400°C, considerably higher than is common practice for W positron moderators. The vacuum of the welder chamber was 1×10^{-5} Torr.

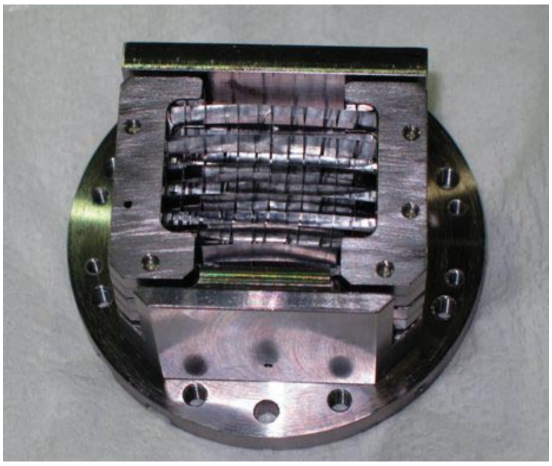

Figure 1
New assembly of the slow positron production unit.

A comparison of the intensity of the slow positron beam before and after the replacement of the unit showed an increased by an order of magnitude to 7×10^7 slow positrons/s. Later, the intensity fell slightly but remains at around 5×10^7 slow positrons/s.

4-3 Photodetachment of the Positronium Negative Ion (Ps^-)

The positronium negative ion (Ps^-) is an exotic system composed of one positron and two electrons bound through Coulomb interaction. Nagashima et al. established a method to produce Ps^- efficiently and stably [1,2]. When the pulsed slow positrons at SPF are injected onto a Na-coated W surface, 1.4% of the positrons are emitted back as a Ps^- pulse. The ions were then successfully photo-detached into a neutral positronium atom and an electron by using an intense photon beam from a Q-switched Nd:YAG laser (1 J/pulse at 1064 nm, 12 ns FWHM, 25 pps) synchronized to the Ps^- bunch [3]. Figure 3 shows the details of the crossed beam region. The results are shown in the Highlight section of this Activity Report (see p 68). The intensity of the Doppler shifted annihilation γ-rays from the accelerated Ps^- ions decreased upon photon irradiation. This indicates that the Ps^- ions are converted into neutral Ps atoms, of which 3/4 are ortho-Ps which do not annihilate into 2γ but into 3γ. The lower limit of the Ps^- photo-detachment cross section estimated from the decrease is $2.1 \times 10^{-17} cm^2$, which is consistent with theoretical results.

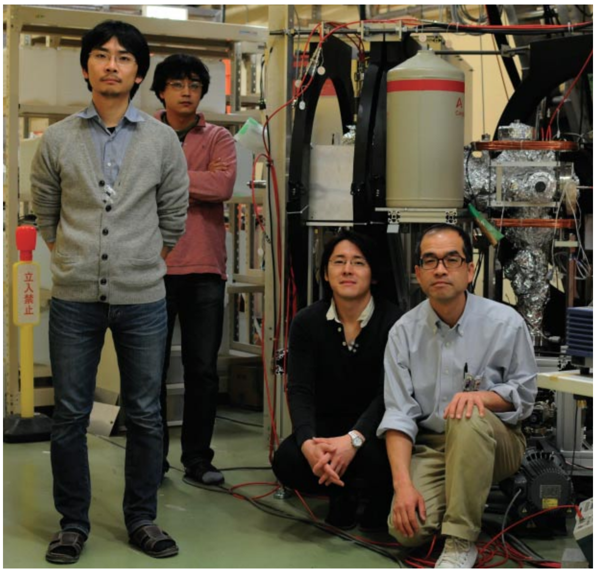

Figure 2
Photograph of Mr. Michishio, Dr. Tachibana, Mr. Suzuki and Prof. Nagashima.

This achievement marks the first step toward the creation of an energy tunable Ps beam that can be used in UHV environments.

REFERENCES

[1] Y. Nagashima, T. Hakodate, A. Miyamoto, and K. Michishio, *New J. Phys.* **10** (2008) 123029.

[2] H. Terabe, K. Michishio, T. Tachibana, and Y. Nagashima, *New J. Phys.* **14** (2012) 012058.

[3] K. Michishio, T. Tachibana, H. Terabe, A. Igarashi, K. Wada, T. Kuga, A. Yagishita, T. Hyodo and Y. Nagashima, *Phys. Rev. Lett.* **106** (2011) 153401.

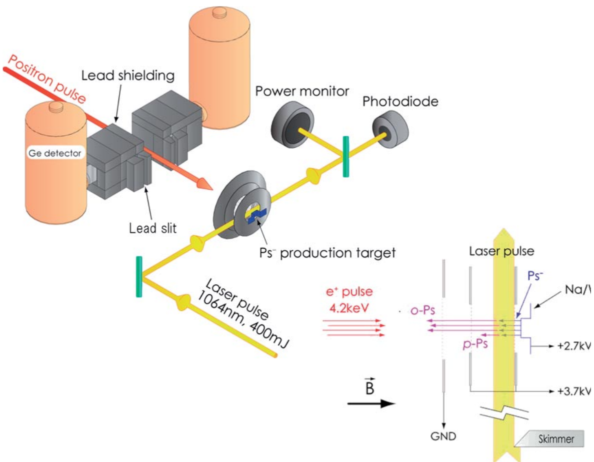

Figure 3
Details of the setup for the Ps- photodetachment [3].

