PLASMA GENERATION

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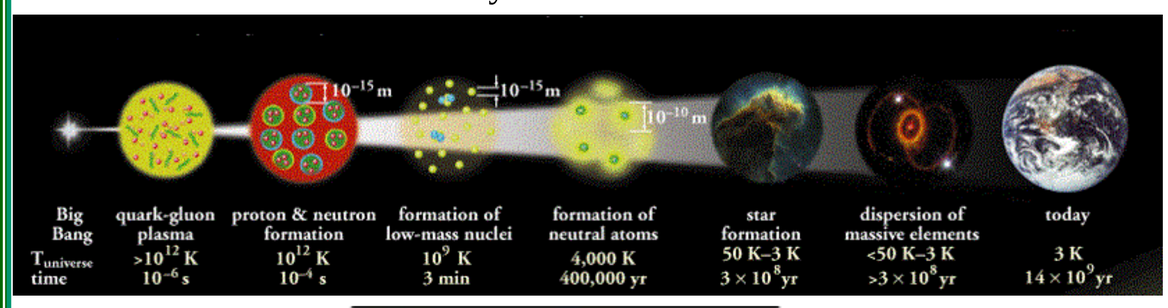
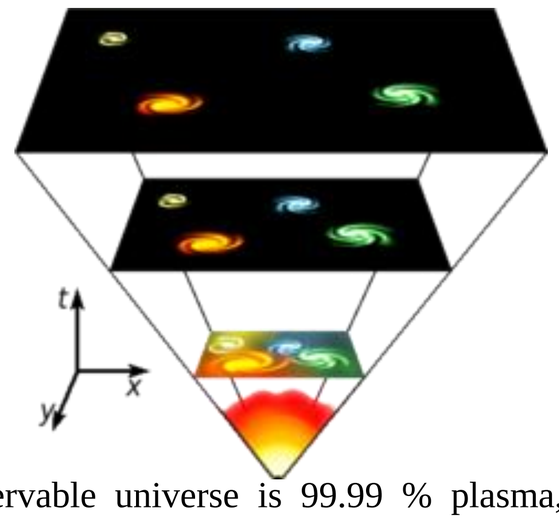
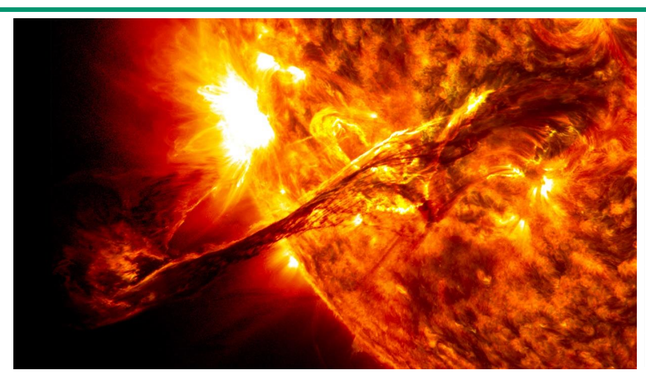
Except for the **Big-Bang** , the violent explosion presumed to have happened 13.7 billion years ago, as the **cause and reason** of the observable universe (Hubble Volume !), it seems everything Originated from Plasma. So the "**First Matter**" to start with may be PLASMA !

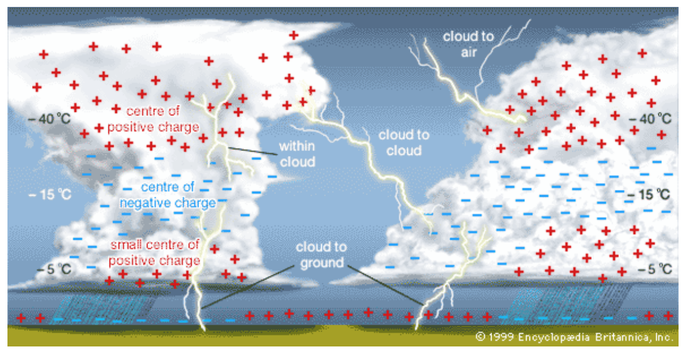




Though the observable universe is 99.99 % plasma, it require **extreme temperatures / energy and special conditions** for the ionization of matter to occur in normal earth like atmosphere and situations .



