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電子陽電子プラズマ生成のための小型ダイポール磁場トラップの開発状況

Development status of a compact superconducting levitated dipole trap for electron-positron plasma formation

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The goal of the APEX project [1] is the formation of magnetically-confined electron-positron plasmas and their experimental understanding. Such matter-antimatter plasmas are in a class of pair-plasmas, consisting of equal-mass charged particles, whose unique wave and stability properties are theoretically and numerically predicted [2,3]. Realization of pair-plasmas with the electron-positron system enables studies on pair-plasma properties ranging from low to high frequency ranges, which were not possible in past studies. Because available positron beam intensity is by far weaker than that of electrons, ultra-high injection efficiency and excellent trapping time are required for the formation of positron plasmas. Then the creation of pair-plasmas is achieved by simultaneous trapping of these positrons and electrons. APEX plans to operate a toroidal dipole trapping configuration at the NEPOMUC facility [4], a fission reactor-based world's strongest slow-positron source running at Technical University Munich, Germany. So far, we have conducted positron experiments with a prototype dipole trap with a permanent neodymium magnet [5] at NEPOMUC. Initial results include loss-less (100% efficiency) injection of positron beam by means of a pair of E×B electrodes located at the edge confinement region [6] and stable trapping of positrons for approximately 1.5 s [7].

In the experiments described above, all magnetic field lines in the trapping region intersect the permanent magnet surface. Because positrons are transported into the loss cone of magnetic mirror of the poles with a time scale decided by neutral collisions, long trapping is not realized without biasing the magnet surface. Although this mirror loss can be suppressed by positively biasing the magnet, of course just for positrons, such bias potential breaks the axisymmetry of electric fields due to the electrode configuration of the system, especially the E×B electrode plates. Because the canonical angular momentum of a particle is no longer conserved, benign trapping properties are not expected in such a system.

From this perspective, we plan to replace the permanent magnet to a superconducting (SC) coil winding that generates closed field lines in the dipole field trapping region. In the final state of the electron-positron plasma experiment of APEX, we will levitate the SC coil using a feedback-controlled system so that disturbance to plasmas is minimized.

Although such a levitated dipole experiment, or *artificial magnetosphere* [8], was successfully constructed and succeeded to confine very high-β plasmas in past studies, we need to develop a new dipole trap suitable for the operation at positron beamline and the realization of a high-density state of rare antimatter particles. Here we are on a way to develop a compact levitated dipole trap focusing on plasma and atomic physics experiments including the electron-positron system, realized by the direct (i.e. without using circulation fluid) cooling of high-temperature SC (HTS) coil winding. The key issues of such a system are feasible and reliable cooling method, stable levitation control, and development of efficient positron and electron injection and trapping schemes. For such purposes, we are conducting optimization studies of coil parameters and cooling test with Bi-2223 HTS coil windings. We will present required parameters of the dipole trap based on the past positron experiments and status of the SC trap development.

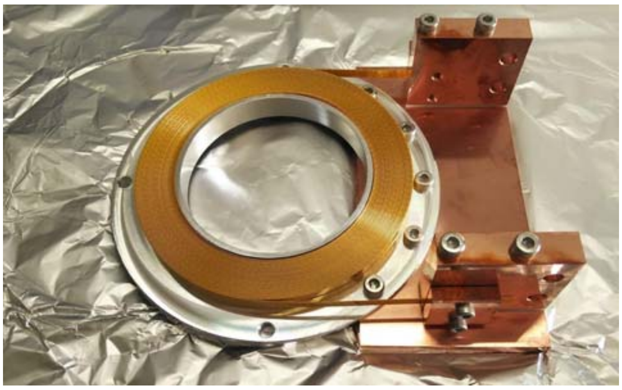

Fig.1: A Test winding for the excitation coil with Bi-2223 SC tape, to be operated by direct cooling.

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