Nuclear Research Center
EAEA

4th Plasma Course at BUE
Different Applications of Plasma Physics

Azza Ahmed Talab

Associate Professor
Egyptian Atomic Energy Authority
NRC, Plasma Physics and Nuclear Fusion Department – Cyclotron Facility
azza_talab@yahoo.com

Outline:

- Plasma Classification.
- Plasma Processing and Low Energy Plasma Science.
- Generation of plasma in Different Experiments.
- Cold Plasma Experiments.
- Hot Plasma Experiments.

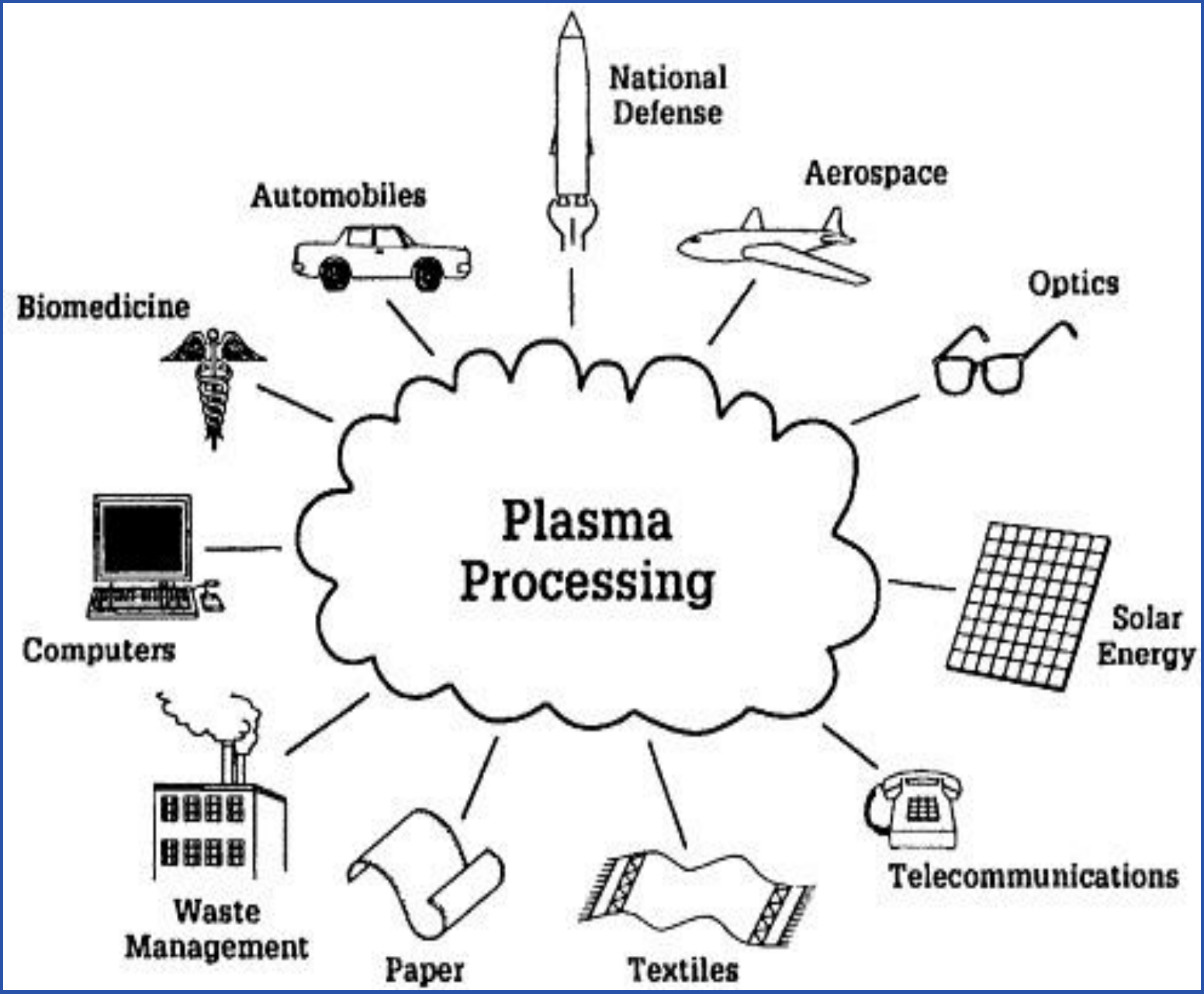
Plasma Classification

- Plasmas are described by many characteristics, such as temperature, degree of ionization, and density.

- A plasma is sometimes referred to as being "hot" if it is nearly fully ionized, or "cold" if only a small fraction, (for instance 1%) of the gas molecules are ionized, but other definitions of the terms "hot plasma" and "cold plasma" are common. Even in cold plasma the electron temperature is still typically several thousand centigrade.

Plasma Processing and Low Energy Plasma Science

- Plasma processing technologies are of vital importance to several of the largest manufacturing industries in the world. Foremost among these industries is the electronics industry, in which plasma-based processes are indispensable for the manufacture of very large-scale integrated microelectronic circuits. Plasma processing of materials is also a critical technology in, for example, the aerospace, automotive, steel, biomedical, and toxic waste management industries. Most recently, plasma processing technology has been utilized increasingly in the emerging technologies of diamond film and superconducting film growth. Because plasma processing is an integral part of the infrastructure of so many vital industries, it is important for both the economy and the national security that any country maintain a strong leadership role in this technology.


National Defense
Aerospace
Automobiles
Optics
Biomedicine
Plasma Processing
Computers
Solar Energy
Waste Management
Paper
Textiles
Telecommunications

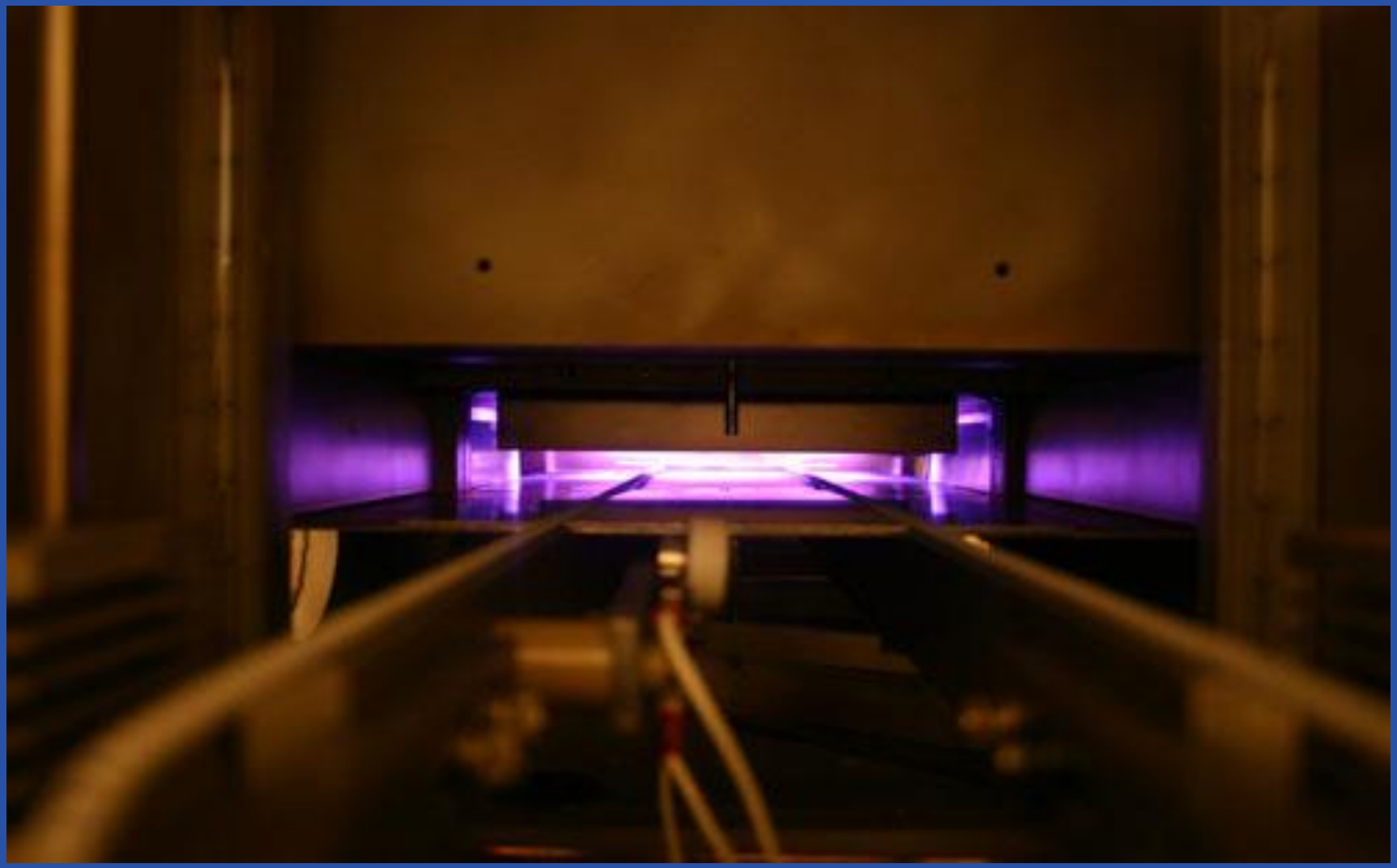
Cold Plasma Experiments

- Cold plasma is a partially ionised gas comprising ions, electrons, ultraviolet photons and reactive neutrals such as radicals, excited and ground-state molecules.

- Cold plasma technologies have found extensive application in material processing for over 30 years and they are now widely used in the manufacture of semiconductors, magnetic media and special glasses, and for metal coating, etc.

- The success of these techniques is related to their ability to change the surface properties of a material by physical or chemical modification of its most external layers (≤ 1 μm), without modifying its bulk characteristics.

The plasma glowing inside the vacuum chamber

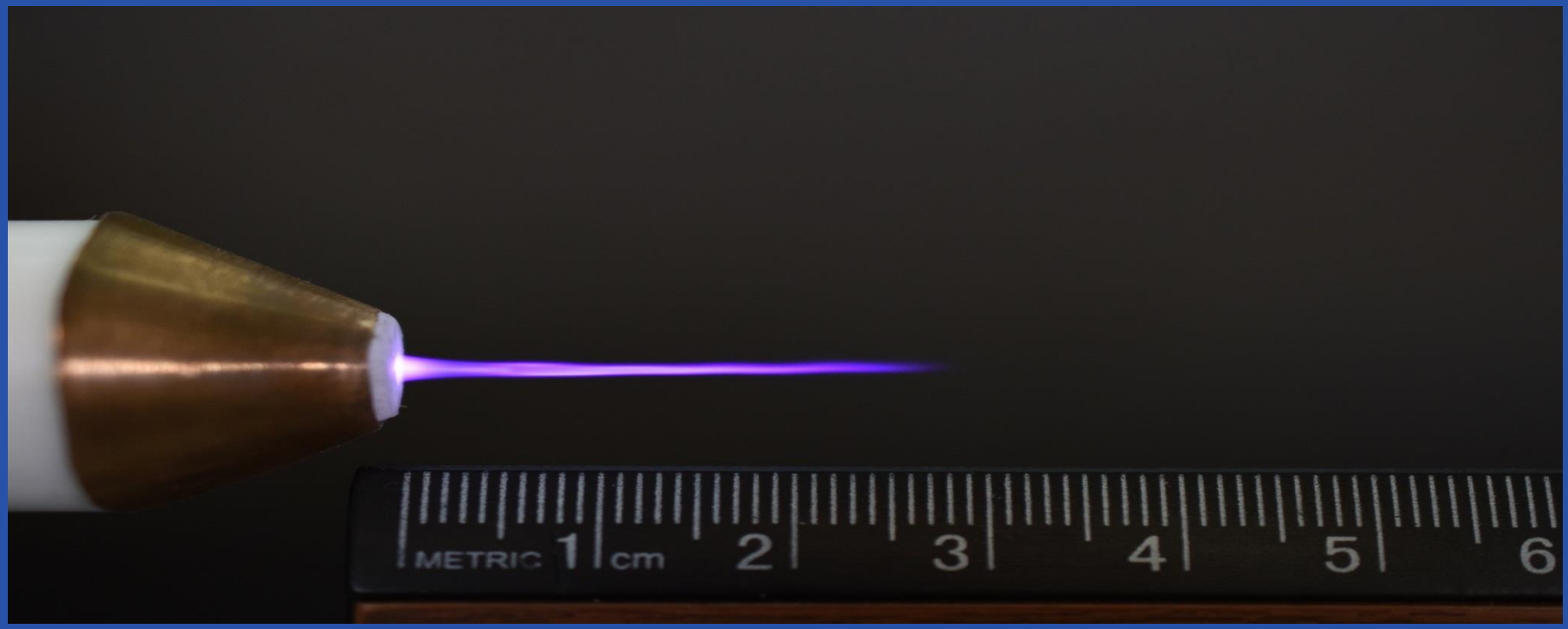


Magnetron Sputtering Deposition

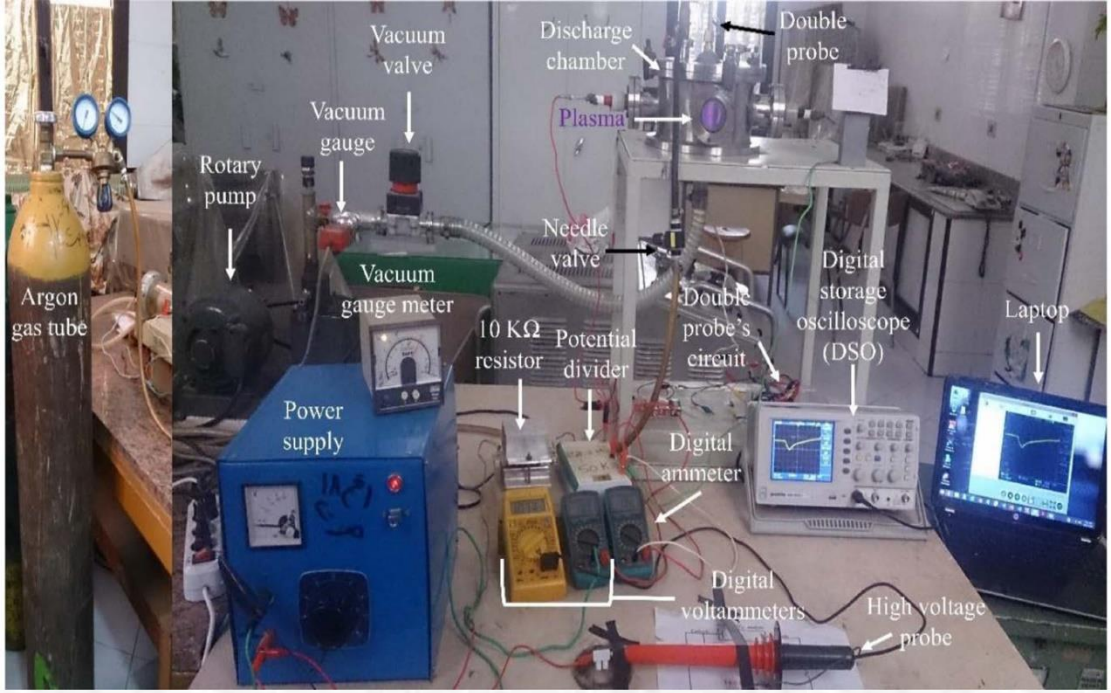
- Magnetron Sputtering is a Plasma Vapor Deposition (PVD) process in which a plasma is created and positively charged ions from the plasma are accelerated by an electrical field superimposed on the negatively charged electrode or "target".

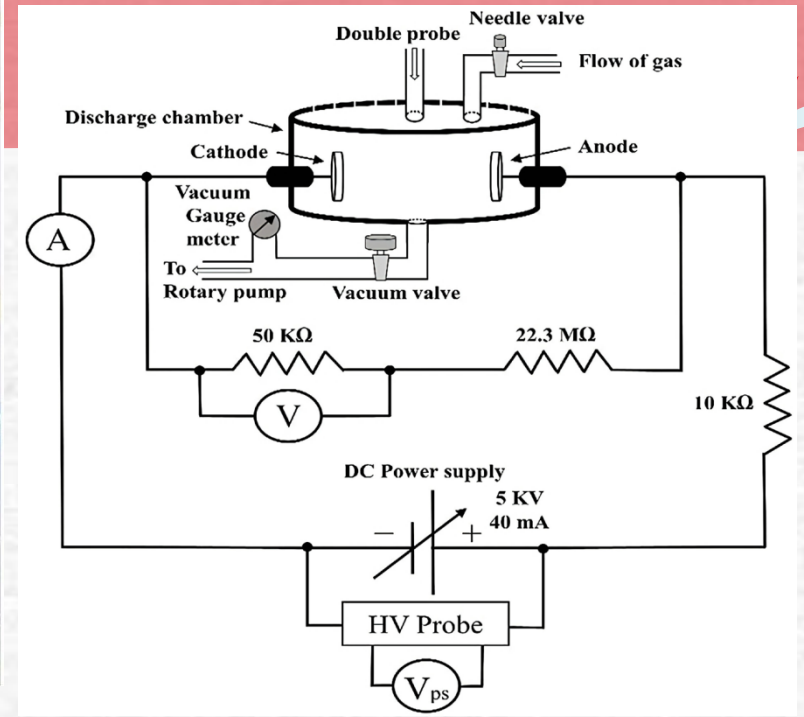
- The targets are fabricated from materials that one subsequently wishes to deposit on the surface of the component facing the electrode.

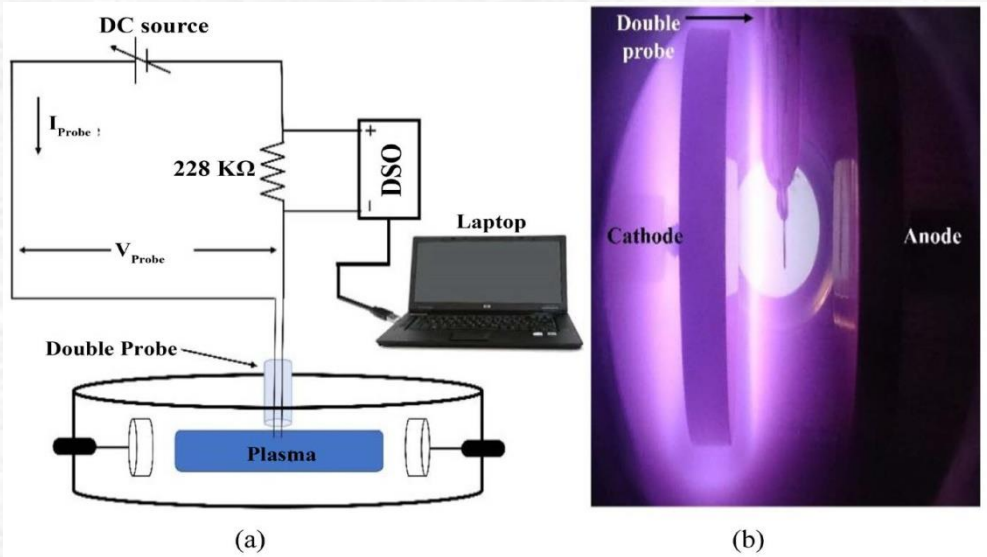
Plasma Jet



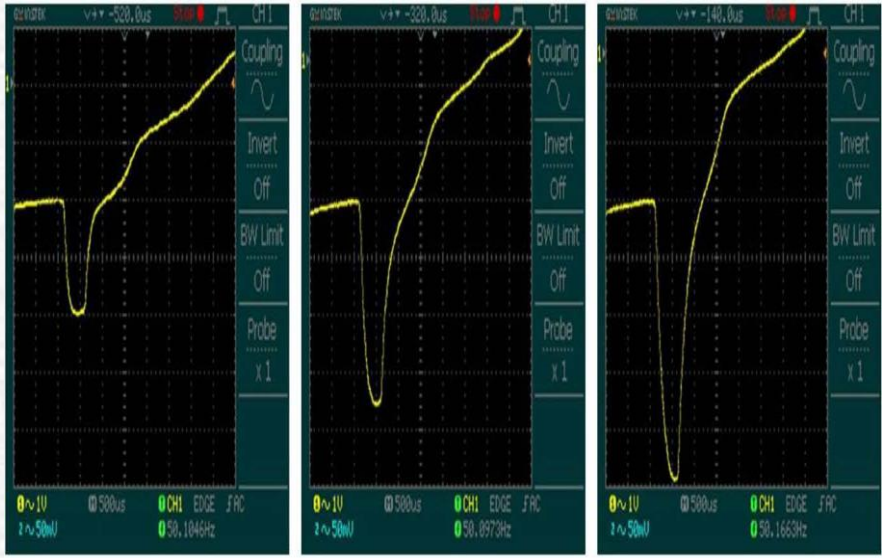
Inside the plasma jet, which essentially consists of an electrode and a nozzle, a cold plasma is generated with the help of alternating voltage.