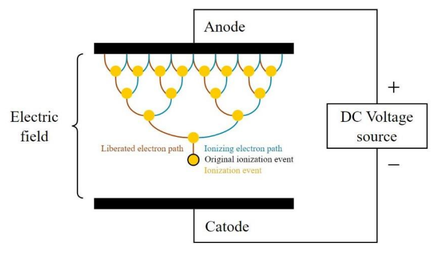
The **extreme high temperatures** aided by the the **enormous gravitational forces** and the associated phenomena keep the hydrogen gas ionized and so the Sun and Stars in plasma form



The **Very high voltage static electricity** that builds up across clouds and earth result in ionization of gas in between resulting in the high density plasma visualized as lightening !

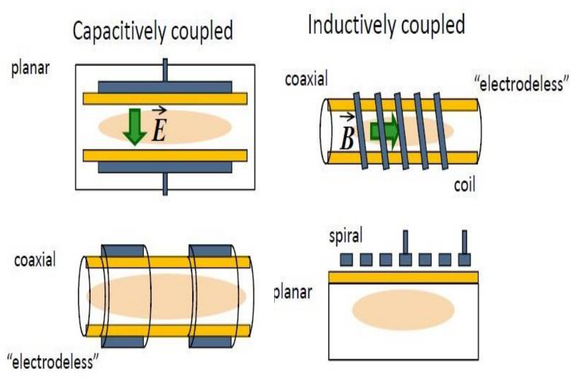
Auroras happens when **charged particles from sun** during solar flare penetrate the earth's magnetic shield and ionize the particles in atmosphere emitting bursts of photons

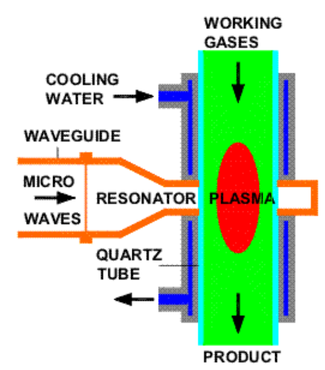
Man Made Plasma: Wide range of potential applications demands plasmas with different characteristics. This require many different ways of generating it. Basic idea is to supply energy to neutral gas of right combination to generate charge carries which in turn collide with more neutral particles of supply gas forming and sustaining plasma .



Application if electric field is the commonly used method in generating and sustaining low temperature plasma. Any volume of gas has a few electrons and ions due to cosmic ray or radio active interactions within the gas. These get accelerated by the field and cause further ionization of neutral which in turn leads to avalanche of charged particles. A balance of loss and generation of charged particle ultimately lead to a steady-state plasma conditions.

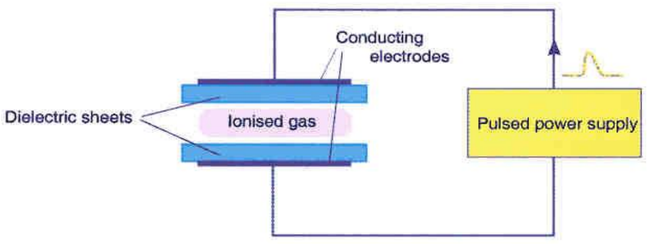
Capacitively and inductively coupled RF discharges operates in the range of 1- 100 MHz, typically at 13.56 MHz λ at 10^{-3}mbar to 10 mbar gas pressure. The electromagnetic wave energy launched into ionize the gas and sustain the plasma used for processing applications

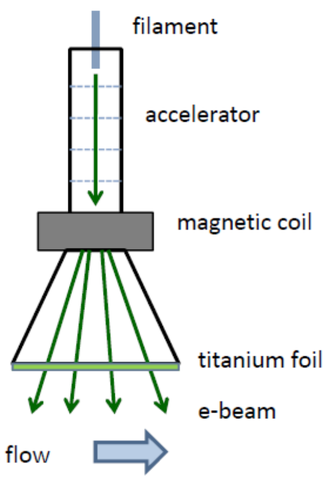




Microwave Energy transferred into electrons created by thermionic emission at typical frequency 2.45 GHz / 12.24 cm λ in different modes. High plasma densities of up to 10^{13} particle cm^{-3} and temperatures ~ 10^{3} K achieved with higher electron temperatures

