Modified Penning-Malmberg Trap for Storing Antiprotons

One set of electrodes is used for both transmission and reception.

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A modified Penning-Malmberg trap that could store a small cloud of antiprotons for a relatively long time (weeks) has been developed. This trap is intended for use in research on the feasibility of contemplated future matter/antimatter-annihilation systems as propulsion sources for spacecraft on long missions. This trap is also of interest in its own right as a means of storing and manipulating antiprotons for terrestrial scientific experimentation.

The use of Penning-Malmberg traps to store antiprotons is not new. What is new here is the modified trap design, which utilizes state-of-the-art radio-frequency (RF) techniques, including ones that, heretofore, have been used in radio-communication applications but not in ion-trap applications.

A basic Penning-Malmberg trap includes an evacuated round tube that contains or is surrounded by three or more collinear tube electrodes. A steady axial magnetic field that reaches a maximum at the geometric center of the tube is applied by an external source, and DC bias voltages that give rise to an electrostatic potential that reaches a minimum at the center are applied to the electrodes. The combination of electric and magnetic fields confines the charged particles (ions or electrons) for which it was designed to a prolate spheroidal central region. However, geometric misalignments and the diffusive cooling process prevent the steady fields of a basic Penning-Malmberg trap from confining the particles indefinitely.

In the modified Penning-Malmberg trap, the loss of antiprotons is reduced or eliminated by use of a “rotating-wall” RF stabilization scheme that also heats the antiproton cloud to minimize loss by matter/antimatter annihilation. The scheme involves the superposition of a quadrupole electric field that rotates about the cylindrical axis at a suitably chosen radio frequency.

The modified Penning-Malmberg trap (see Figure 1) includes several collinear sets of electrodes inside a tubular vacuum chamber. Each set comprises either a single metal tube or else a tube that is segmented into four electrodes each.

A colinear set of electrodes is used to generate an RF signal that is applied to the electrodes. The RF signal is generated by an RF signal generator and is fed through a 90° hybrid coupler and then through two baluns to generate four replicas of the signal at relative phase shifts of 0°, 90°, 180°, and 270° (see Figure 2). These signal replicas are fed through -6-dB directional couplers, then via coaxial cables to the vacuum chamber. The signal is then routed to a phase cancellation network, which filters out the drive signal with the difference representing the plasma interaction. Inside the vacuum chamber, twisted-pair wires feed the signals from the coaxial cables to the four electrodes of each segmented electrode tube.

It is not necessary to use a different set of electrodes for moni-
Two-Photon Fluorescence Microscope for Microgravity Research
The benefits of two-photon fluorescence microscopy are realized at reduced cost.
John H. Glenn Research Center, Cleveland, Ohio

A two-photon fluorescence microscope has been developed for the study of biophysical phenomena. Two-photon microscopy is a novel form of laser-based scanning microscopy that enables three-dimensional imaging without many of the problems inherent in confocal microscopy. Unlike one-photon optical microscopy, two-photon microscopy utilizes the simultaneous nonlinear absorption of two near-infrared photons. However, the efficiency of two-photon absorption is much lower than that of one-photon absorption, so an ultra-fast pulsed laser source is typically employed.

On the other hand, the critical energy threshold for two-photon absorption leads to fluorophore excitation that is intrinsically localized to the focal volume. Consequently, two-photon microscopy enables optical sectioning and confocal performance without the need for a signal-limiting pinhole. In addition, there is a reduction (relative to one-photon optical microscopy) in photon-induced damage because of the longer excitation wavelength. This reduction is especially advantageous for in vivo studies. Relative to confocal microscopy, there is also a reduction in background fluorescence, and, because of a reduction in Rayleigh scattering, there is a $4\times$ increase of penetration depth.

The prohibitive cost of a commercial two-photon fluorescence-microscope system, as well as a need for modularity, has led to the construction of a custom-built system (see Figure 1). This system includes a coherent mode-locked titanium: sapphire laser emitting 120-fs-duration pulses at a repetition rate of 80 MHz. The pulsed laser has an average output power of 800 mW and a wavelength tuning range of 700 to 980 nm, enabling the excitation of a variety of targeted fluorophores. The output from the laser is attenuated, spatially filtered, and then directed into a confocal scanning head that has been modified to provide for side entry of the laser beam. The laser output coupler has been replaced with a dichroic filter that reflects the longer-wavelength excitation...