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OFFICE OF NAVAL RESEARCH  
END-OF-THE YEAR REPORT  
PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS/STUDENT REPORTS

for

GRANT N00014-96-10579  
PR Number 96PR 00453-01

Physics of Positron Plasmas in the Laboratory

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PUBLICATIONS/PATENTS/PRESENTATIONS/HONORS REPORT

PR Number: 96PR 00453-01  
Contract/Grant Number: N00014-96-10579  
Contract/Grant Title: Physics of Positron Plasmas in the Laboratory  
Principle Investigator: Professor Clifford M. Surko  
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- a. Number of papers submitted to refereed journals, but not published: 2
- b. Number of papers published in refereed journals: 6
- c. Number of books or chapters submitted but not yet published: 0
- d. Number of books or chapters published: 0
- e. Number of printed technical reports/non-refereed papers: 0
- f. Number of patents filed: 0
- g. Number of patents granted: 0
- h. Number of invited presentations: 5
- I Number of submitted presentations: 0
- j. Honors/Awards/Prizes for contract/grant employees: 0
- k Total number of full-time equivalent graduate students and post-doctoral associates supported during this period, under this R&T project number:
  - Graduate Students: 1
  - Post Doctoral Associates: 1
  - Including number of
    - Female graduate students: 0
    - Female post doctoral associates: 0
    - Minority graduate students: 0
    - Minority post doctoral associates: 0
    - Asian Graduate students: 0
    - Asian post doctoral associates: 0
- l. Other funding: Complementary project on positron-molecule interactions funded by the National Science Foundation, grant # PHY-9600407.

**GRANT N00014-96-10579**  
**Physics of Positron Plasmas in the Laboratory**  
**Publications and Invited Presentations**

**a. Papers submitted to refereed journals**

1. Studies of Positron-Matter Interactions using Stored Positrons in an Electrostatic Trap, K. Iwata, R. G. Greaves, C. Kurz, S. J. Gilbert, and C. M. Surko, *Proc. 11th Int'l Conf. on Positron Annihilation*, Kansas City, MO, May 1997, to be published by World Scientific.
2. New Source of Ultra-cold Positron and Electron Beams, C. Kurz, S. J. Gilbert, R. G. Greaves and C. M. Surko, *J. Nuclear Instruments and Methods B*, submitted.

**b. Papers published in refereed journals**

1. Positron Annihilation in a Simulated Interstellar Medium, K. Iwata, R. G. Greaves and C. M. Surko, *Can J. Phys.*, **74**, 407 (1996).
2. Solid Neon Moderator for Positron Trapping Experiments, R. G. Greaves and C. M. Surko, *Can J. Phys.*, **74**, 445 (1996).
3. Stored Positrons for Antihydrogen Production, C. M. Surko, R. G. Greaves, and M. Charlton, *Hyperfine Interactions* **109**, 181 (1997).
4. Gamma-ray Spectra From Positron Annihilation on Atoms and Molecules, K. Iwata, R. G. Greaves, and C. M. Surko, *Phys. Rev. A* **55**, 3586 (1997).
5. Antimatter Plasmas and Antihydrogen, R. G. Greaves and C. M. Surko, *Phys. Plasma* **4**, 1528 (1997).
6. Creation of a Monoenergetic Pulsed Positron Beam, S. J. Gilbert, C. Kurz, R. G. Greaves, and C. M. Surko, *Appl. Phys. Lett.* **70**, 1944 (1997).

**h. Invited Presentations**

1. R. G. Greaves, "The UCSD positron accumulator," International Conference on Antimatter Gravity and Antihydrogen Spectroscopy, Sepino Italy, May 1996.
2. C. M. Surko, "Antimatter plasmas and antihydrogen," plenary review, APS Plasma Physics Division meeting, Denver CO, November 1996.

3. C. M. Surko, "A monoenergetic pulsed positron beam and other new research tools using traps," International Workshop on Positrons in Atomic Physics, Nottingham England, July 1997.
4. C. M. Surko, "Experiments with trapped positrons," International Conference on Electron and Atomic Physics, Vienna Austria, July 1997.
5. R. G. Greaves, "Experiments with stored positrons," Workshop on Nonneutral Plasmas, Boulder CO, July 1997.

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**Physics of Positron Plasmas in the Laboratory**  
**Summary**

We continue to lead the world in the efficient accumulation and storage of low-energy positrons. In the past year, we have designed and begun to build the next-generation positron trap. We expect this device to be capable of furnishing cold positrons at a rate of  $10^{10}$  per hour from a 150 mCi  $^{22}\text{Na}$  radioactive source.

We had begun the first laboratory studies of electron-positron plasmas, passing an electron beam through a positron plasma. We have now developed a new method to generate a high-quality electron beam (0.16 eV FWHM at beam energies from  $\sim 0.2$  to 9 eV), and with it we are able to study the entire range of instability of the lowest order mode of the positron plasma confined in a quadrupole potential well. These experiments motivated new theory (by D. H. E. Dubin), and theory and experiment are in excellent, quantitative agreement. This same approach should allow us to study the instability in long cylindrical plasmas, which approximates the infinite plasma case.

We developed a new technique to make cold charged-particle beams. It involves cooling a trapped single-component plasma and then extracting the particles by carefully pushing them past over a potential barrier. It is useful for both electron and positron beams. In both cases, it has practical advantages over other state-of-the-art techniques. Of particular interest is the ability to make ultra-cold and bright pulsed positron beams. There are many potential uses of such beams, including atomic and molecular physics studies, identification of molecular species, the ionization of molecules without fragmentation, and the characterization of solid surfaces. Currently, this technique can produce pulsed positron beams with 10  $\mu\text{s}$  bursts of  $10^5$  positrons in the energy range from 0 to 9 eV, with a parallel energy spread (and comparable perpendicular energy) of 18 meV FWHM. As a figure of merit, this beam has a brightness of  $1 \times 10^9 \text{ s}^{-1} \text{ rad}^{-2} \text{ mm}^2 \text{ eV}^{-1}$ , which exceeds that of other techniques. This line of research is in its infancy and several potential improvements are envisioned.

The positron accumulation technique that we have developed will be used by the ATHENA collaboration at CERN in an experiment designed to form, trap and conduct precision measurements on antihydrogen. The next generation trap, described above, will be duplicated by them and used in this experiment.

Other aspects of the research include precise studies of atomic and molecular physics using the positron trapping and manipulation techniques developed in this project. We discovered previously that the annihilation of low-energy positrons with atoms and molecules is enhanced by many orders of magnitude for the case of

large molecules, and we continue to pursue consequences of this discovery with the new techniques described above. Latest results include determination that positrons annihilate with valence electrons and with equal probability on any valence electron, the first measurements of inner shell annihilation, and the first systematic studies of the dependence of atomic annihilation rates on positron temperature.