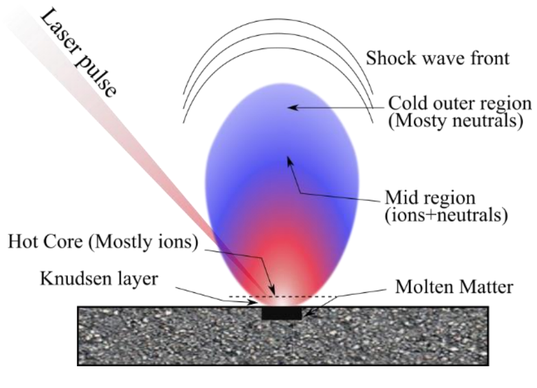
DBD discharge or 'silent discharge' is generated with dielectric barrier on electrodes in gas-filled small gap. 1–100 kV , 50 Hz–1 MHz is used to generate filaments of current density is 100–1000 A cm^{-2}, electron density is 10^{14}–10^{15} cm^{-3}, and energy 1–10 eV. - A non thermal plasma at atmospheric pressure is the advantage witch has wide applications



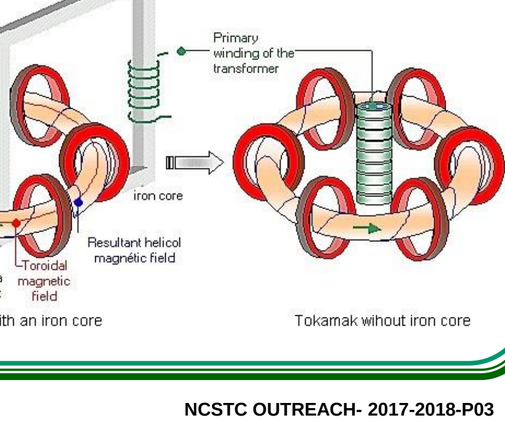


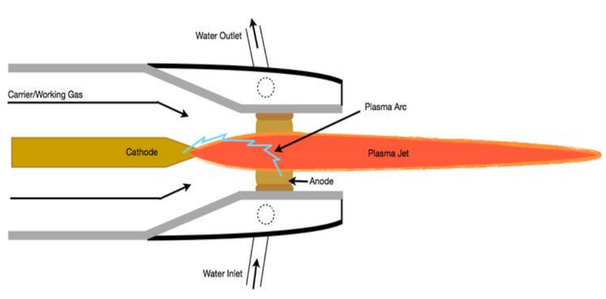
Electron beams , assisted Magnetic fields 0.01-0.02 T, could be used to generate plasma of good uniformity plasma of m^2 sizes. Energy transfer rate transfer write upto 70 % possible. High electron densities can be produced at high pressures with independent control over ion and radical fluxes.

The **laser induced Plasma**, with many application, is generated by laser ablation which starts with electronic energy absorption (~fs) and ends at particle recondensation (~ms). Process is governed by thermal, non-thermal or a combination of both. Different systems based on thermal, mechanical, photo physical, photochemical exist.



The **cascaded arc** is a wall-stabilized thermal electric arc discharge capable of producing high-density argon and hydrogen plasmas 10^{19} – 10^{24} $/cm^{-3}$ low <u>electron temperature</u> (~1 eV) . It consists of a gas inlet, cathodes, cascaded plates isolatd by insulatots , a nozzle and an anode. Gas flow is typically ~ 2×10^{20} particles per second at a discharge current of 100–300 A.





Thermal plasmas in **Plasma Torches** are achieved by DC,AC and RF currents and discharges in different configurations. Consists of electrodes of copper / tungsten / graphite / molybdenum / silver etc. and plasma is formed from the continuously flowing working gas /fluid. Thermal efficiency of 90% is easily possible with power range from 1 kW tp 200kW at $6x10^3$ to $50x10^3$ K over a range and type of sources.

In Tokamaks Plasma is generated by **resistance (ohmic) heating** by which a puff of gas gets ionized and become the secondary winding to the primary coil (central magnetic coil) called Ohmic Transformer. Plasma of 100s of million degree centigrade and densities suitable for nuclear fusion is produced and tried to be maintained in the Tokamak then for sufficient duration .

Illustrations owed to Internet websites and readily available on image search with related keywords