Toward creation of electron-positron plasmas in a laboratory

H. Saitoh[1,2], J. Stanja[1], E. Stenson[1], U. Hergenhahn[1], and T. Sunn Pedersen[1,3]

[1] Max Planck Institute for Plasma Physics, Garching and Greifswald, Germany
haruhiko.saitoh@ipp.mpg.de
[2] Graduate School of Frontier Sciences, The University of Tokyo, Kashiwa, Japan
[3] Ernst-Moritz-Arndt-Universität Greifswald, Greifswald, Germany

Abstract

Electron-positron plasmas own unique properties as one of pair-plasmas, plasmas consisting of equal-mass charged particles [1], which are fundamentally different from conventional ion-electron plasmas. Electron-positron plasmas have long been studied theoretically and numerically in relation to astrophysical phenomena observed for example in pulsar magnetospheres. Recently, remarkable stability properties of electron-positron plasmas have been predicted [2]. These studies on pair-plasmas are important for understanding fundamental properties of plasmas, as well as for providing insights into astrophysical phenomena. In order to create electron-positron plasmas in a laboratory, experiments in linear magnetic trapping configurations, such as Penning-Malmberg trap [3] and magnetic mirror [4] have been conducted. In the field of high-energy electron-positron plasmas, laser-based generation of dense electron-positron pairs was reported recently [5]. We, the PAX (Positron Accumulator eXperiment) and APEX (A Positron-Electron Experiment) teams [6], plan to create the first magnetically-confined electron-positron plasmas in a novel approach. We will operate toroidal traps (superconducting stellarator [7] and dipole [8] devices) in combination with a linear accumulator device at NEPOMUC [9], the world's strongest moderated positron source.

In this contribution, we present progress toward the creation of magnetically-confined electron-positron plasmas in IPP [10]. In the PAX accumulation experiment, we have conducted non-neutral (pure electron) plasma experiments with a 2.3 T Penning-Malmberg trap. More than one hour of confinement and observation of a collective mode of non-neutral plasmas were demonstrated. In the linear configuration, studies on remoderation and diagnostics of positron beams are also ongoing. In the APEX injection and confinement project, we have stated on-line experiments with intense positron beams at the NEPOMUC facility. We have characterized the positron beam for wide energy range including low energy range suitable for trapping in a dipole field configuration. In a prototype dipole trap, generated by a permanent magnet, efficient (40%) injection of the remoderated 5 eV positron beam from NEPOMUC was realized. After injection, we also observed relatively long confinement (~ 5 ms) of positrons in the prototype dipole field trap. Based on these results, we are conducting design and operation studies on a superconducting levitated dipole experiment suitable for the confinement of electron-positron pair-plasmas.

[1] V. Tsytovich, Comments Plasma Phys. Cont. Fusion **4**, 91 (1978).
[2] P. Helander, Phys. Rev. Lett. **113**, 135003 (2014).
[3] R. G. Greaves and C. M. Surko, Phys. Rev. Lett. **75**, 3846 (1995).
[4] H. Higaki *et al.*, Appl. Phys. Express **5**, 106001 (2015).
[5] G. Sarri *et al.*, Nat. Commun. **6**, 6747 (2015).
[6] T. Sunn Pedersen *et al.*, New J. Phys. **14**, 035010 (2012).
[7] P. W. Brenner and T. Sunn Pedersen, Phys. Plasmas **19**, 19050701 (2012).
[8] Z. Yoshida *et al.*, Phys. Rev. Lett. **104**, 235004 (2010).
[9] C. Hugenschmidt *et al.*, New J. Phys. **14**, 055027 (2012).
[10] H. Saitoh *et al.*, New J. Phys. **17**, 103038 (2015); J. Stanja *et al.*, NIMA **827**, 52 (2016).