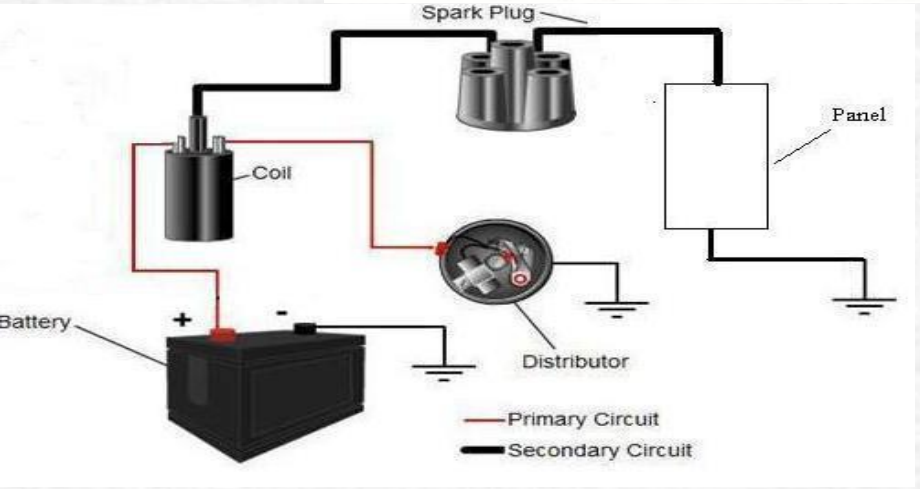

Vacuum valve
Discharge chamber
Double probe
Vacuum gauge
Plasma
Rotary pump
Needle valve
Vacuum gauge meter
Argon gas tube
Double probe's circuit
Digital storage oscilloscope (DSO)
Laptop
10 KΩ resistor
Potential divider
Power supply
Digital ammeter
Digital voltammeters
High voltage probe

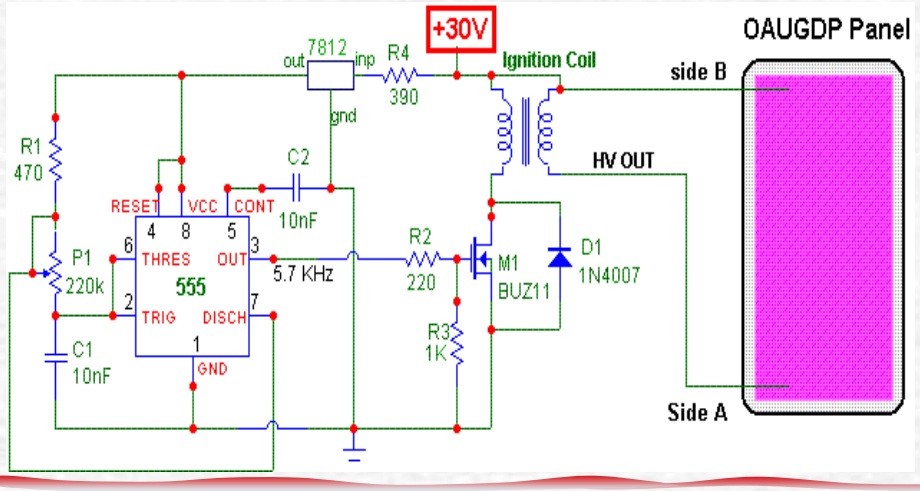

Needle valve
Double probe
Flow of gas
Discharge chamber
Cathode
Anode
Vacuum Gauge meter
A
To Rotary pump
Vacuum valve
50 KΩ
22.3 MΩ
10 KΩ
V
DC Power supply
5 KV
40 mA
HV Probe
Vps

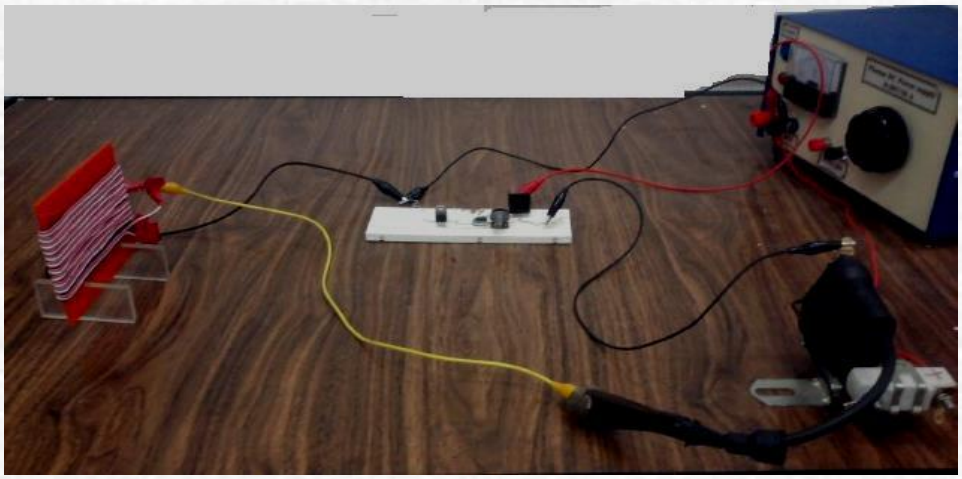

DC source
I Probe
228 KΩ
DSO
Laptop
V Probe
Double Probe
Plasma
(a)

Double probe
Cathode
Anode
(b)

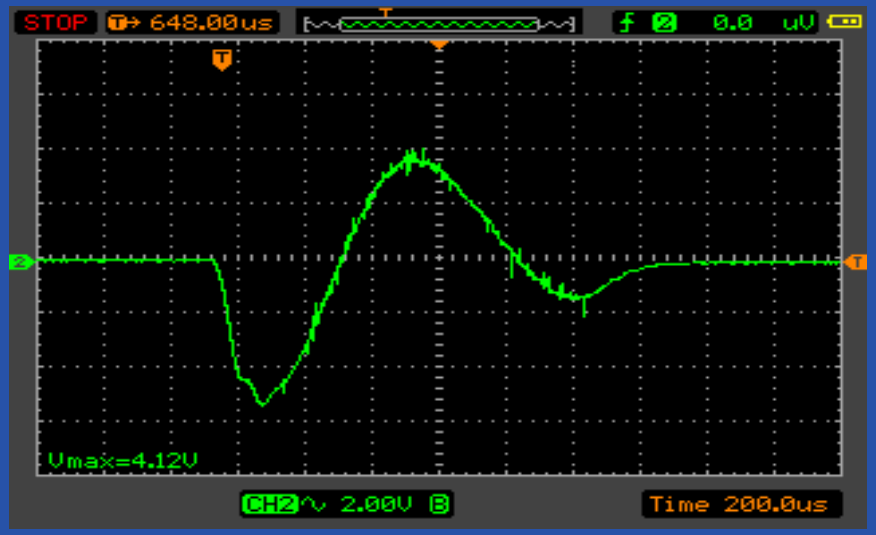

Coupling
Invert
Off
BW Limit
Probe
x1
(c)

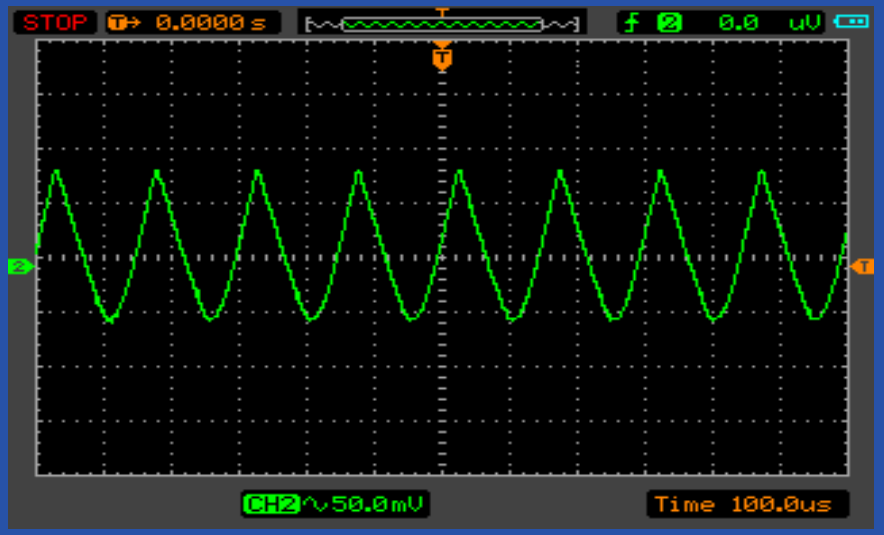

Spark Plug
Coil
Panel
Battery
+
-
Distributor
Primary Circuit
Secondary Circuit

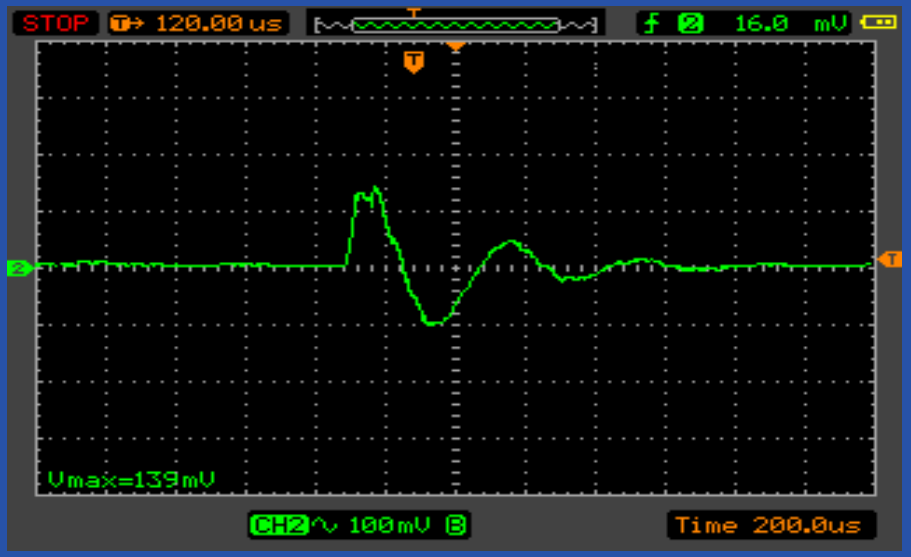

+30V
7812
out
inp
gnd
R4
390
Ignition Coil
OAUGDP Panel
side B
HV OUT
R1
470
C2
10nF
RESET
VCC
CONT
4
8
5
6
THRES
OUT
3
555
2
TRIG
DISCH
7
1
GND
P1
220k
C1
10nF
5.7 KHz
R2
220
M1
BUZ11
D1
1N4007
R3
1K
Side A

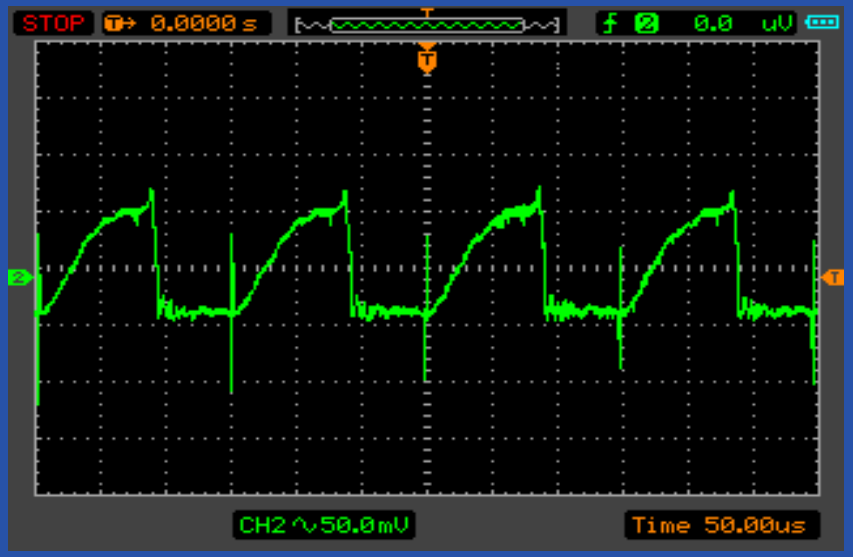


One Atmosphere Uniform Glow Discharge Plasma (OAUGDP)

