Journal of Physics: Conference Series **635** (2015) 082003 doi:10.1088/1742-6596/635/8/082003

Development of an energy-tunable positronium beam apparatus using the photodetachment of the positronium negative ion

L. Chiari* [1], **K. Michishio*** [2], **N. Oshima†** [3], **Y. Nagashima*** [4]

* Department of Physics, Tokyo University of Science, 1-3 Kagurazaka, Shinjuku, Tokyo 162-8601, Japan
† National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki 305-8568, Japan

Synopsis We report on the development of an energy-tunable positronium beam apparatus at Tokyo University of Science. The positronium beam is generated using the photodetachment of the positronium negative ion, a bound state of one positron and two electrons. Positronium negative ions are efficiently emitted from a Na-coated tungsten surface by bombardment with a slow positron beam. The intermediate-energy positronium beam produced in this fashion can be used for fundamental studies of antimatter-matter interactions with solid surfaces.

Positronium is a bound state of a positron and an electron and is produced in gases, liquids and insulators. It may also form when positrons impinge on metallic surfaces and a fraction is re-emitted bound to a target electron [1]. However the maximum emission energy of positronium in that case is just a few eV and its neutral nature prevents the formation of a beam by electrostatic acceleration.

So far energy-tunable positronium beams have been produced using the charge-exchange reaction of energetic positrons with gas molecules [2], where the positronium energy is set by the energy of the primary positron beam. Here we report on the development of a new, monochromatic and energy-tunable positronium beam apparatus at Tokyo University of Science. The positronium beam is produced using the photodetachment of the positronium negative ion [3], a bound state of two electrons and one positron [4].

A slow positron beam is generated by a ^{22}Na isotope (~20 mCi) in conjunction with a solid Ne moderator. The positrons are guided by a strong axial magnetic field (600 G) into a buffer-gas trap containing a mixture of N_2 and CF_4 gases [5], where they thermalize and are accumulated to form the source for a pulsed beam (~100 Hz). The positron beam then passes through a buncher in order to reduce the pulse width.

The slow positron beam is subsequently accelerated to an energy of several keV before being focussed onto a Na-coated W (100) surface placed within a weaker magnetic field (~3 G). Efficient and durable emission of positronium negative ions from Na-coated W surfaces has been observed [6]. Those positronium negative ions are then accelerated using a static electric field and a positronium beam with a given kinetic energy is generated by photodetachment using a Q-switched Nd:YAG laser (1064 nm, 10 W) [7].

The incident energy of the positronium beam produced in this fashion will range from a few hundred eV to several keV. Hence, it will extend and complement the energy range that is and currently accessible with beams produced using the charge-exchange reaction with gas molecules [8]. The positronium beam at the target is anticipated to be around 1 mm in size with an intensity of the order of 100 positronium atoms per second.

Advantages of the present technique include the concurrent achievement of high-energy and ultra-high-vacuum compatibility. This will enable the investigation of solid surface structures, such as reflection high-energy positronium surface diffraction.

References

[1] P. G. Coleman 2000 *Positron beams and their Applications* (World Scientific, Singapore)
[2] N. Zafar *et al* 1996 *Phys. Rev. Lett.* **76** 1595
[3] K. Michishio *et al* 2011 *Phys. Rev. Lett.* **106** 153401
[4] Y. Nagashima *et al* 2014 *AIP Conf. Proc.* **1588** 27
[5] S. J. Gilbert *et al* 1997 *Appl. Phys. Lett.* **70** 1944
[6] H. Terabe *et al* 2012 *New J. Phys.* **14** 015003
[7] K. Michishio *et al* 2012 *Appl. Phys. Lett.* **100** 254102
[8] G. Laricchia and H. R. J. Walters 2012 *Riv. Nuovo Cimento* **35** 305

[1] E-mail: luca.chiari@rs.tus.ac.jp
[2] E-mail: michishio@rs.tus.ac.jp
[3] E-mail: nagayasu-oshima@aist.go.jp
[4] E-mail: ynaga@rs.kagu.tus.ac.jp