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A collimated, energy-tunable positronium beam for the investigation of positronium scattering with surfaces

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Interactions of positronium (Ps) atoms with materials have long been of interest in research fields, such as atomic and molecular physics, material science and radiation chemistry. When Ps atoms interact with solid surfaces, specular reflection [1] and the spin conversion reaction [2], as well as pick-off annihilation, may take place. If a coherent beam of Ps atoms impinges onto single-crystal surfaces, the diffraction phenomenon of elastically scattered Ps atoms might also occur. This technique might be a unique probing of surface structures owing to the neutrality, lightness and outermost surface sensitivity of Ps [3]. However, because of Ps neutrality and short-lived nature, the production of a Ps beam, that is applicable to surface scattering studies, is very challenging.

In recent years, we have succeeded in the efficient generation of positronium negative ions (Ps^-), in which an electron is weakly bound to a positronium atom [4]. This technique made it possible to observe its photodetachment [5] and resonant photodetachment [6], and consequently to produce an energy-tunable Ps beam [7]. In the present work, we show the production of a collimated, tunable Ps beam based on a trap-based positron system [8], which can output nano-second positron bursts. Those positron bursts were magnetically guided and focused onto an efficient Ps^- converter, a Na-coated W(100) film of 100 nm thick [4]. The Ps^- ions emitted from the opposite surface of the film were focused and accelerated by a simple electrostatic lens and then photodetached by a nano-second IR laser pulse to form a Ps beam in the energy range of 200 eV – 3300 eV. In order to reduce the angular divergence, a collimator with a diameter of 1 mm was installed, resulting in a collimated beam with an angular spread of less than 0.1 degrees. This high quality beam can be applied to positronium diffraction experiments with the grazing incidence geometry.

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