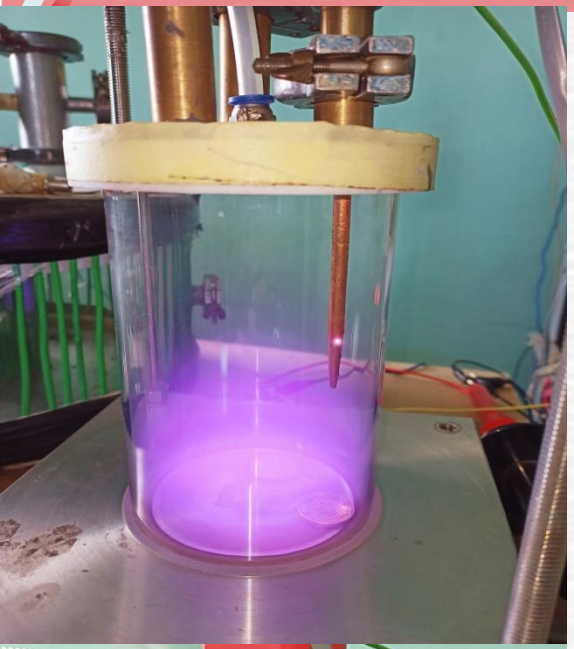


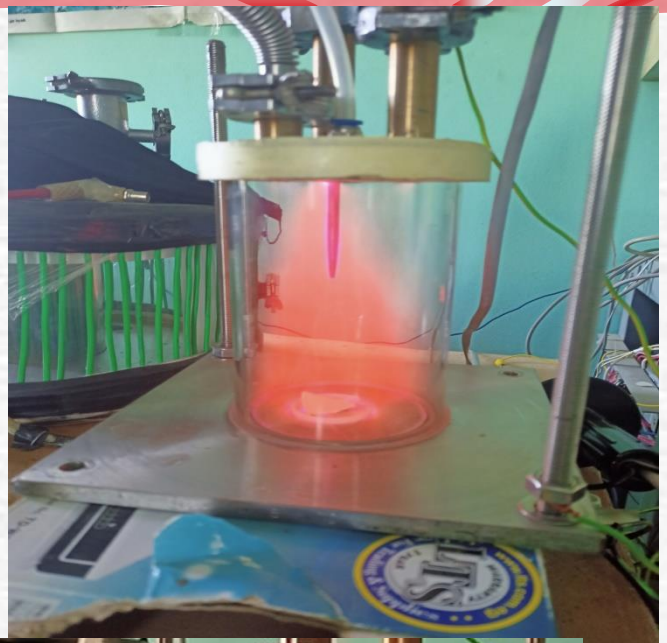


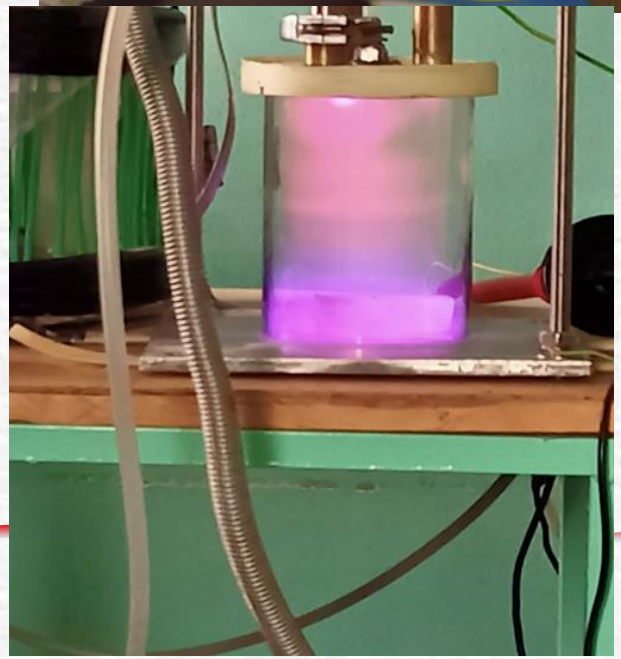




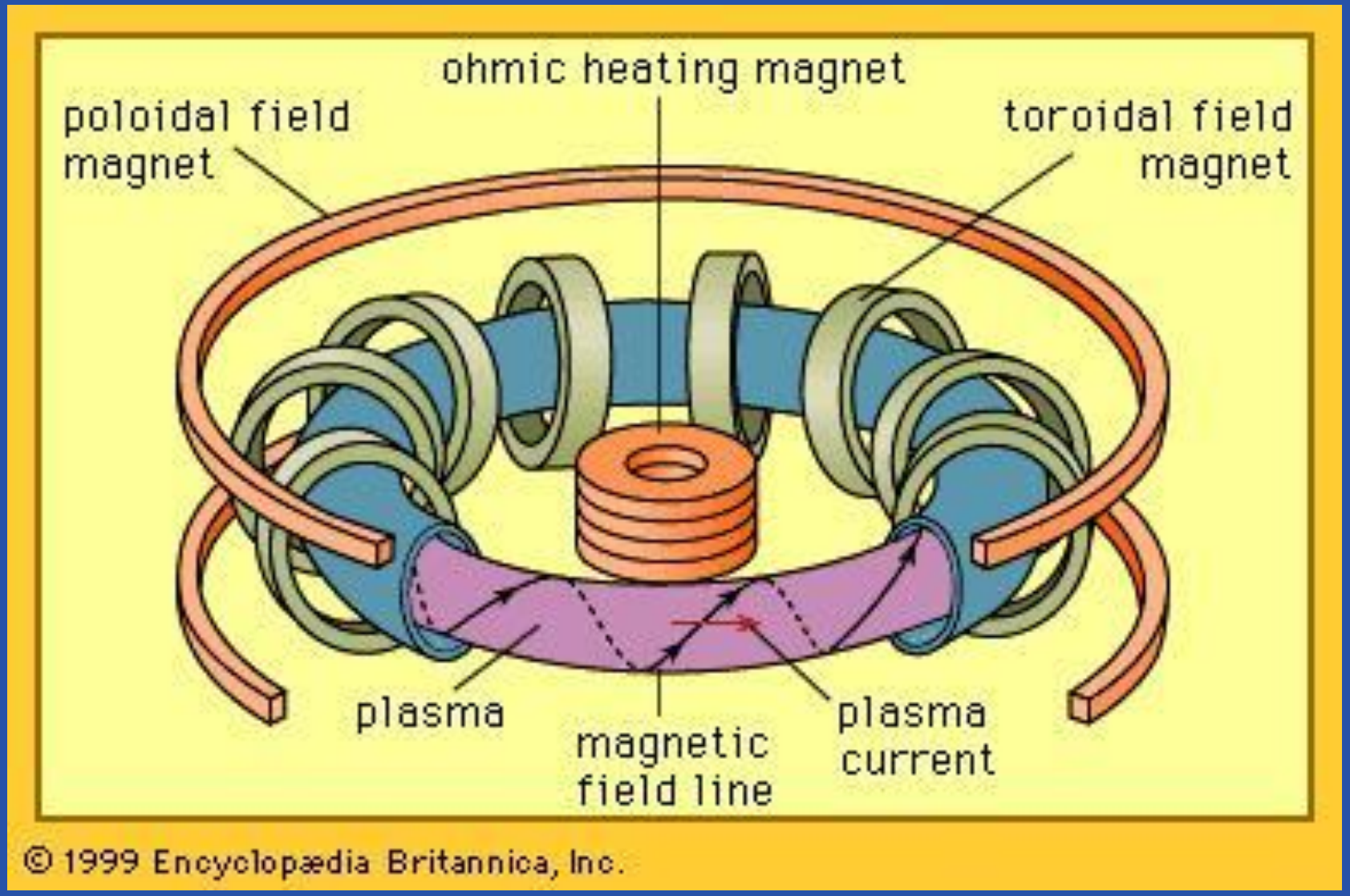
Recent Trends & Future research plan



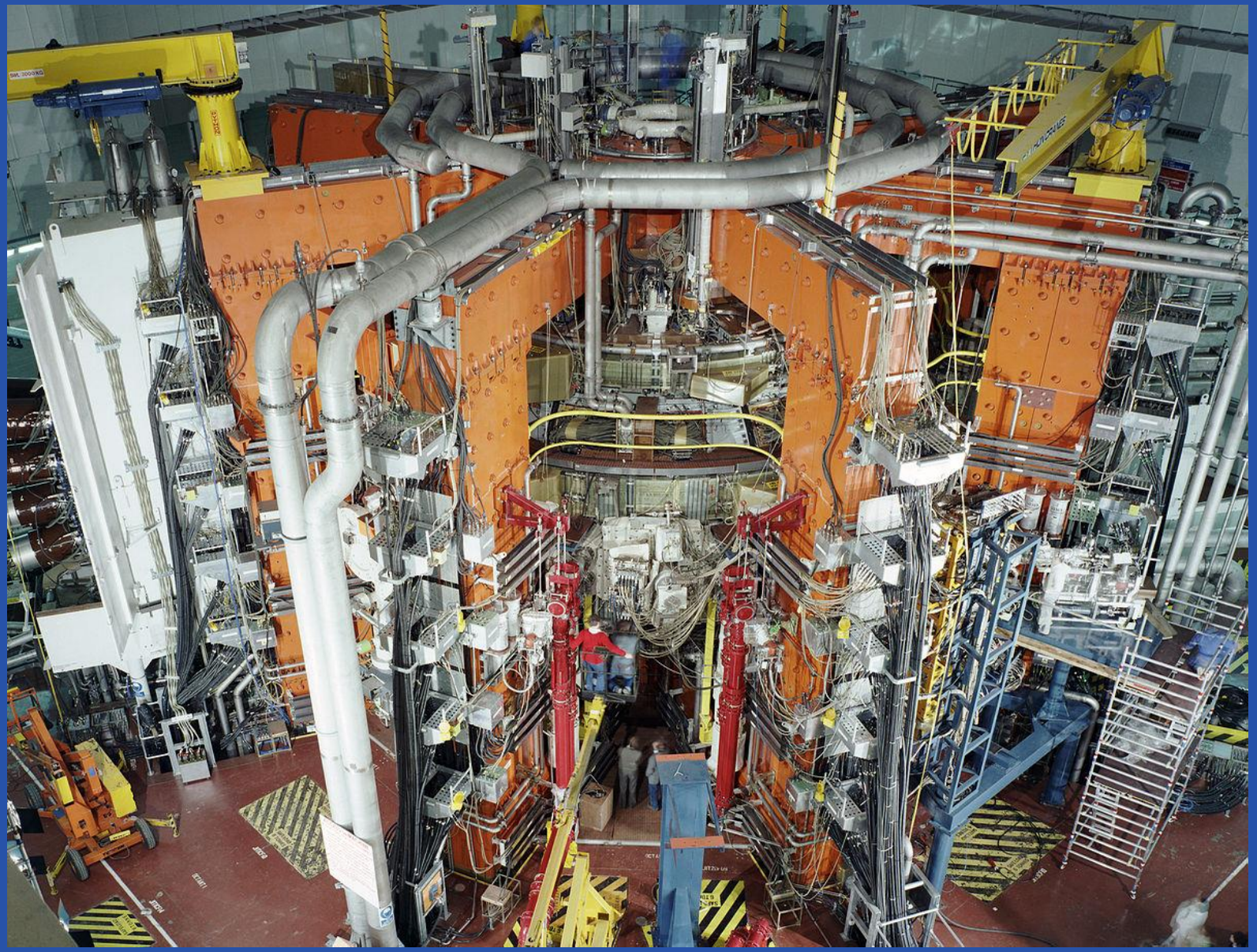




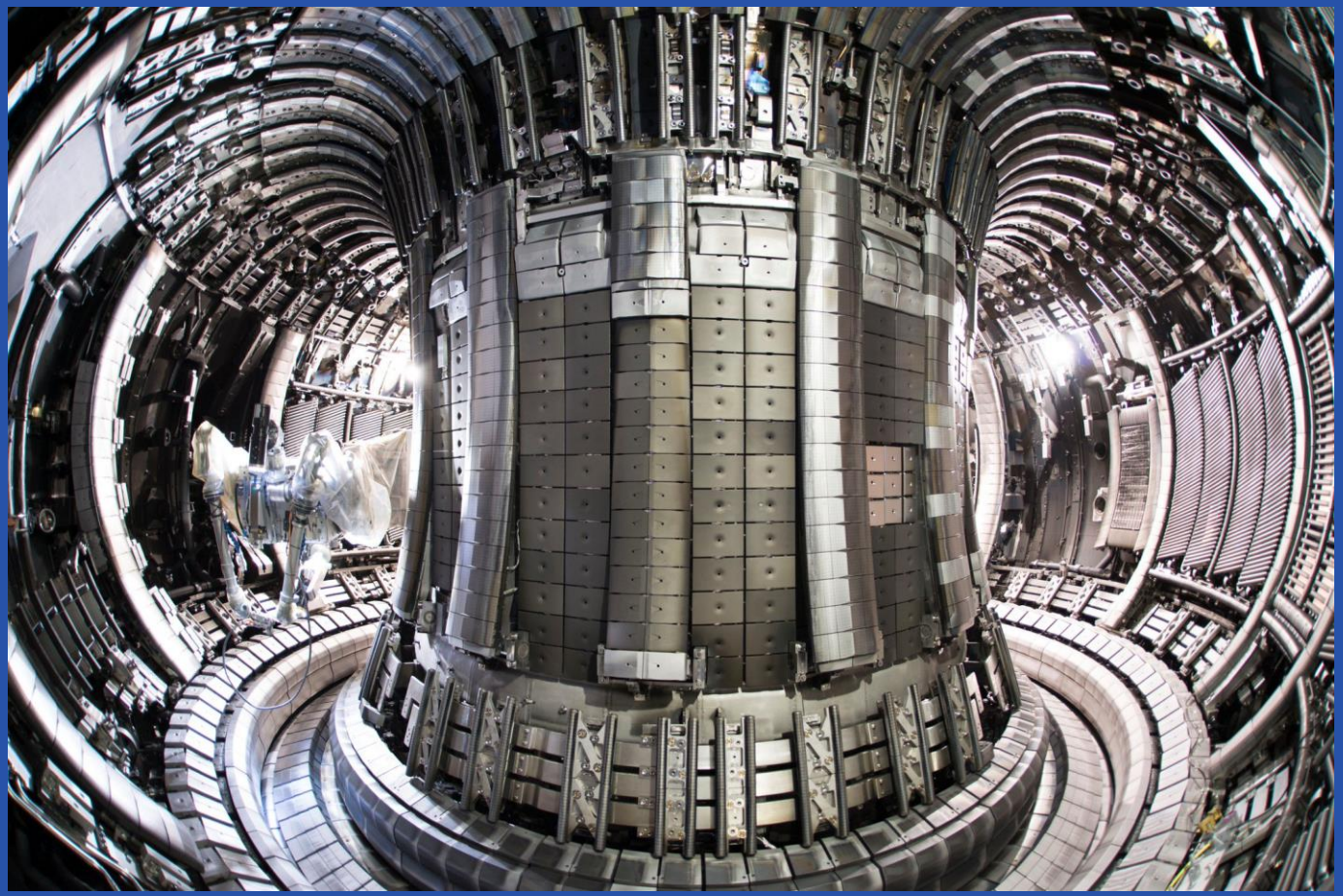
Thermal -Plasma Experiments
Tokamak



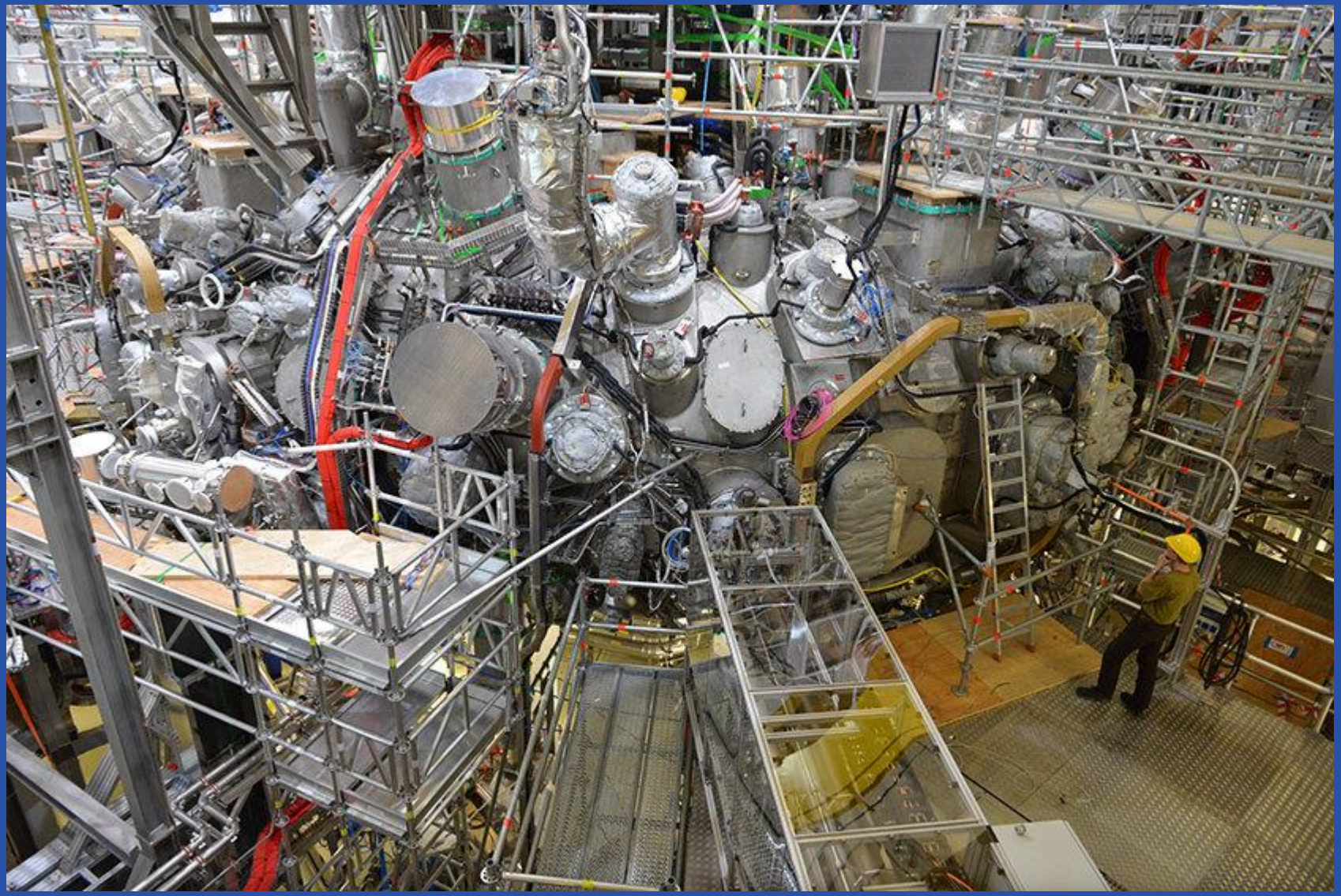
The Joint European Torus (JET) magnetic fusion experiment in 1991



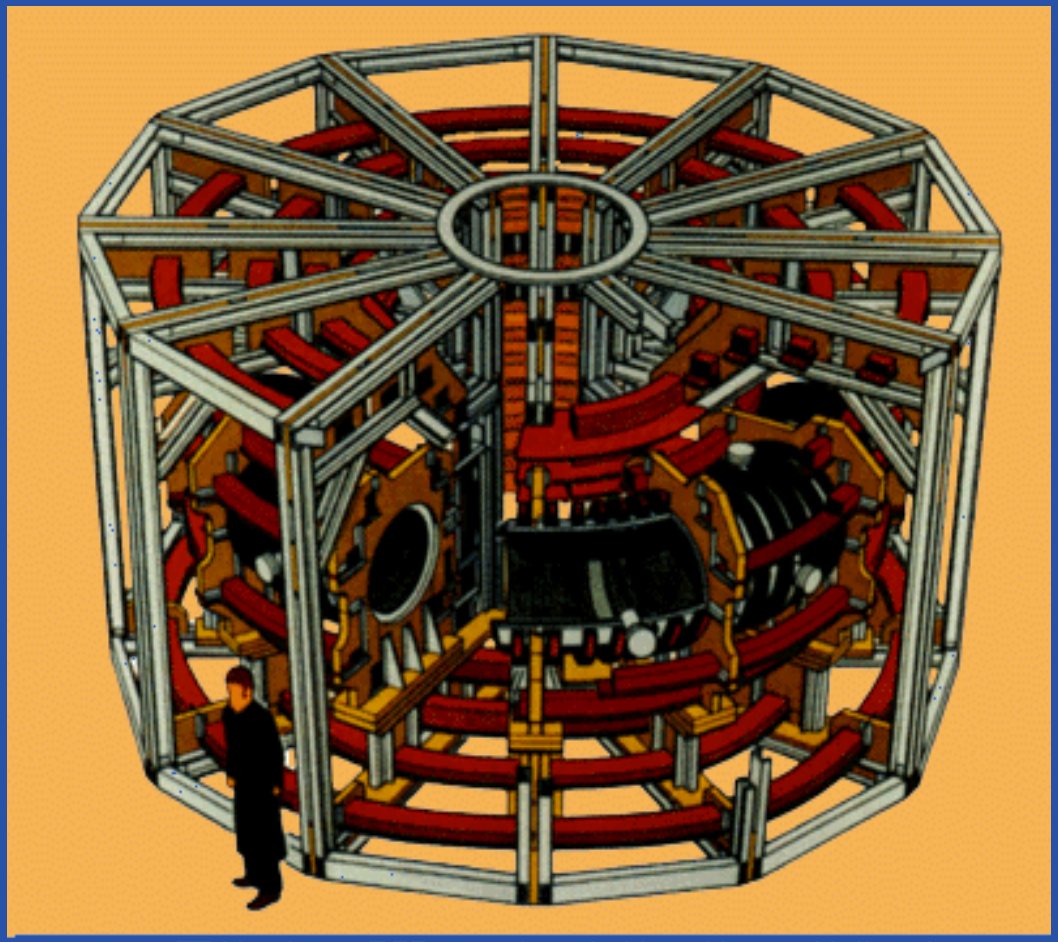
ITER



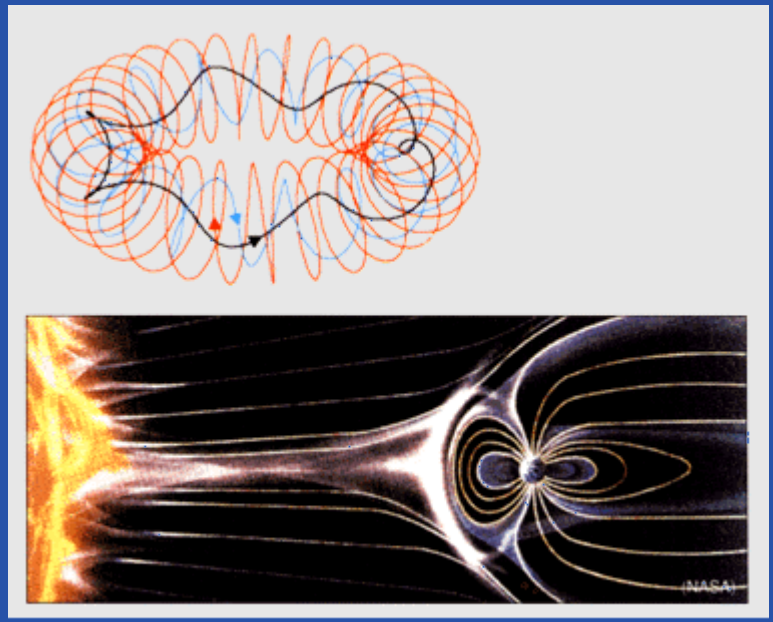
Peak performance: new stellarator experiments



RFP

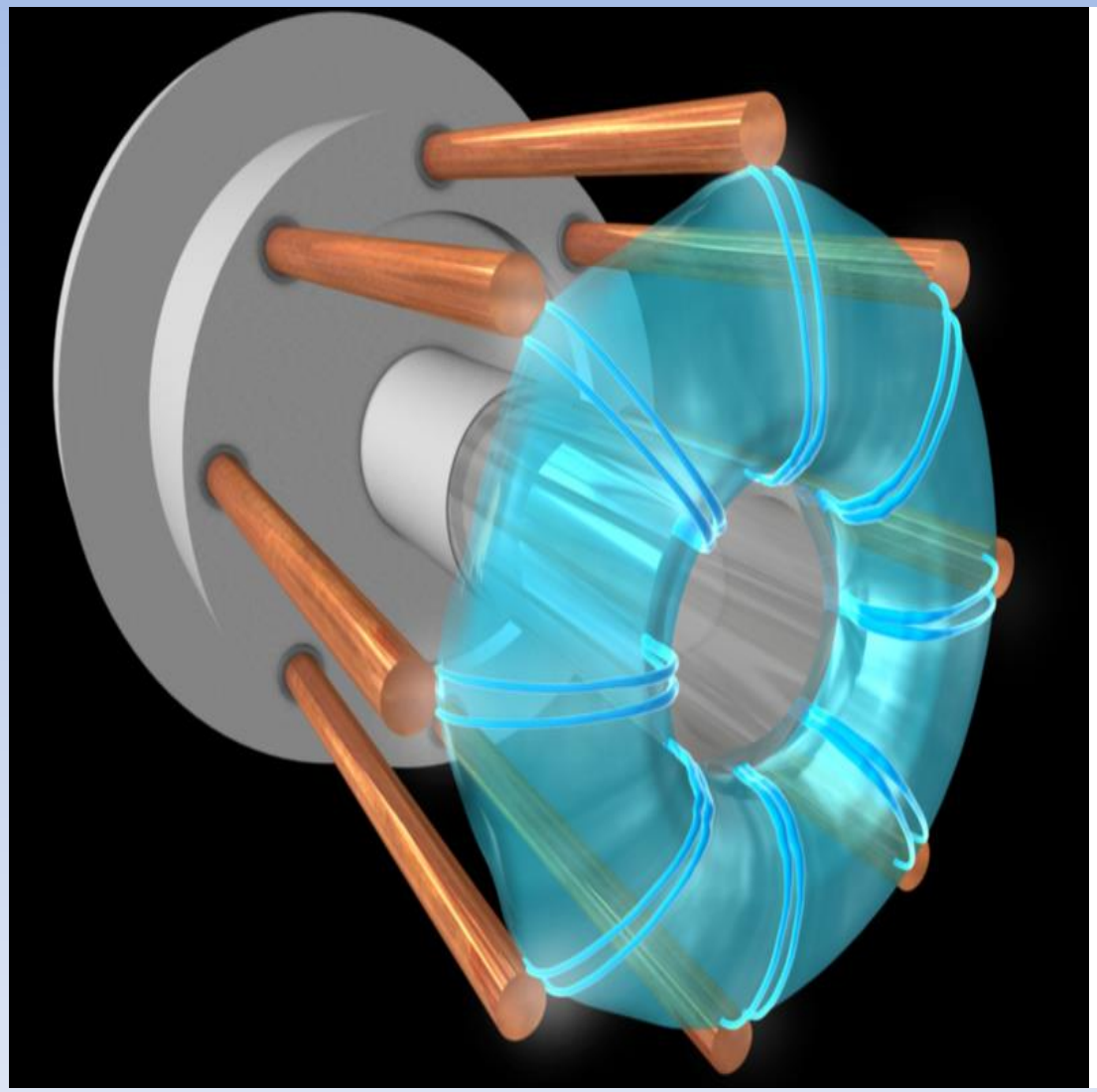


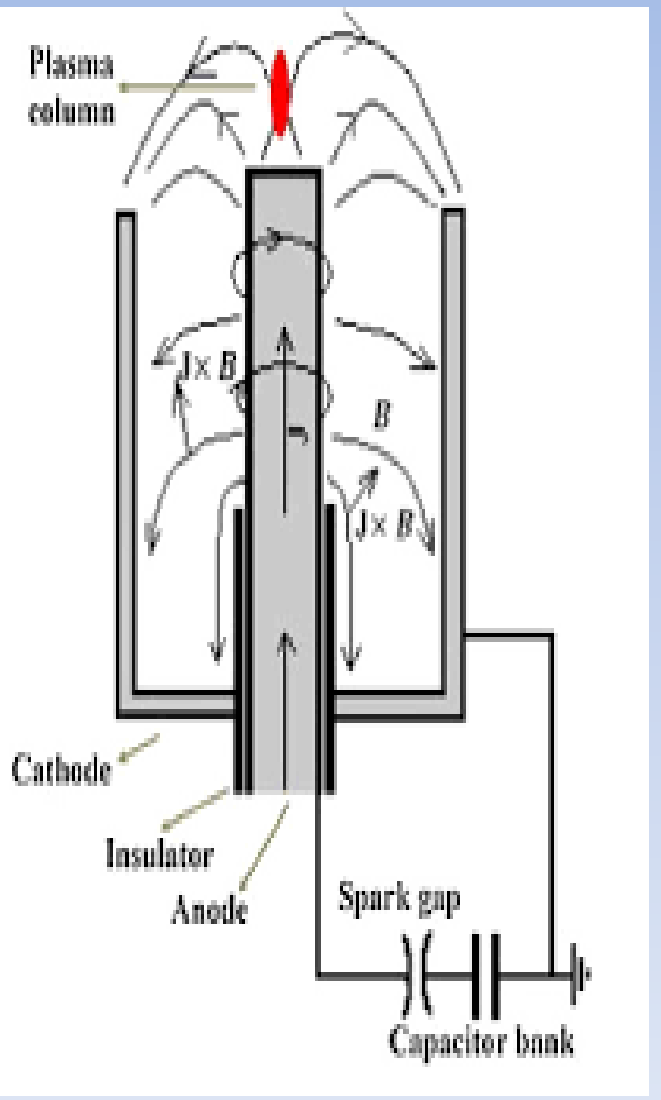
ZT-H, a large RFP experiment at Los Alamos National Laboratory (canceled during construction,1990).



