Collimation of Neutral Electron-Positron Beams


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Electron-Positron beams represent a unique state of matter that present overall charge neutrality. These beams are believed to be emitted as highly collimated astronomical jets by some of the most powerful and distant astrophysical objects in the Universe such as Black-holes, pulsars, and quasars. Theory suggests that as these beams propagate through space instabilities occur between the electrons and positrons as they interact with the interstellar medium. This causes the electrons and positrons to filament out into separate beam-lets that set up strong magnetic fields between them. What drives the micro-physics behind such phenomena is an on going area of research. To gain a deeper understanding of how these neutral pair plasmas are formed and their dynamics, a small scale reproduction in the laboratory would open the doors for a new field of research into the world of laboratory astrophysics.

Despite the intrinsic difficulty in reproducing neutral pair plasmas in the laboratory, recent experiments carried out using a laser driven set-up have for the first time created a neutral ion free electron-positron plasma, with high-density and divergence on the order of 20 mrad [1]. However, although small this divergence leads to the beam quickly losing density, so that within the first few mm any collective behaviour in the plasma is lost. For a meaningful study of the dynamics of electron-positron beams in the laboratory, it is necessary that these beams be kept highly collimated. Numerical simulations indicate that an electron beam with a converging full-cone angle of 20 mrad incident onto a lead target, initiates an electrodynamic cascade that produces a highly collimated neutral electron-positron beam [2]. Here, through analytical and numerical analysis we show that the electron beam can be converged onto the target by using a system comprising of three miniature magnetic quadrupoles. Also we present the first data obtained with said quadrupoles using the Hercules laser facility at the Center for Ultrafast Optical Science at the University of Michigan, USA.

References