

# Sympathetically Laser-Cooled and Compressed Positron Plasmas<sup>1</sup>

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Cold, dense positron plasmas are one ingredient for making cold antihydrogen. We present results on trapping and sympathetic laser-cooling of positrons in a Penning trap which can produce high densities ( $\geq 4 \times 10^9 \text{ cm}^{-3}$ ) and low temperatures ( $\lesssim 4 \text{ K}$ ). In our experiment positrons from a 2 mCi  $^{22}\text{Na}$  source travel along the axis of a 6 T magnet and through the trap after which they strike a Cu reflection moderator crystal. Up to a few thousand positrons are trapped, compressed, and lose energy through Coulomb collisions (sympathetic cooling) with laser-cooled  $^9\text{Be}^+$ . By imaging the  $^9\text{Be}^+$  laser-induced fluorescence, we observe centrifugal separation of the  $^9\text{Be}^+$  ions and positrons, with the positrons coalescing into a column along the trap axis (see Fig. 1 below). This indicates the positrons have the same rotation frequency and comparable density to that of the  $^9\text{Be}^+$  ions ( $\sim 4 \times 10^9 \text{ cm}^{-3}$ ). The number of trapped positrons calculated from this density and the volume of the non-fluorescing column agrees, within measurement uncertainties, with the positron number obtained by ejecting the positrons from the trap and measuring the annihilation radiation. The gradient in the  $^9\text{Be}^+$  fluorescence near the  $^9\text{Be}^+e^+$  boundary places an upper limit of approximately 5 K on the positron temperature of motion parallel to the magnetic field. The positron lifetime was measured to be comparable to the  $^9\text{Be}^+$  confinement time and is  $\geq 8$  days in our room temperature vacuum of  $10^{-8}$  Pa. The distance traveled by a 4 K antiproton before 3-body recombination in a 4 K,  $10^9 \text{ cm}^{-3}$  positron plasma is  $\sim 0.2$  mm.

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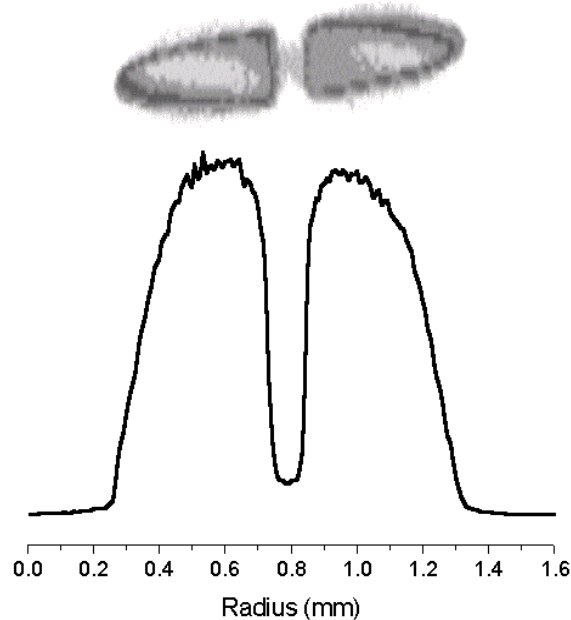


Figure 1. Two species  $^9\text{Be}^+e^+$  plasma showing a side-view image of the plasma and the radial variation of fluorescence integrated over  $z$ . The  $e^+$  are located in the central, non-fluorescing region.