Astrophysical and geophysical dynamos at work. Magnetic-field-generating dynamos are also at work in the RFP and spheromak.

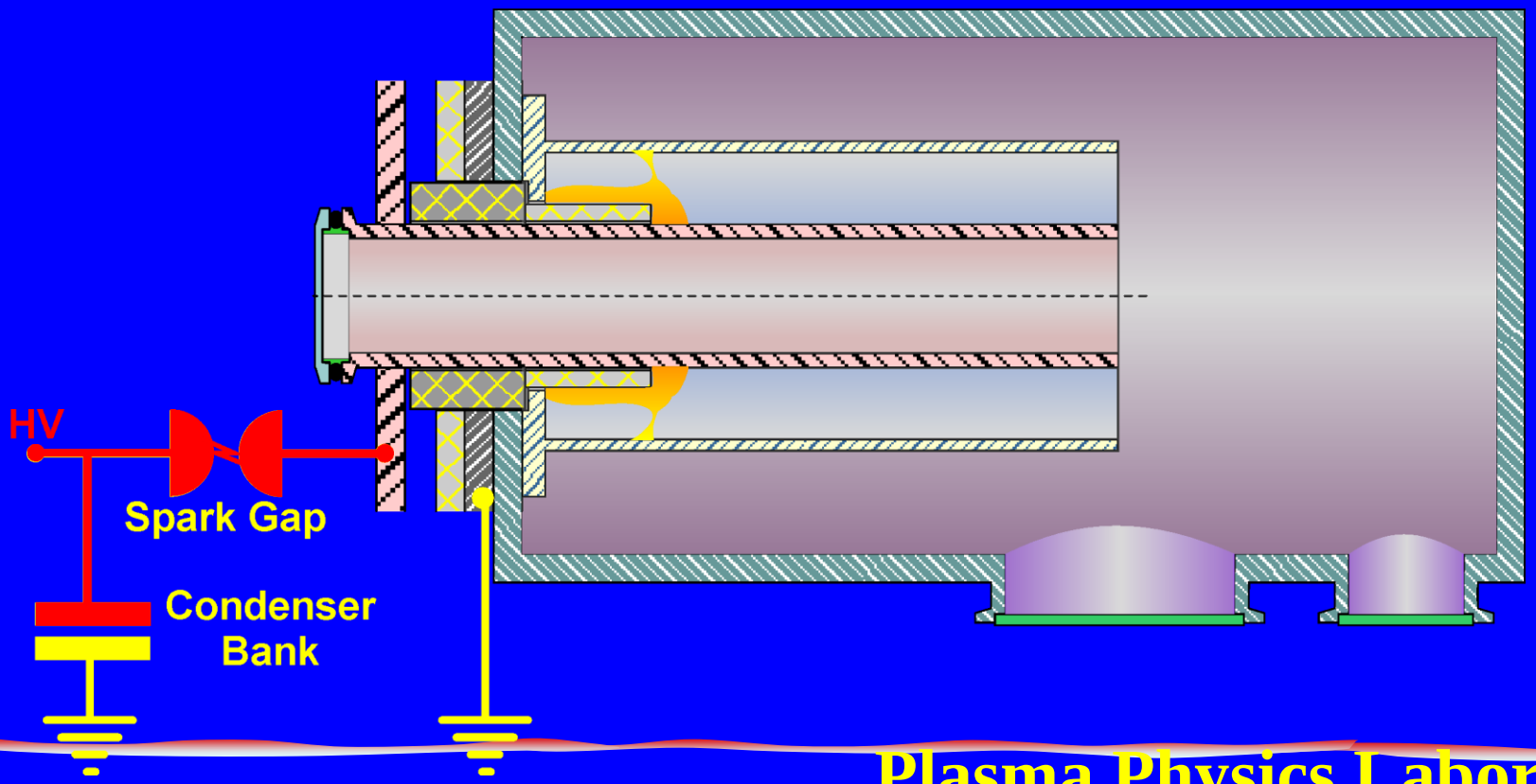
Plasma Focus





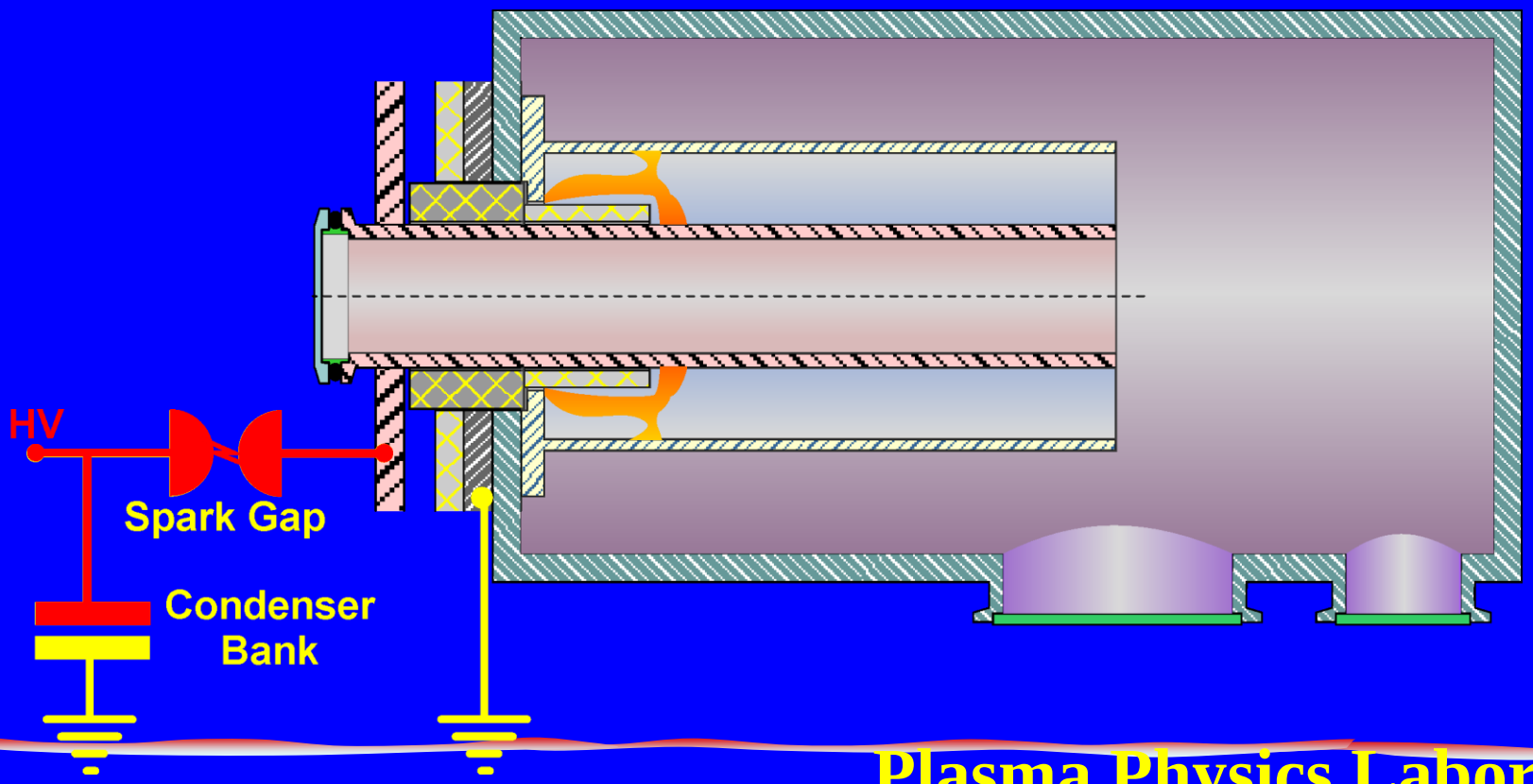
Principle of Operation

Breakdown and Current Sheath Build-Up Phases



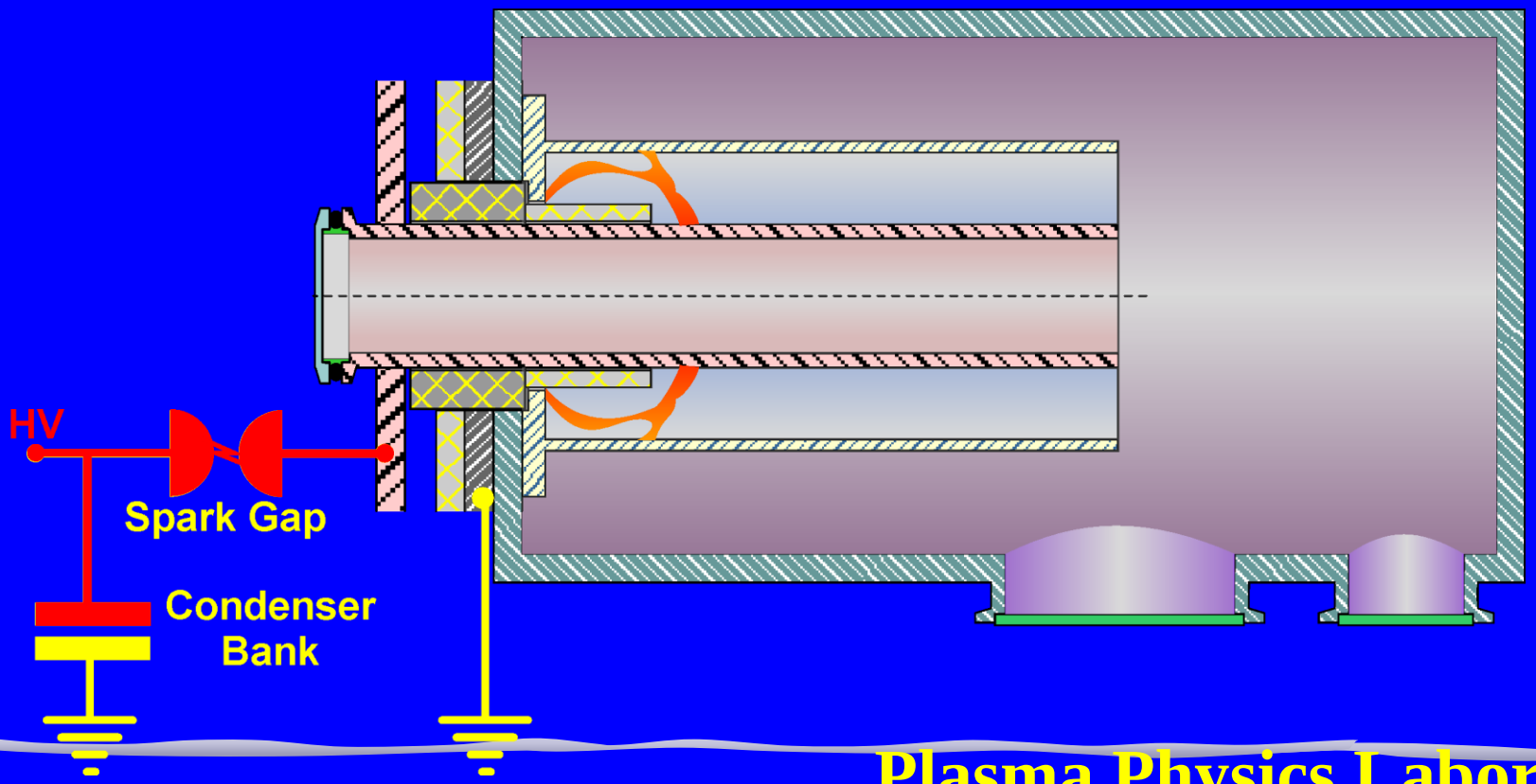
Principle of Operation

Breakdown and Current Sheath Build-Up Phases



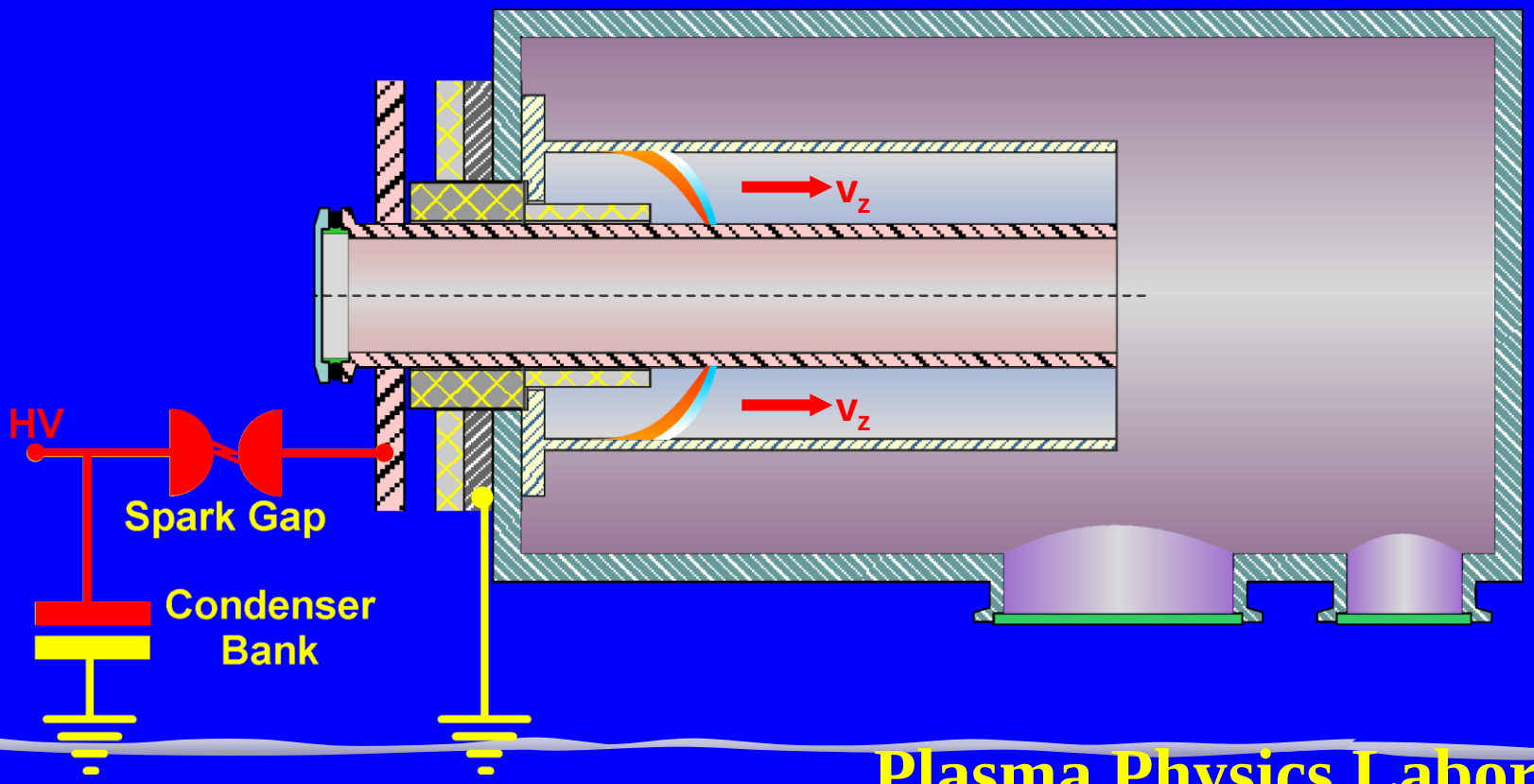
Principle of Operation

Breakdown and Current Sheath Build-Up Phases



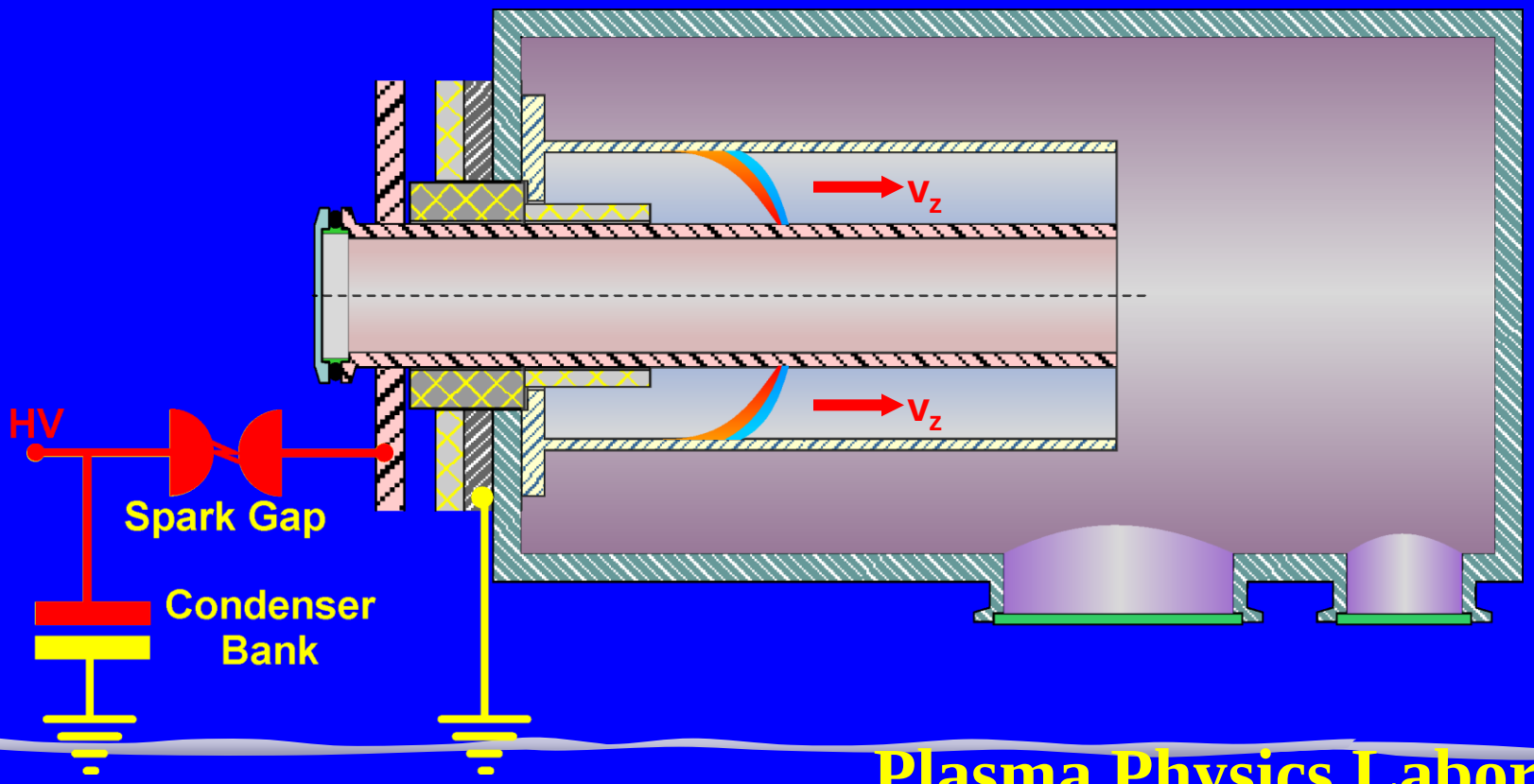
Principle of Operation

Acceleration Phase



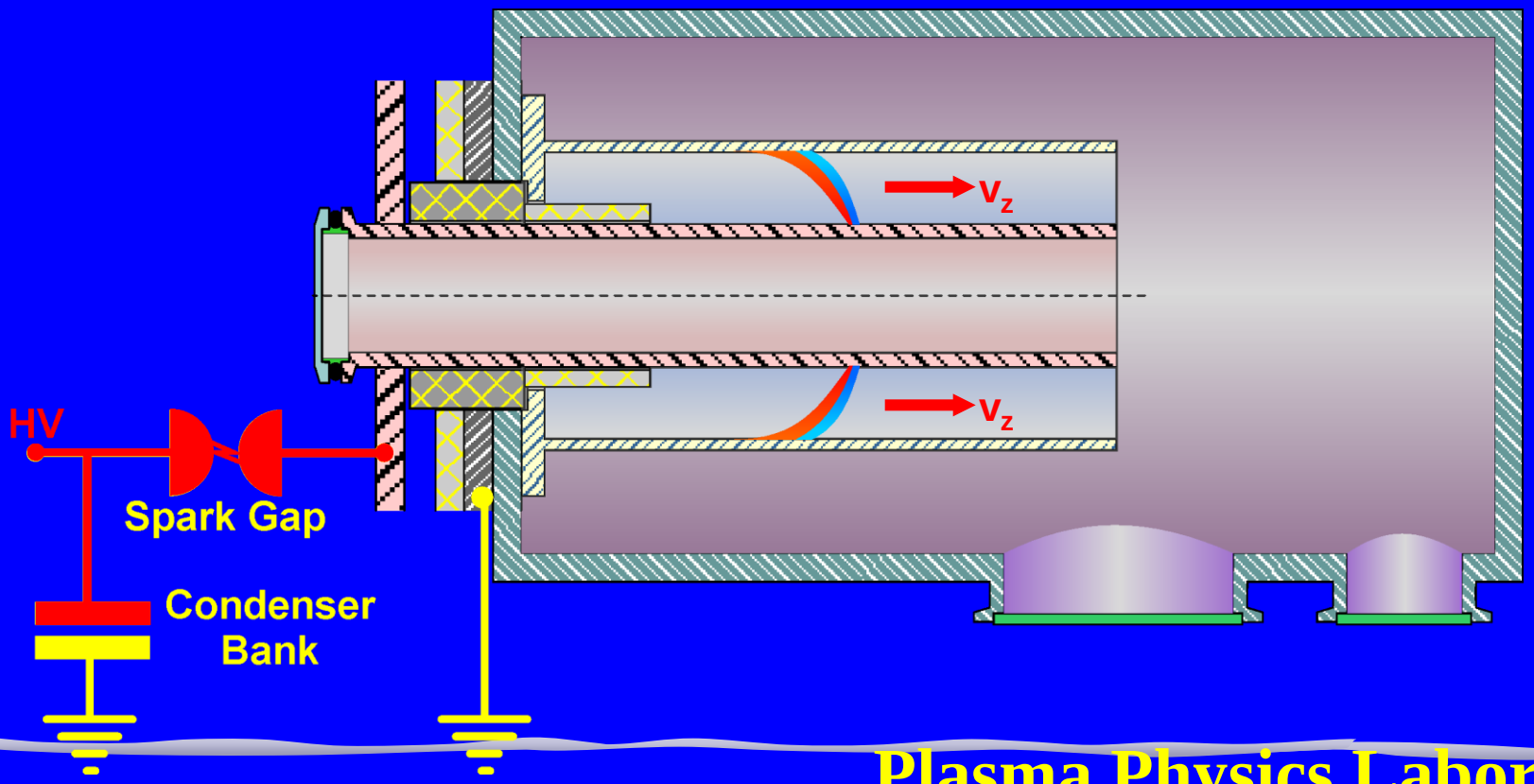
Principle of Operation

Acceleration Phase



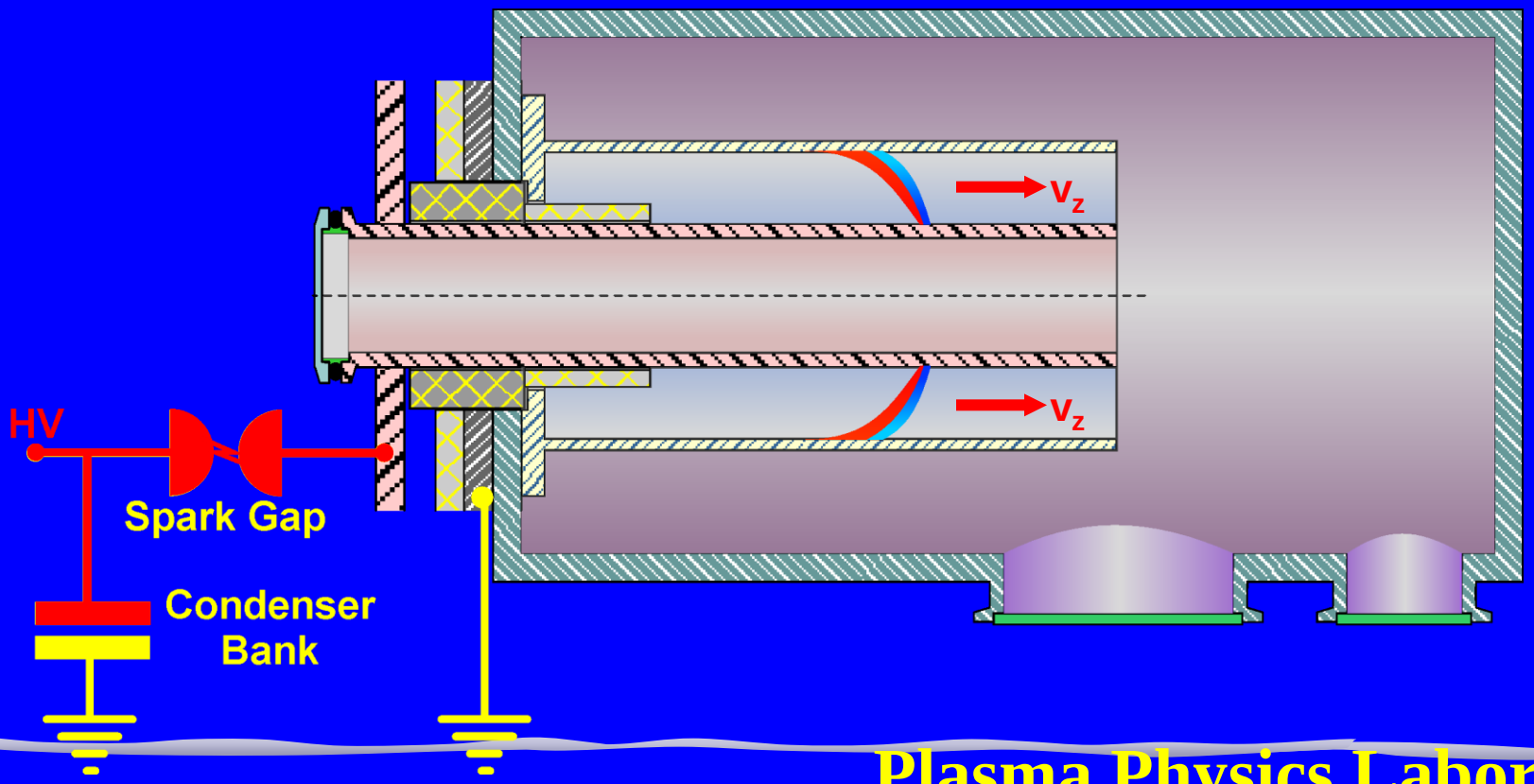
Principle of Operation

Acceleration Phase



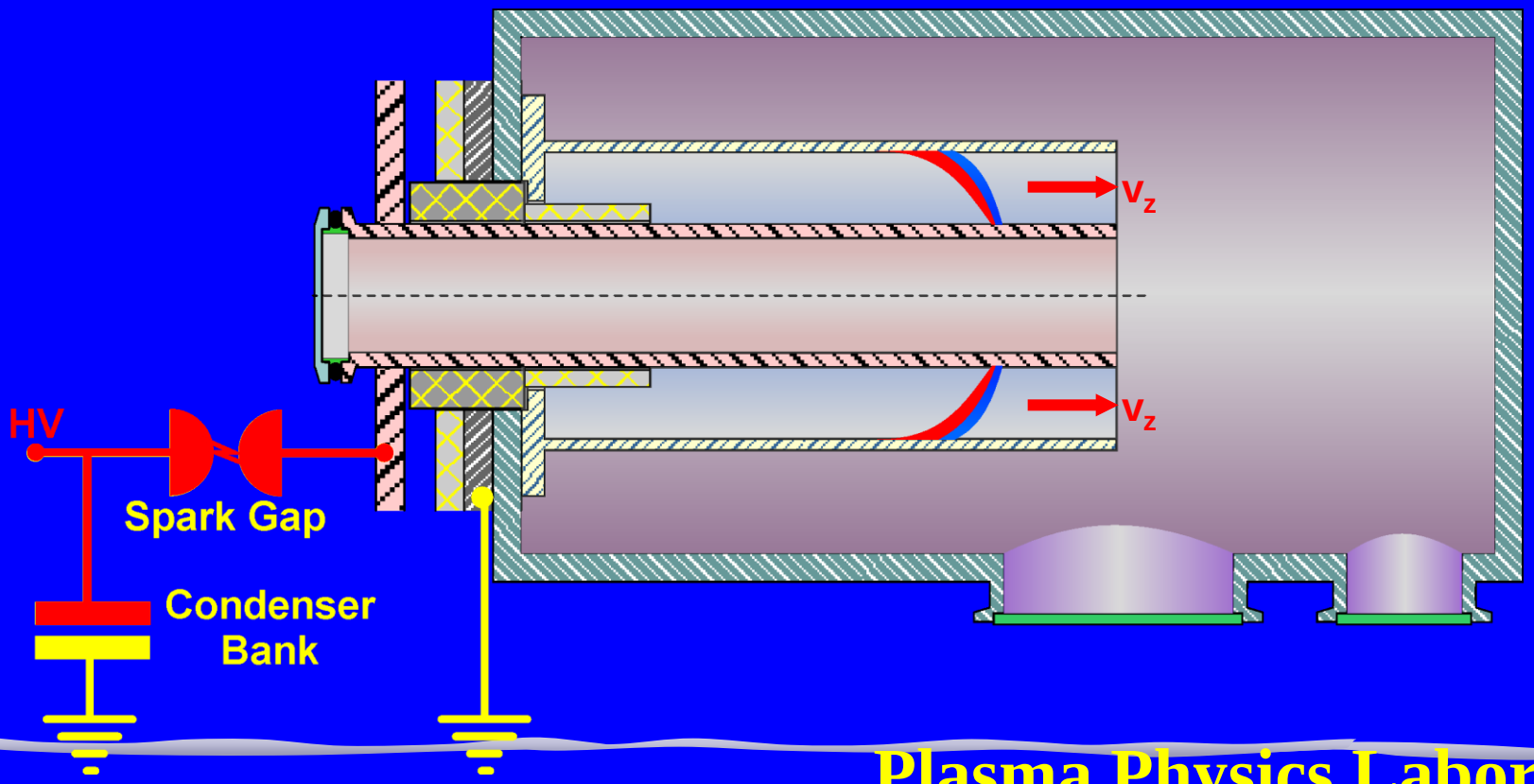
Principle of Operation

Acceleration Phase



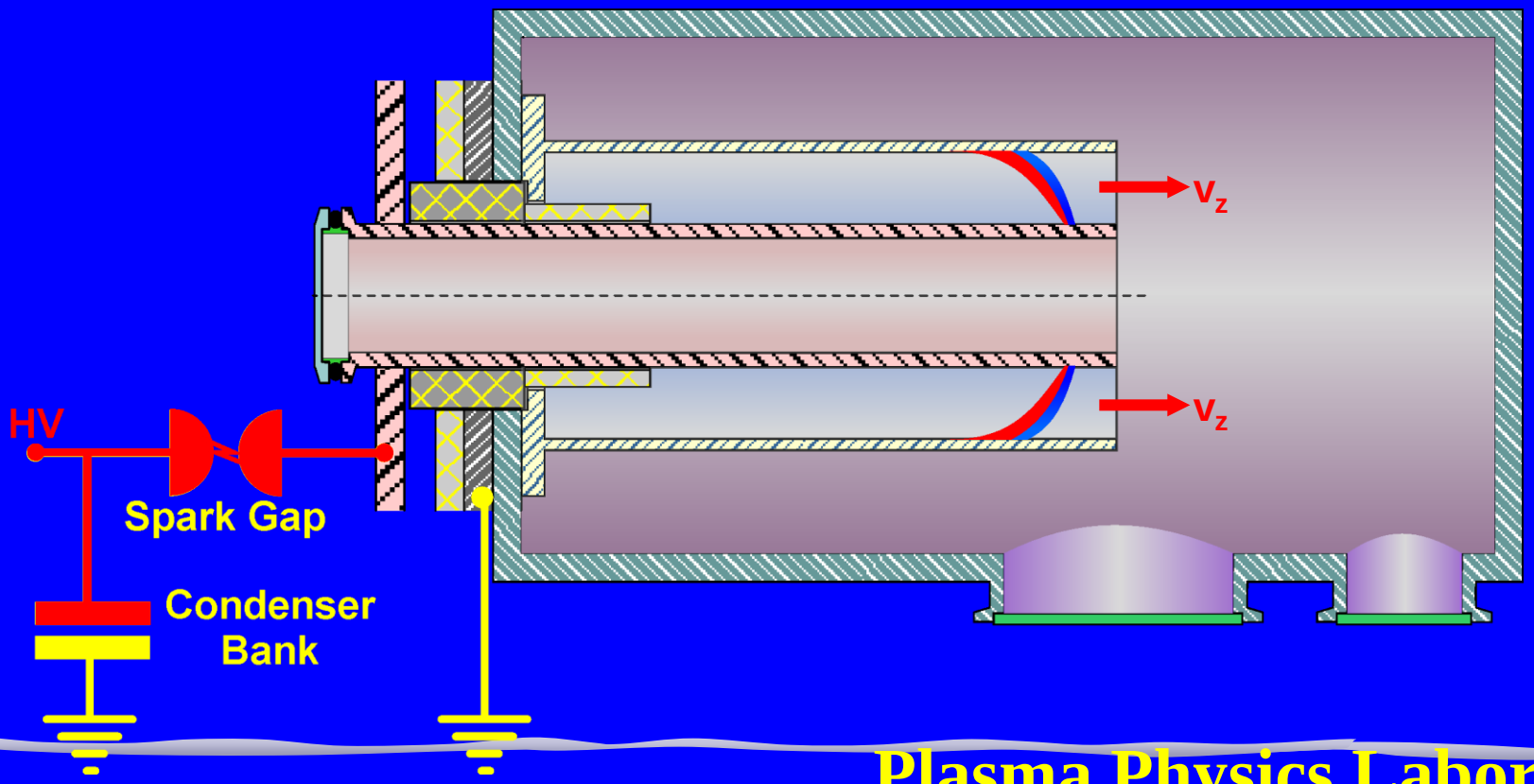
