Plasma Dynamics in RF Traps

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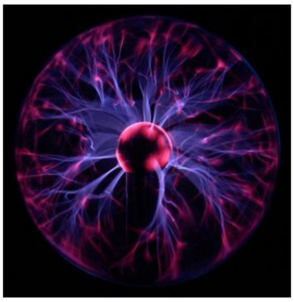
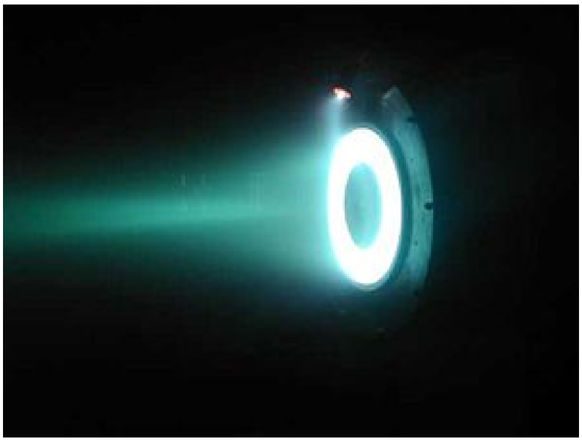
Plasma is a gas of charged particles. Since the properties of a plasma are very different from that of gases of neutral atoms, plasma is also known as the fourth state of matter and more than 99% of the universe if made up of plasma!! Sun, stars, earth's core, lightning, electron gas in a metal are some examples of natural occurences of plasmas.



Plasma Lighting

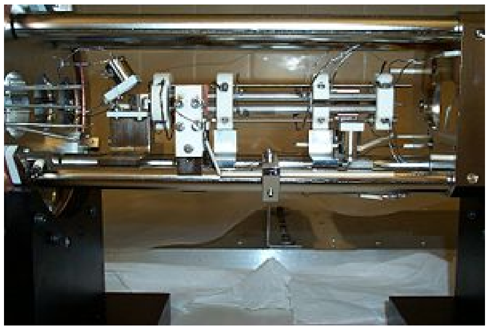
Apart from abundant in nature, plasmas are also widely used for various applications like plasma processing, thin film deposition, plasma lighting, plasma antennas, plasma thrusters for spacecrafts, stealth technology and many more. One of the most recent and most exciting applications of plasma physics is Laser Wake Field Acceleration which is being developed to provide high energy particles for experiments concerning the fundamental laws of physics.



Plasma Thruster for Spacecrafts

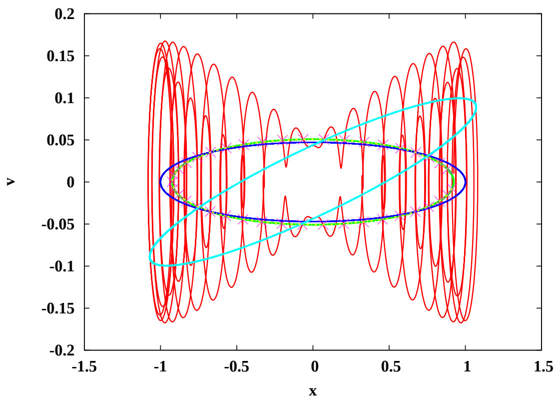
Plasmas also find applications in areas like mass spectroscopy and experimental studies of quantum information theory. In these applications, what one needs is to be able to trap a gas of charged particles of the same species, also known as non-neutral plasmas. RF traps (also known as Paul traps) are widely used to trap such non-neutral plasmas.

In these traps, the plasma is confined by means of a purely linear externally applied electric field that has both a DC and a RF component. These traps were first proposed by W. Paul in 1953 [W. Paul, Rev. Mod. Phys. 62, 531 (1989)] and have been an active area of research since then.



Linear Ion Trap at the University of Calgary

The phase-space particle orbits in such traps is shown in the figure below (red). As can be seen, the orbits are quite complex. To study such orbits, two simplifying techniques are used: Time averaging method and Stroboscopic map. In the figure, the red curve is the full orbit in the (x, v) phase space, the blue curve is for the time averaged orbit and the green and cyan curves are for two stroboscopic maps which are obtained by sampling the full x, v orbit periodically (with the same period as the same as the applied RF field) starting from two different instants of time.



Particle orbits in phase space

We have obtained an analytic expression for the stroboscopic map, and showed that the stroboscopic coordinates can be transformed (rotation and scaling) to give the time averaged coordinates. Using this result, we have solved for the time-periodic distribution function for the plasma.

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