4-4 Installation of RHEPD Station and First Data

A station for reflection high-energy positron diffraction (RHEPD) has been connected to a beamline branch on the ground floor. The RHEPD is a positron version of the reflection high-energy electron diffraction (RHEED). This is a project of Dr. Fukaya (Kawasuso Group) of the Japan Atomic Energy Agency (JAEA).

A remarkable feature of RHEPD is that, since the crystal potential for the positron is positive, positrons incident on the surface with a small glancing angle are totally reflected. Thus, positrons are more sensitive to the topmost layers of crystals than electrons. Kawasuso and Okada put RHEPD to practical use [4]. Fukaya et

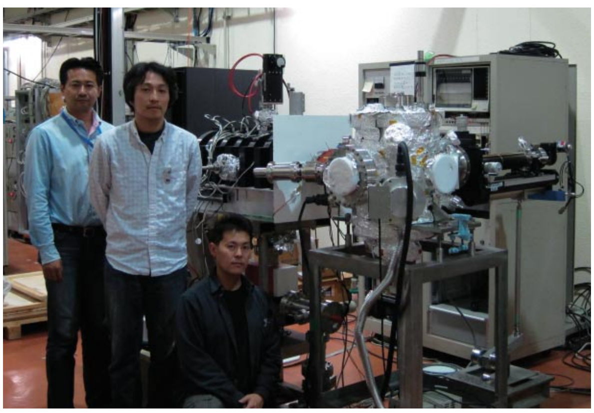

Figure 4
Photograph of Drs. Wada, Fukaya and Maekawa.

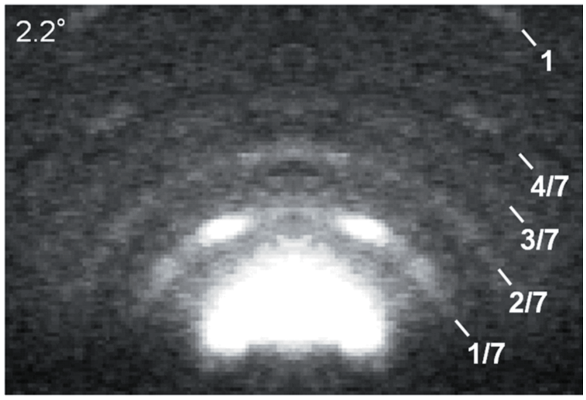

Figure 5
Observed RHEPD pattern for the Si(111)7 × 7 surface.

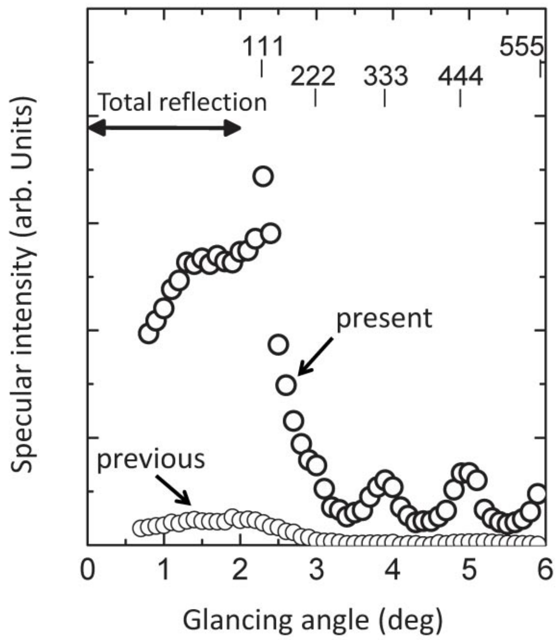

Figure 6
Observed rocking curve for the Si(111) 7 × 7 surface.

al. have used a ^{22}Na-based slow positron beam at JAEA to determine the structure of the In atom chains on the Si(111) surface below the phase transition temperature [5] and studied surface plasmon excitations [6].

It was found that the intensity of the diffracted beam in the new apparatus was 14 times stronger than the former measurements with the ^{22}Na-based beam at JAEA. Figure 5 shows an RHEPD pattern from the Si(111)-7 × 7 surface obtained. The fractional spots from the 7 × 7 superstructure are clearly seen. Figure 6 shows the RHEPD rocking curve of specular spots from the same surface. In addition to the intense total reflection and the (111) Bragg reflection peaks, the (333), (444), and (555) Bragg reflection peaks are clearly observable.

REFERENCES

[4] A. Kawasuso and S. Okada, *Phys. Rev. Lett.*, **81** (1998) 2695.

[5] Y. Fukaya, M. Hashimoto, A. Kawasuso and A. Ichimiya, *Surf. Sci.* **602** (2008) 2448.

[6] Y. Fukaya, A. Kawasuso and A. Ichimiya, *Phys. Rev. B* **79** (2009) 193310.