Principle of Operation

Acceleration Phase



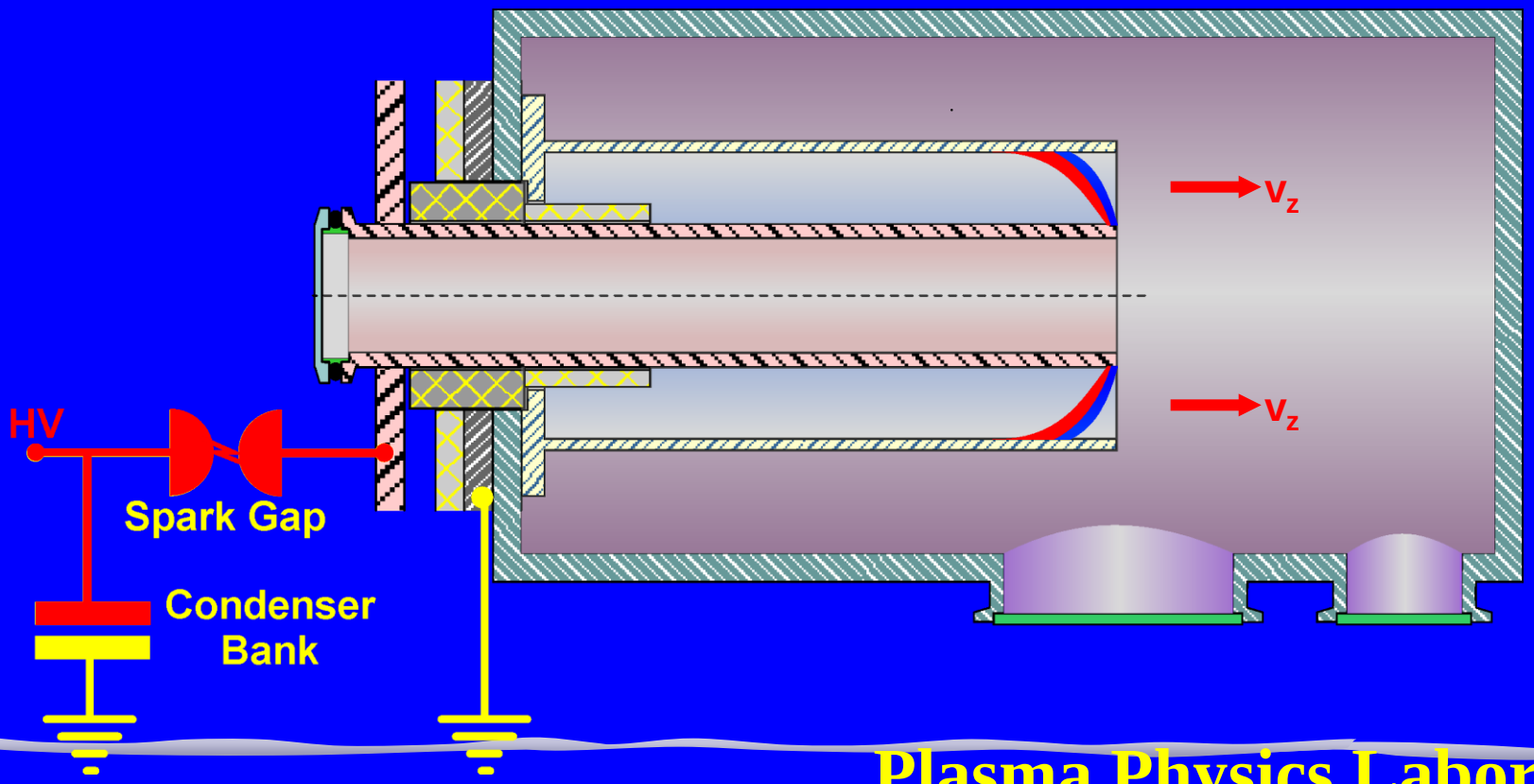
Principle of Operation

Acceleration Phase



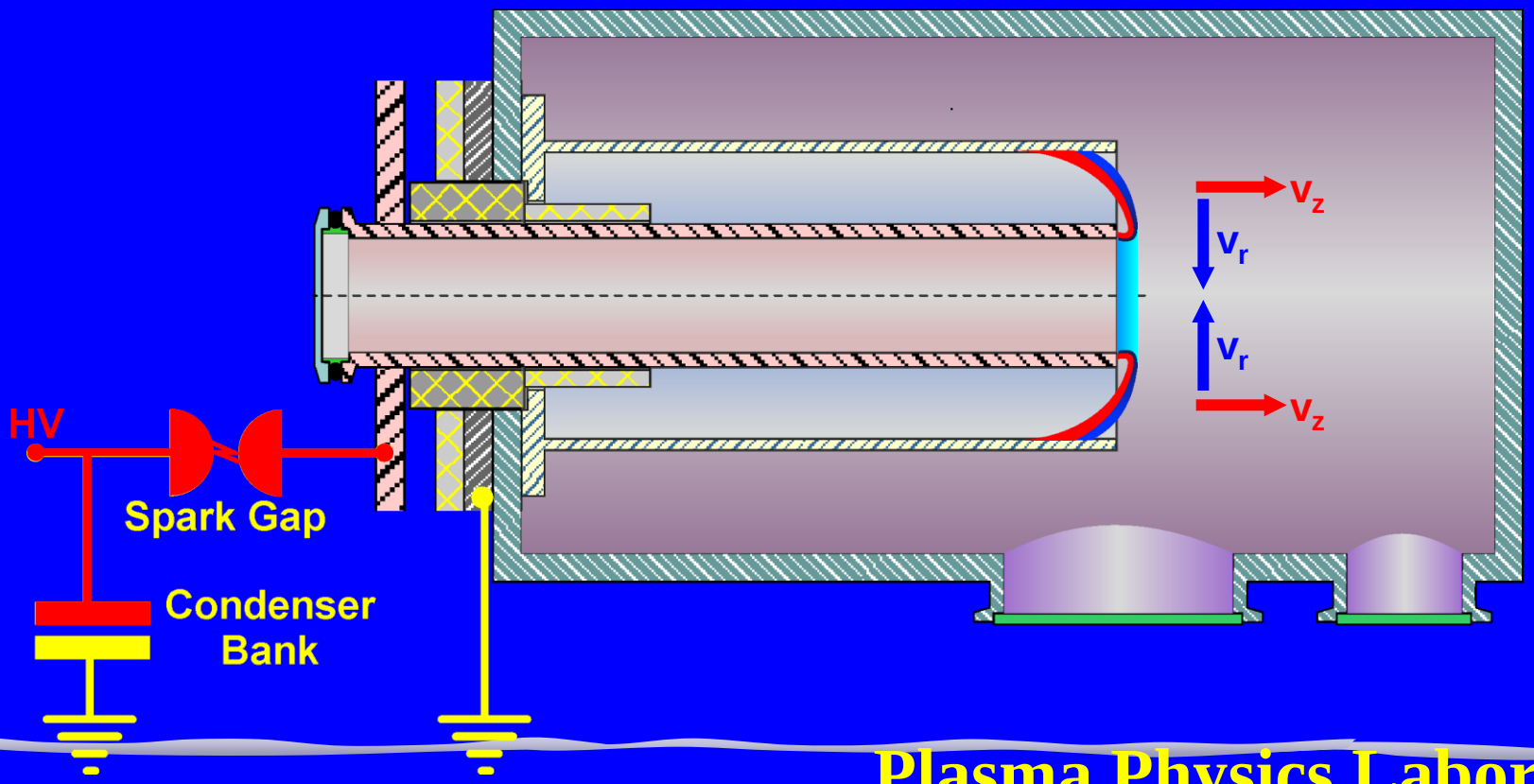
Principle of Operation

Acceleration Phase



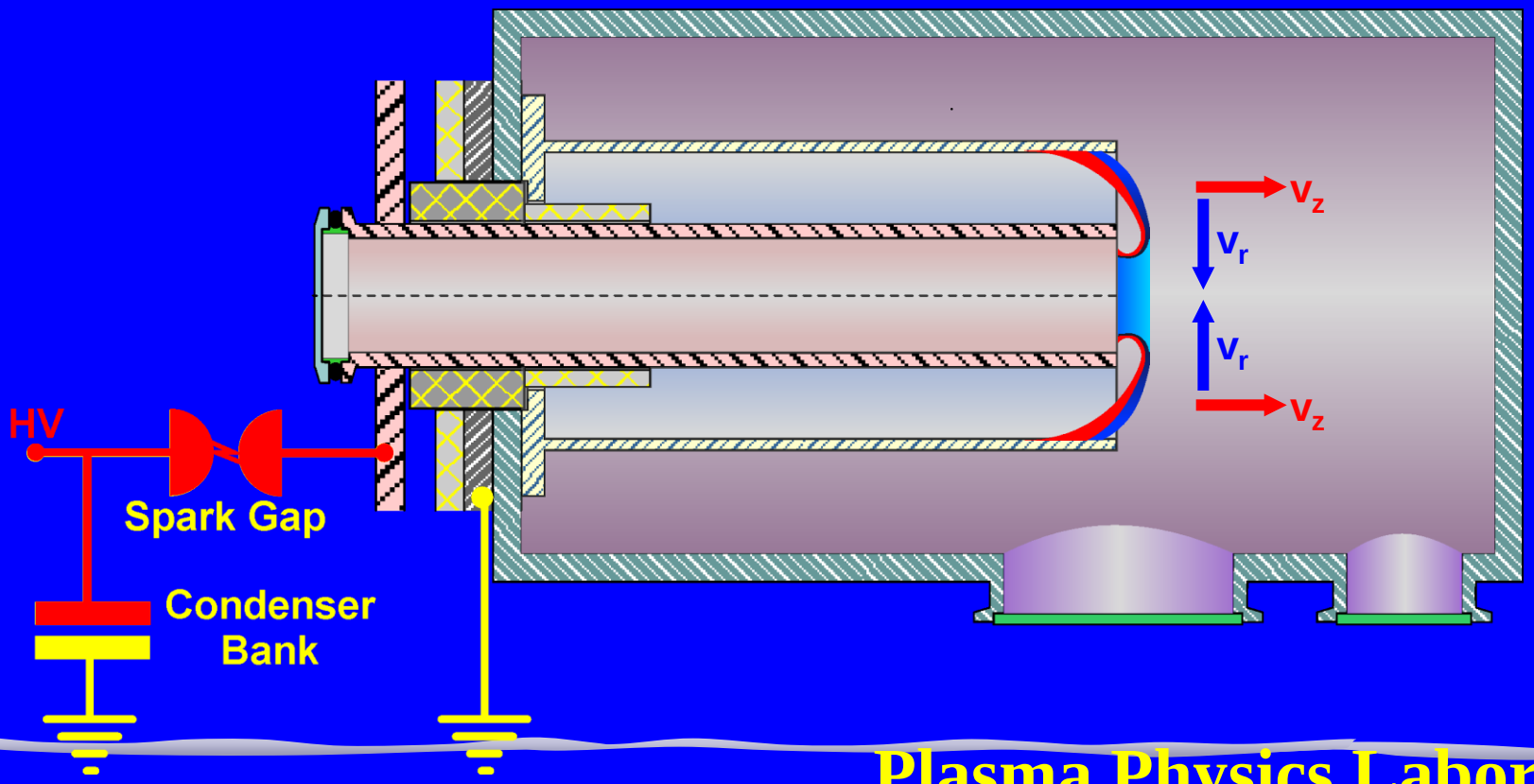
Principle of Operation

Radial Compression Phase



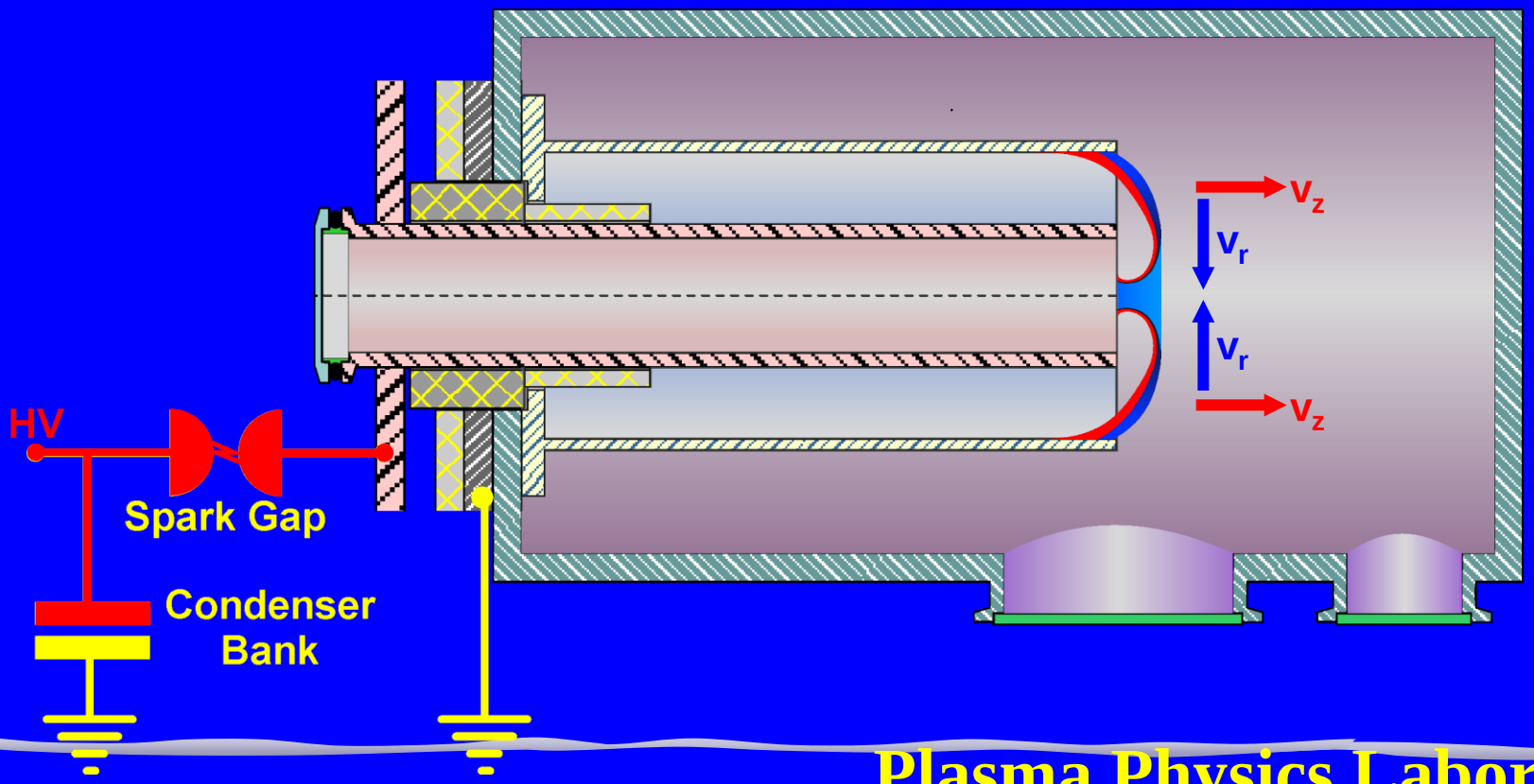
Principle of Operation

Radial Compression Phase



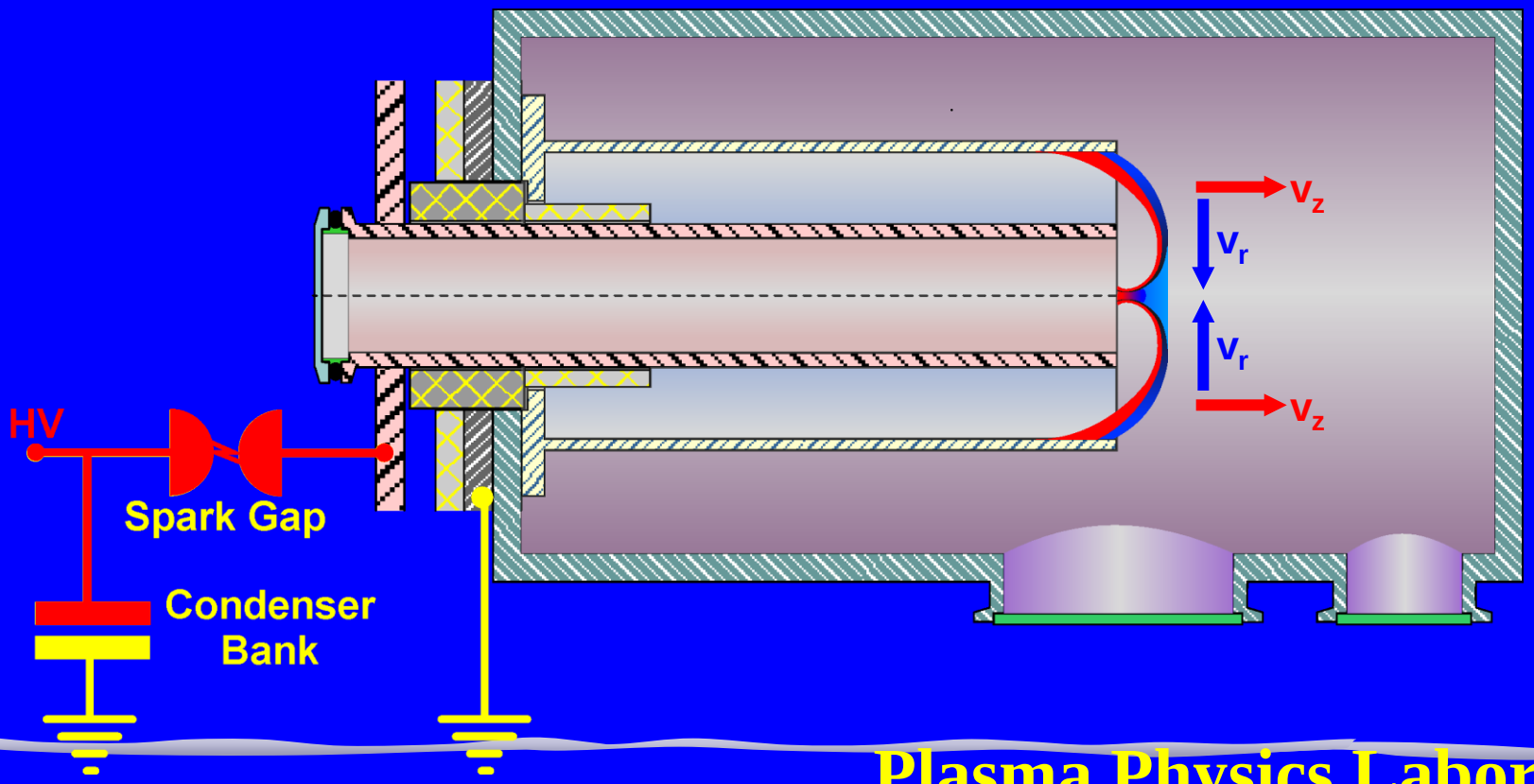
Principle of Operation

Radial Compression Phase

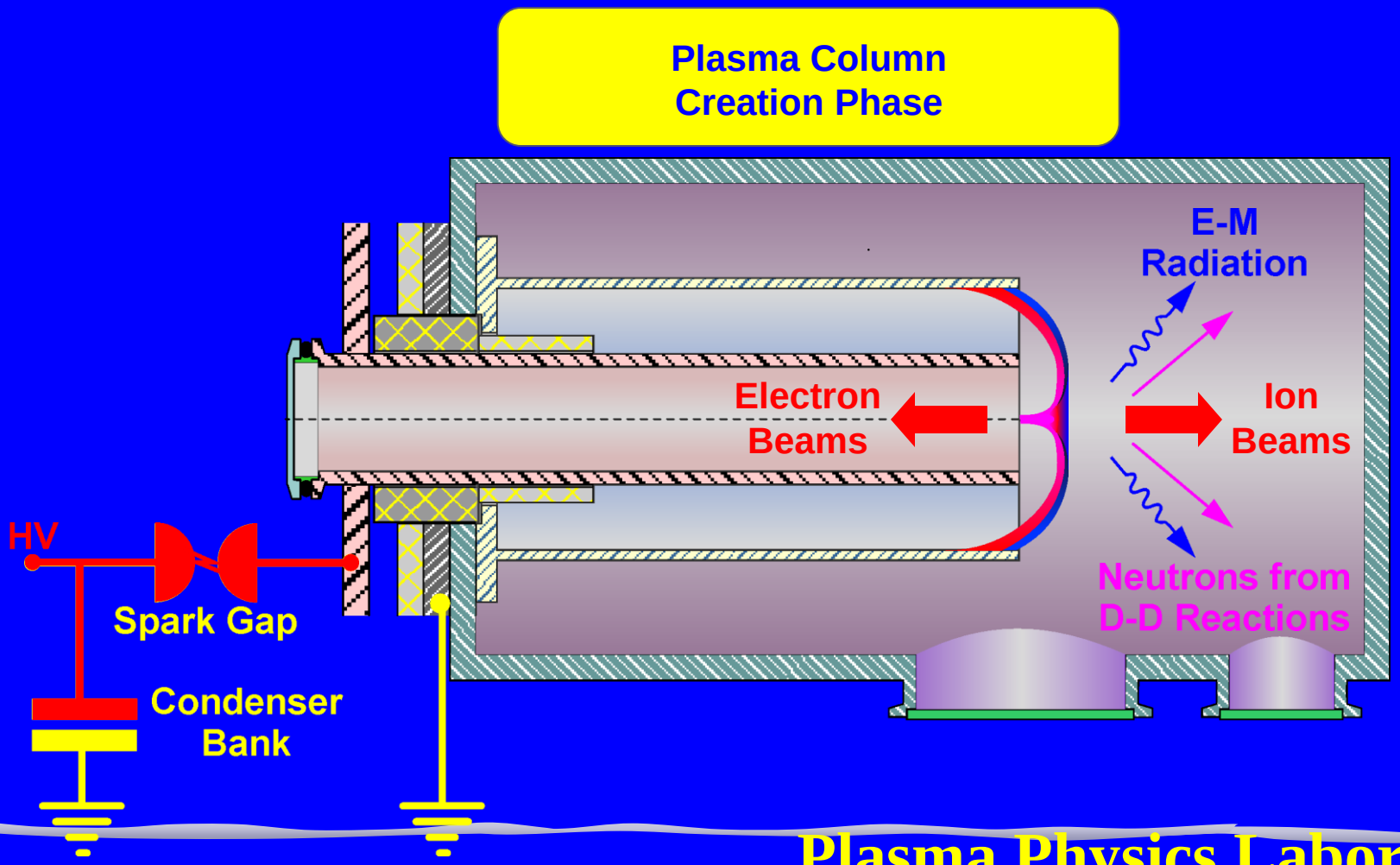


Principle of Operation

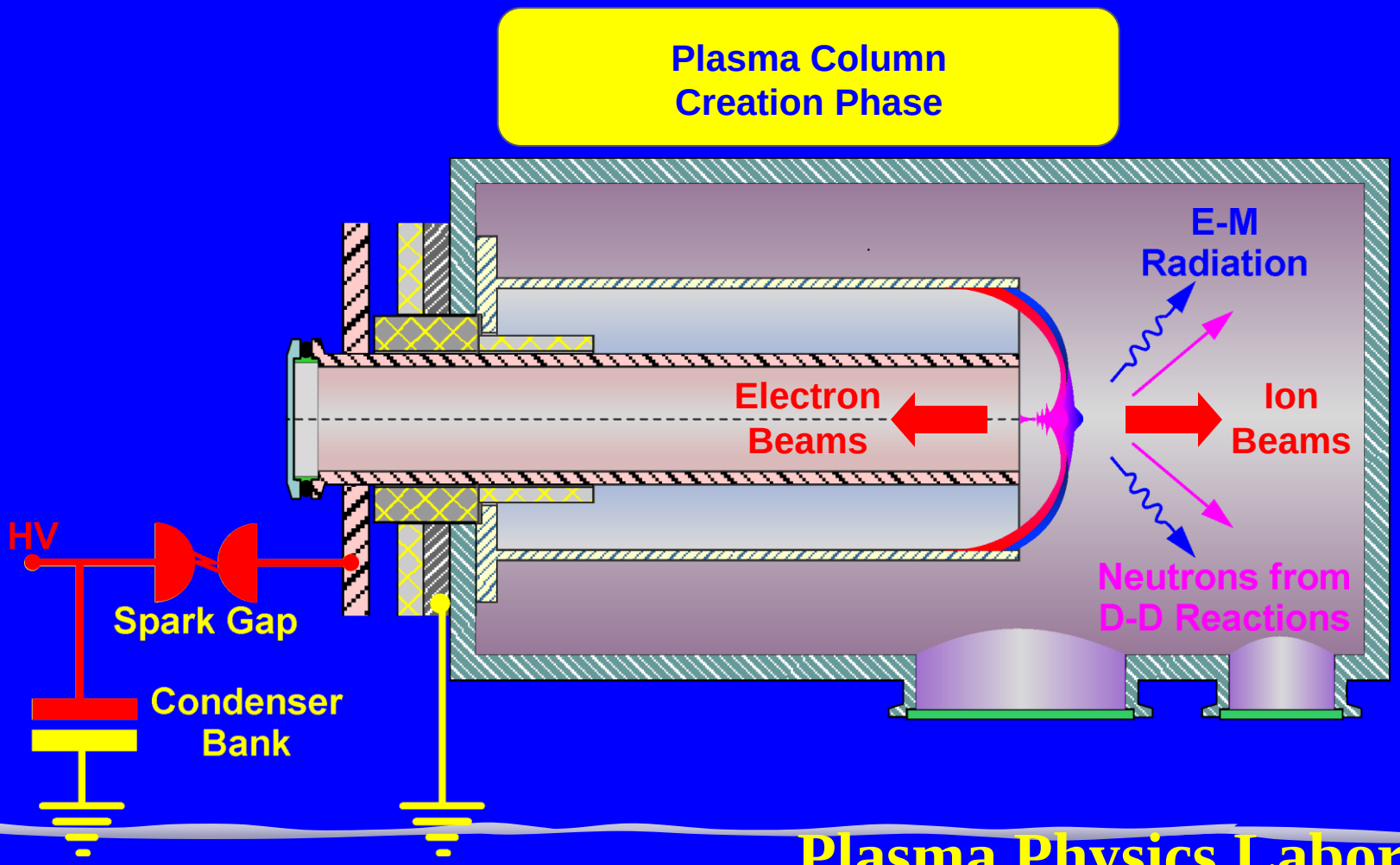
Radial Compression Phase



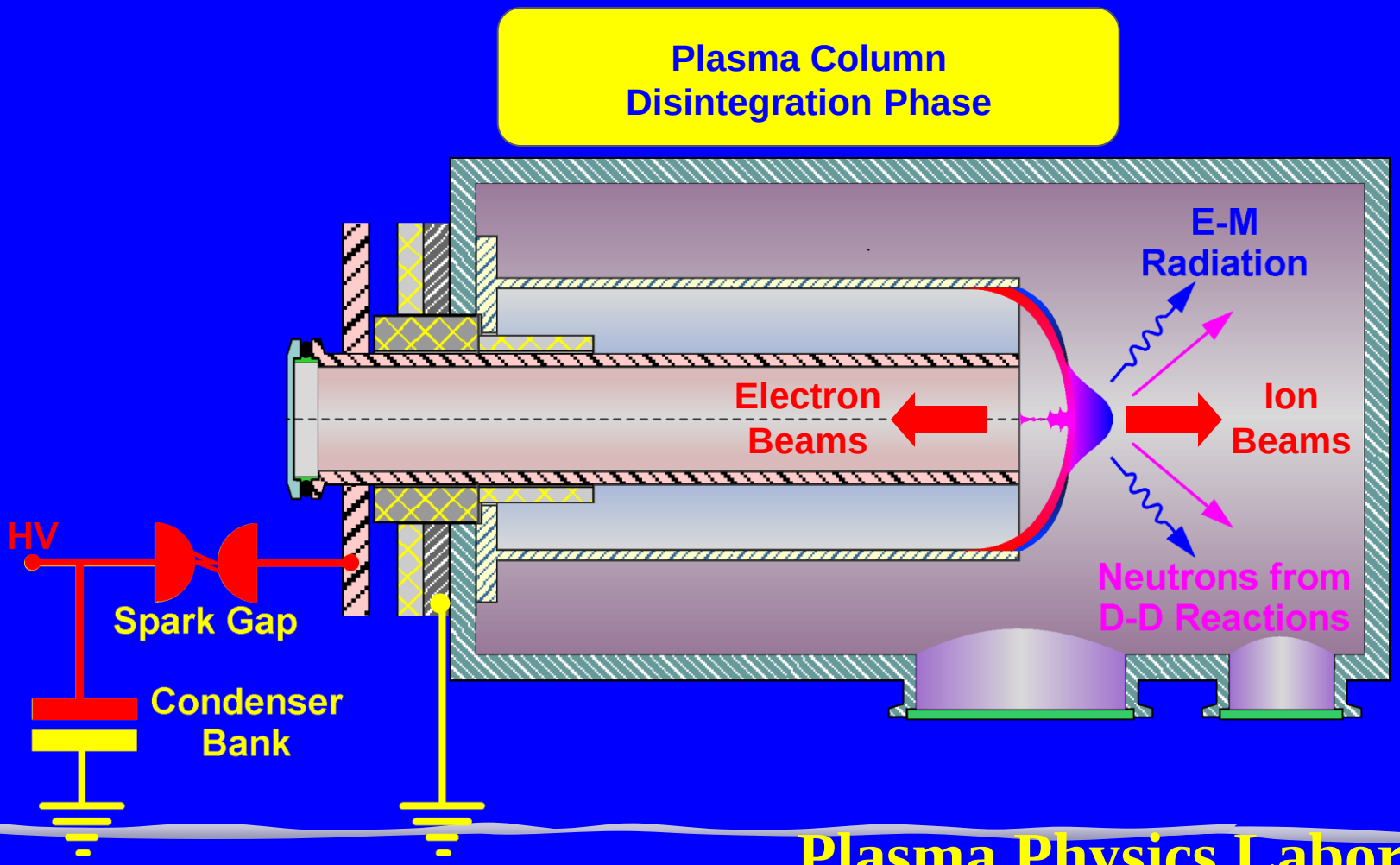
Principle of Operation



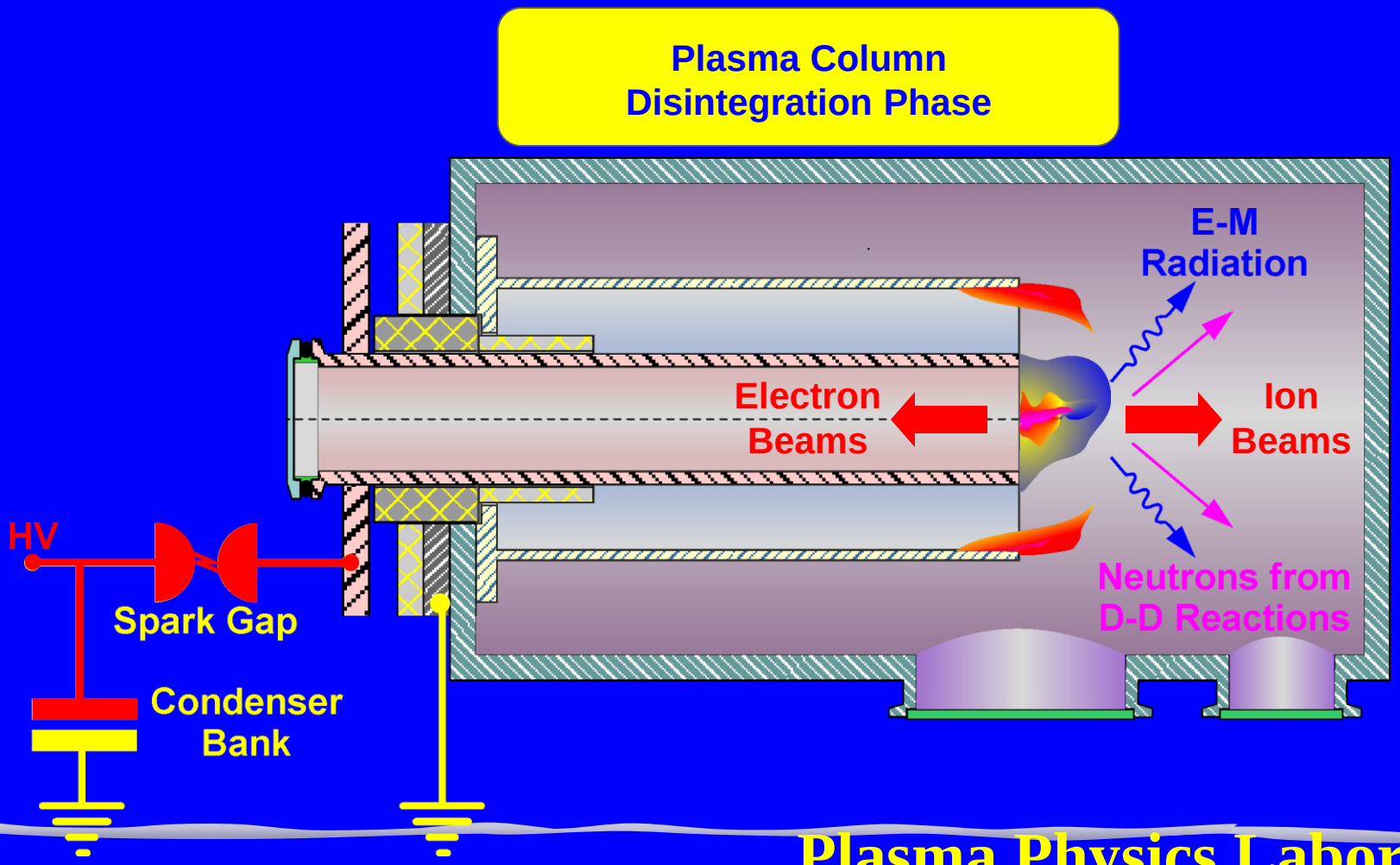
Principle of Operation



Principle of Operation

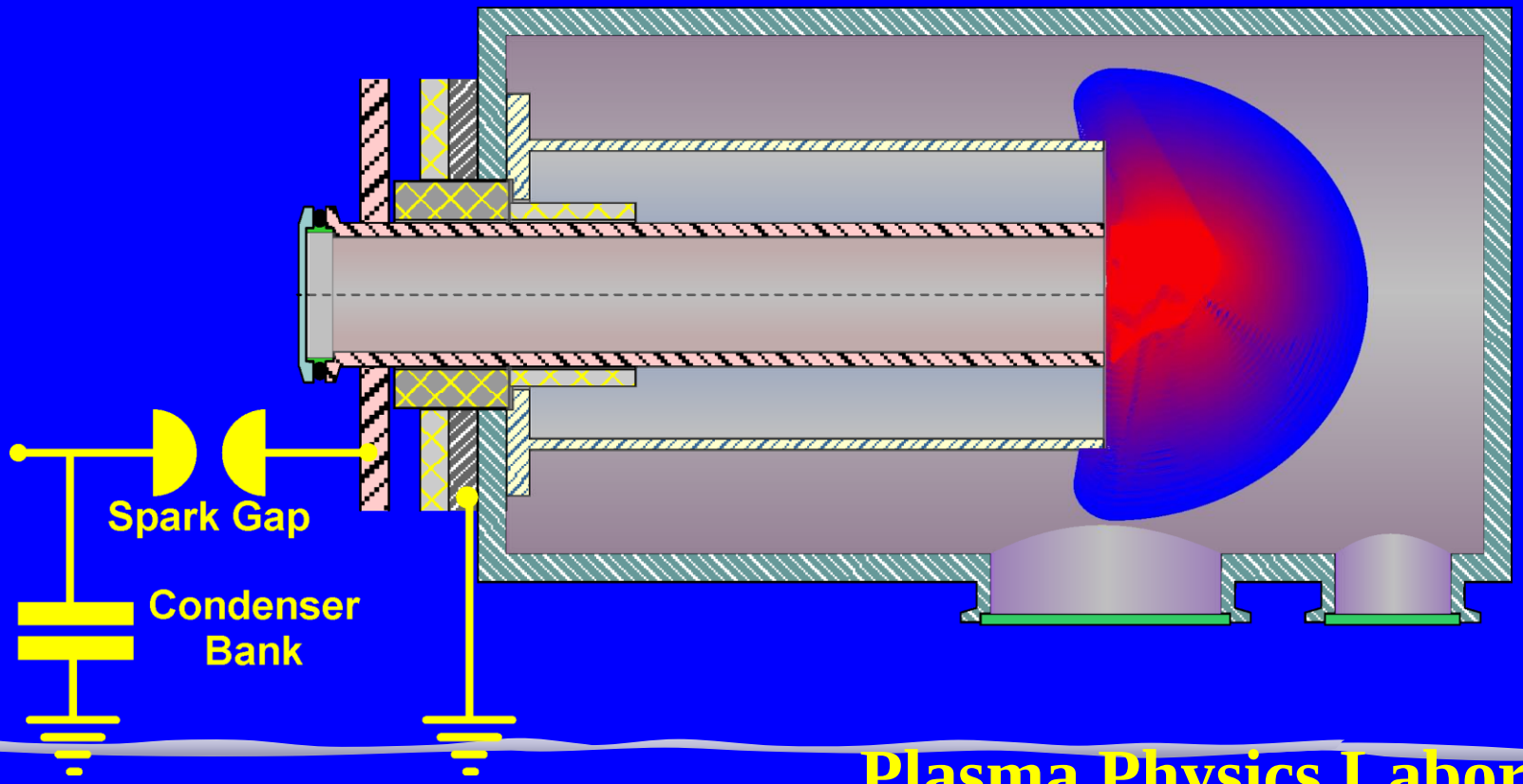


Principle of Operation

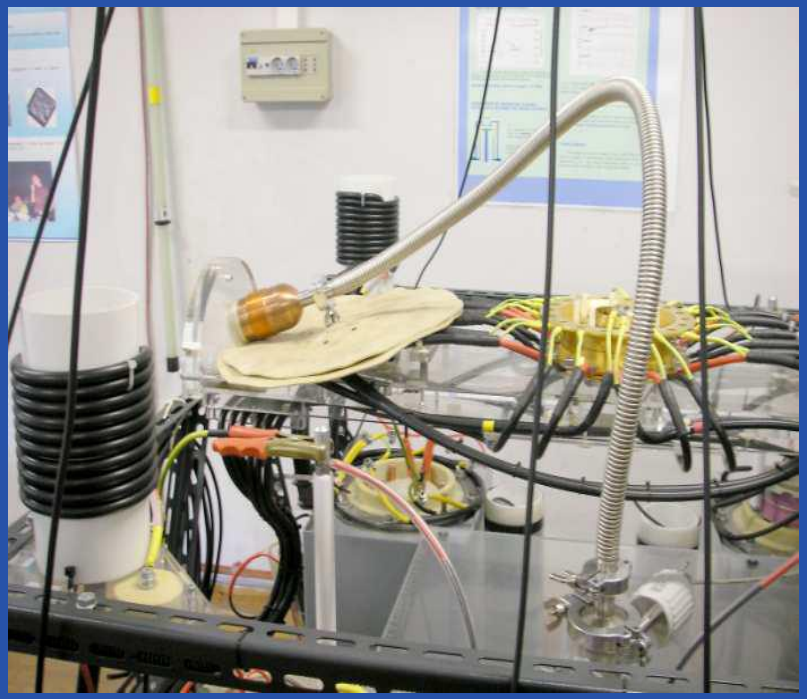


Principle of Operation

End of Discharge



Bora Device



Plasma Arc

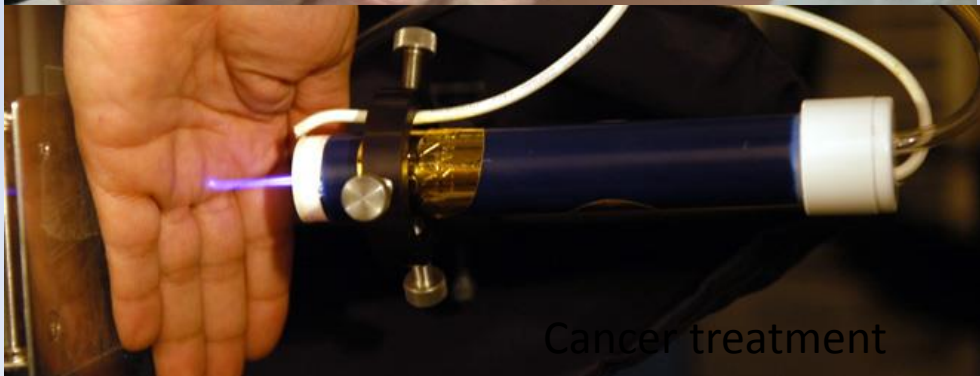
Plasma arc wielding and waste recycling

- Plasma torches like this are the heart of a plasma recycling plant. They can create temperatures of over 10,000 degrees enough to blast waste materials apart into their constituent atoms so they can be reassembled into less harmful materials. Photo by Ames Laboratory courtesy of US Department of Energy, published on Flickr.

Applications of plasma

Medical applications:

- Wound healing
- Dentistry
- Cancer treatment



Applications of plasma

Agriculture:

- Upgrade cotton fabric qualities
- Killing harmful bacteria

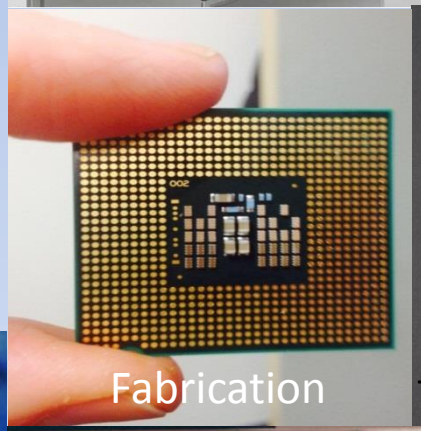
cotton fabric

Killing harmful bacteria

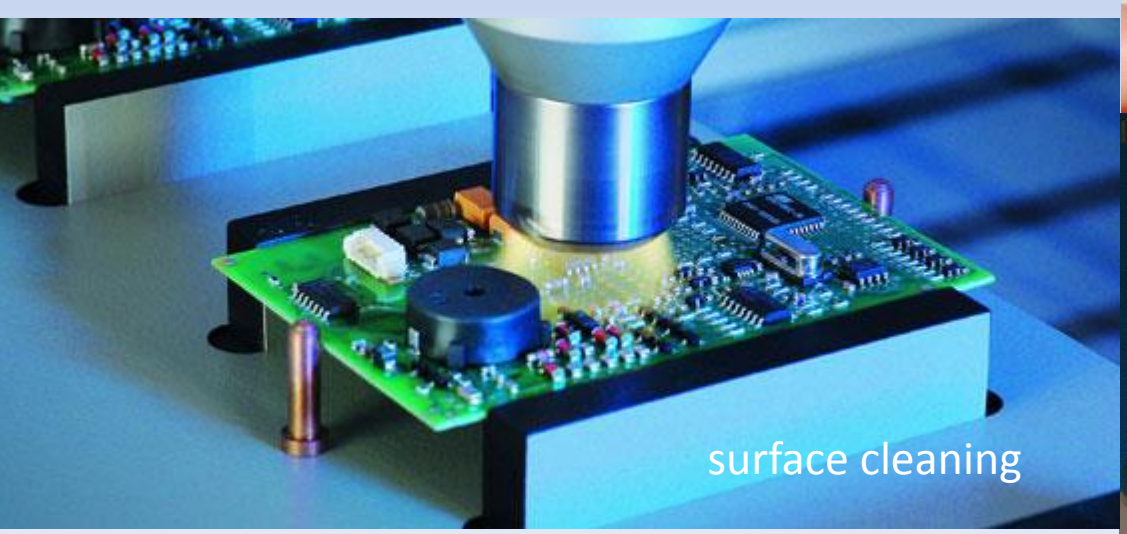
Applications of plasma

Plasma in industry:

- plasma displays.
- Inside fluorescent lamp.
- Fabrication of semiconductor device including reactive ion etching , sputtering and surface cleaning.


Fabrication


fluorescent lamp


surface cleaning


etching , sputtering

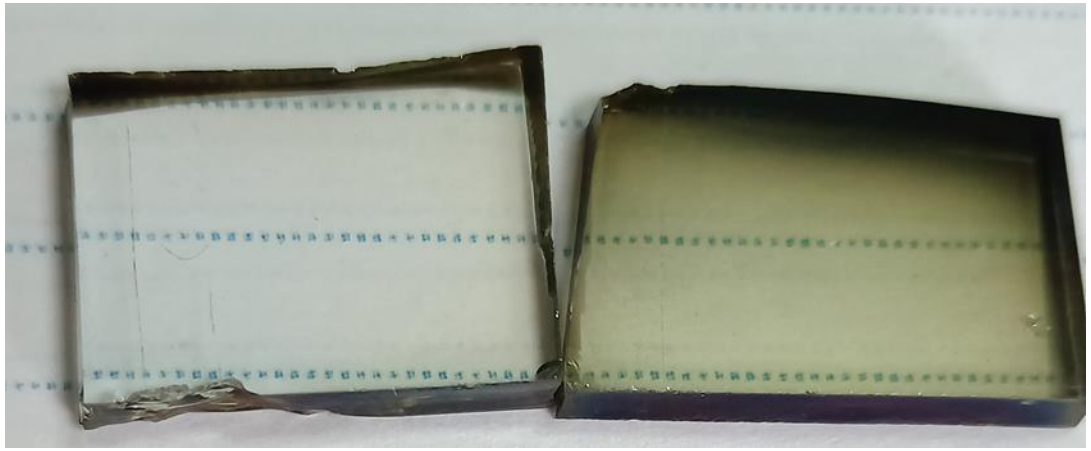
Use plasma Radiation in industrial applications

- Plasmas underlie numerous important technological applications and devices as well as our understanding of much of the universe around us.
- Plasma processing technologies are of vital importance to several of the largest manufacturing industries in the world. Foremost among these industries is the electronics industry, in which plasma-based processes are indispensable for the manufacture of very large-scale integrated microelectronic circuits. Plasma processing of materials is also a critical technology in, for example, the aerospace, automotive, steel, biomedical, and toxic waste management industries.

Use plasma Radiation in industrial applications

- Most recently, plasma processing technology has been utilized increasingly in the emerging technologies of diamond film and superconducting film growth. The dominant role of plasma-treated surfaces in key industrial sectors, such as microelectronics, is well known, and plasmas, certainly experimentally and, in places, industrially, are being used to modify a huge range of material surfaces, including plastics, polymers and resins, paper and board, metals, ceramics and in organics, and biomaterials. Adding to uses the plasma radiation in the field of nanotechnology.

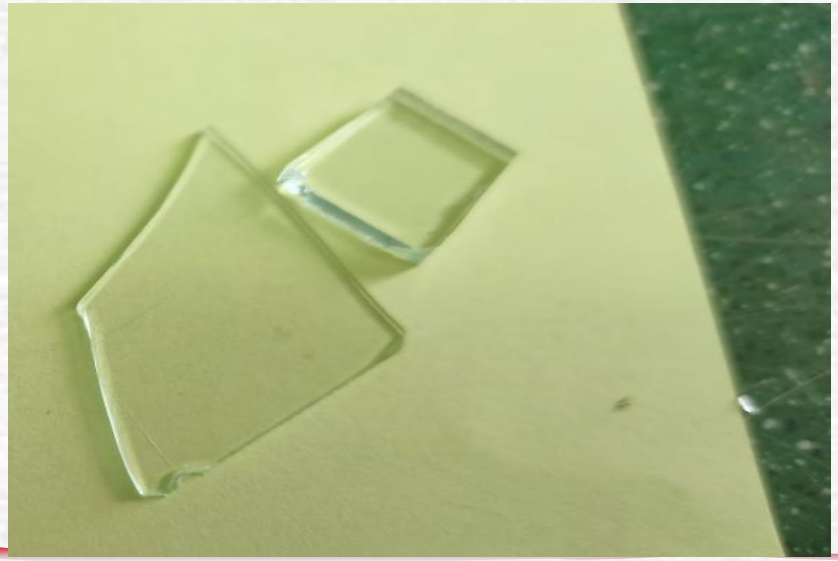
(a) (b) (c)

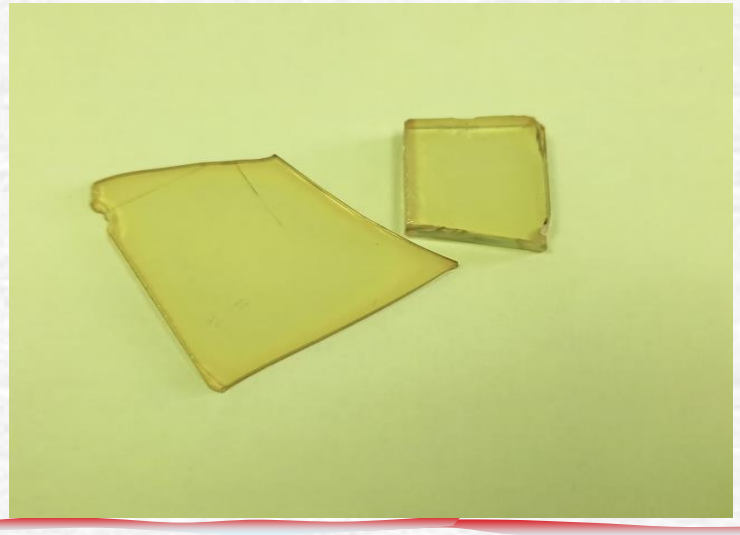



٢٠١٠م
١٤٣١هـ


٥٠
قرشا
50 PIASTRES

Recent Trends & Future research plan

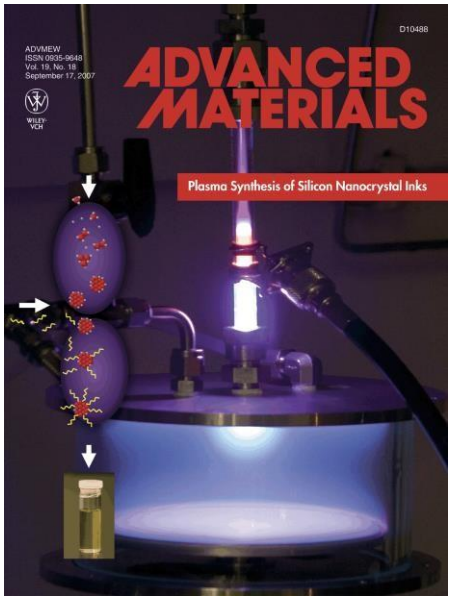




Plasma Science for Modern Nanotechnology

Revolutionary Nanosynthesis Technologies

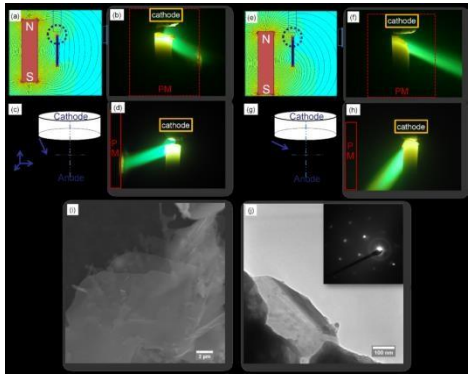
Nanomaterials have the potential to revolutionize many fields, including electronics, energy storage, and environmental and pharmaceutical applications.



Low pressure plasma synthesis of silicon nanoparticles.

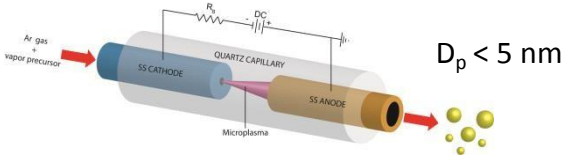
Mangolini and Kortshagen Advanced Materials 2007 Univ. of Minnesota

- **Many existing methods of nanosynthesis use low pressure (10^{-3}-10^{1} torr) and higher pressure ($\leq$ 1 atm.) plasmas to produce a broad range of nanomaterials with various nanostructures:**

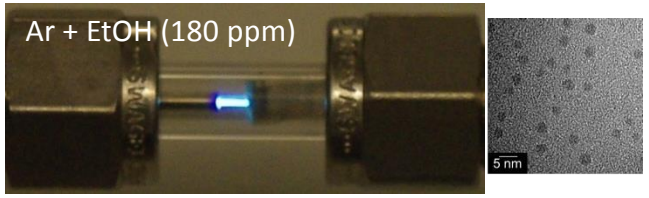


Magnetically controlled arc synthesis of graphene at 500 torr.

Volotskova et al, Nanoscale, 2010 GWU-PPPL-CSIRO



1 atm, room T



Microplasma synthesis of nano diamonds at 1 atm. pressure

A. Kumar et al., Nature Comm. 2013 Case Western Reserve Univ.

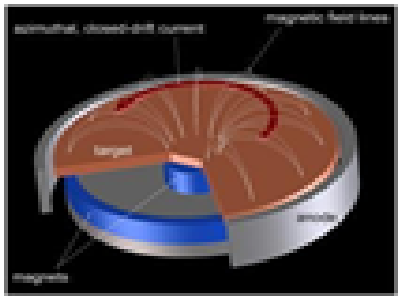
Plasma Science for Modern Nanotechnology

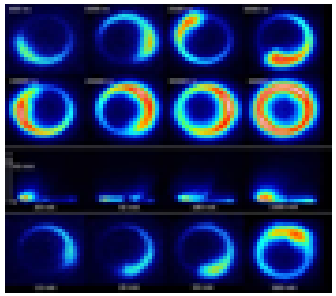
Emerging Plasma-Based Nanotechnologies

- Use low-pressure magnetized plasmas to produce new nanomaterials:

- Synthesis of nanostructural functional coatings using magnetized plasmas

a) b)

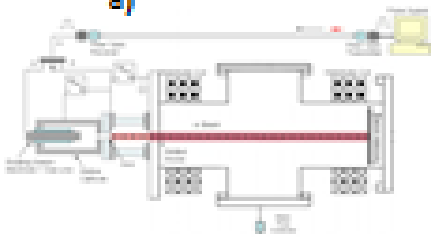


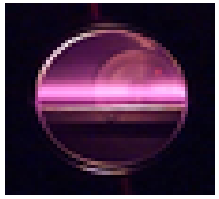


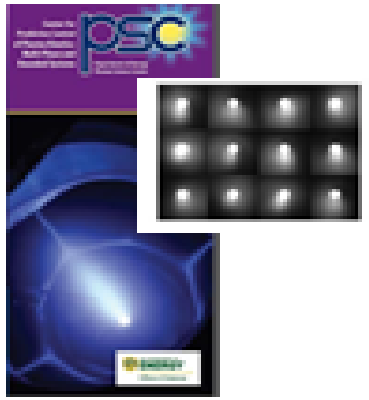
- Sputtering magnetron discharge: (a) High power impulse magnetron (HiPIMS); (b) Plasma non-uniformity rotating in E × B direction (DC Magnetron). *A. Anders et al., IEEE TPS to appear in 2014, APL 2013*

- Functionalization of nanomaterials by magnetically filtered cold plasmas

a) b)

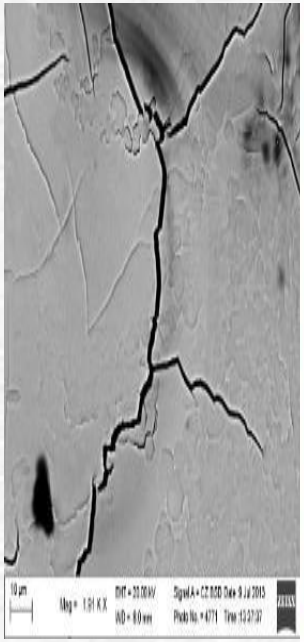


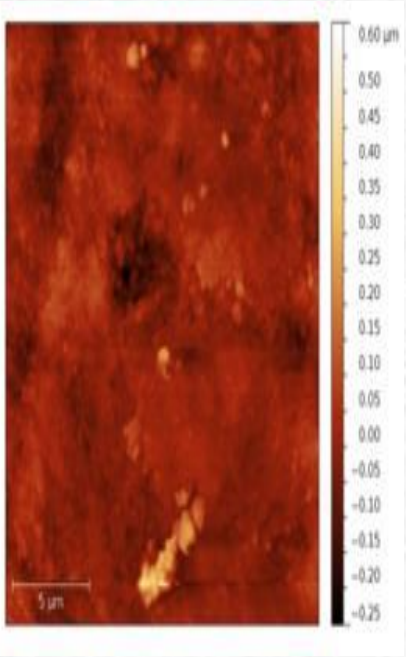


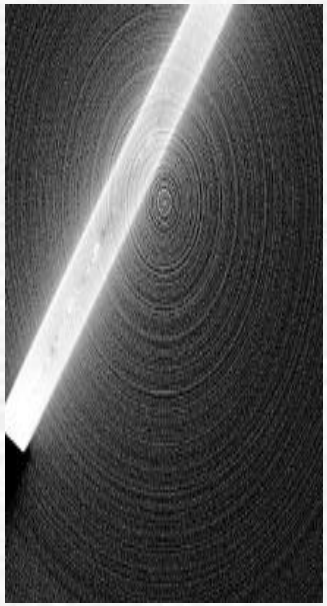


- (a) NRL Electron-beam plasma source for functionalization of graphene. *Baraket, Walton et al. 2014*; (b)PPPL DC-RF plasma-beam system and rotating spoke instability. *Raitses et al., DOE PSC meeting 2012*

- Need understanding of relevant plasma instabilities and plasma-surface interactions at nanoscale level to control quality of synthesis and functionalization processes and nanomaterials.







a) b) c) d) e)

Macroscopic image *(a)* of the tungsten specimen No. 40 after its irradiation in DPF, an optical microscopic picture of it *(b) at the border between zones of irradiation by hot plasma and fast* ion beam, a scanning electron microscopic view *(c) of the part of the same sample with the strongest* action of the ion beam, an atomic force microscopy *(d)* of the sample with its roughness, as well as one cross-section of the Ti foil made by the X-ray micro-tomography *(e)*.

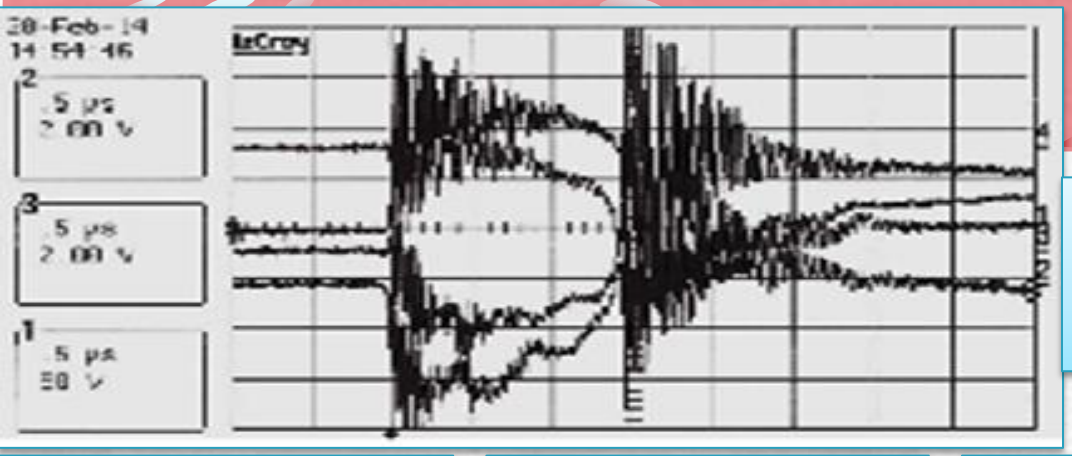
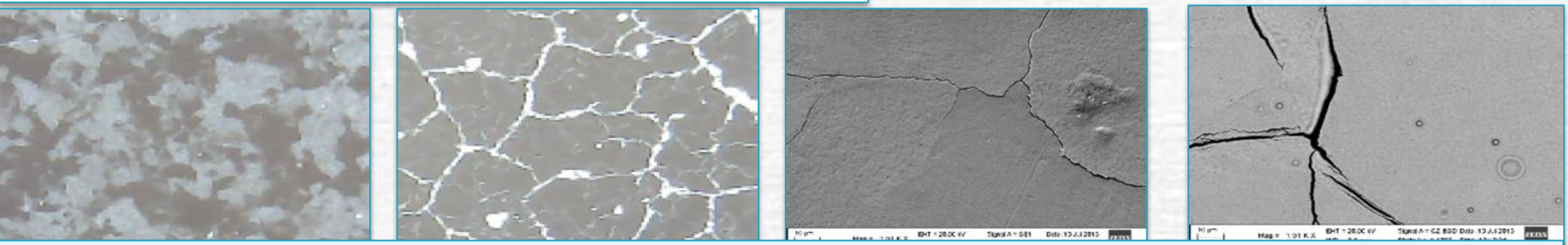
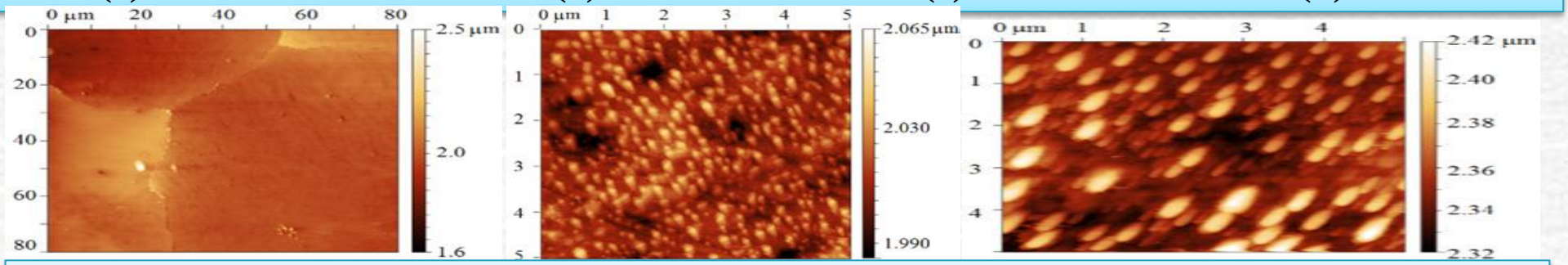


Figure 1. Four oscilloscope traces of dI /dt taken at each of the four capacitors of the DPF bank

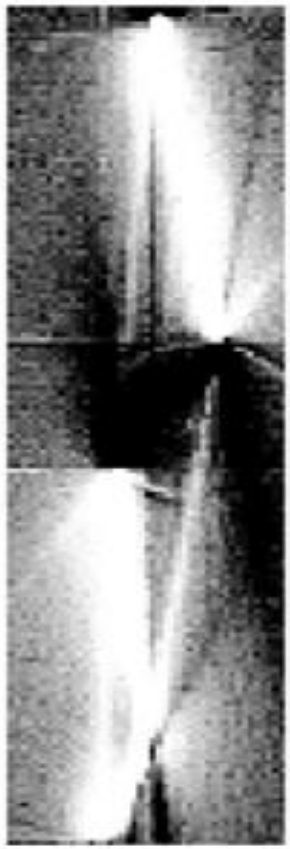


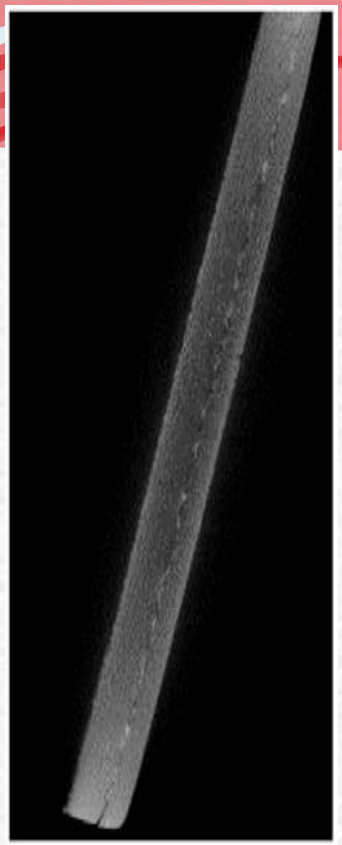
(a) (b) (c) (d)



(e) **(f)** Roughness 10.04 **(g)** Roughness 16.71

Optical microscopic images of the surface of the **DF60** specimen of W before (a) and after (b) irradiation by **7 pulses** of hot plasma and fast deuterons; SEM images of the **DF10** sample after **4 shots** (c) and **DF11** after **8 shots** (d); images of the **DF9** sample after **4 shots** obtained by means AFM ((e) and (f) — different magnifications) and **DF11** after **8 shots** (g).



2 mm



1 mm

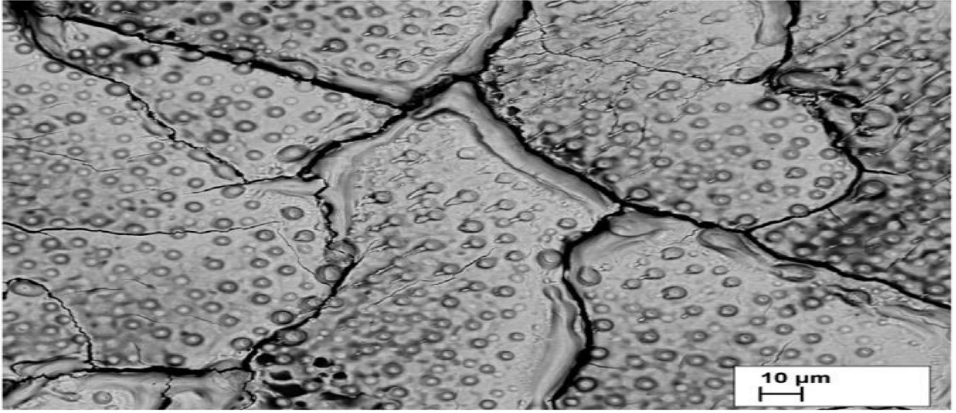
X-ray micro CT images:

(a) 2 cross-sections of the Al foil sample ($10 \times 10 \times 0.5\ mm^3$) before (below) and after (above) irradiation;

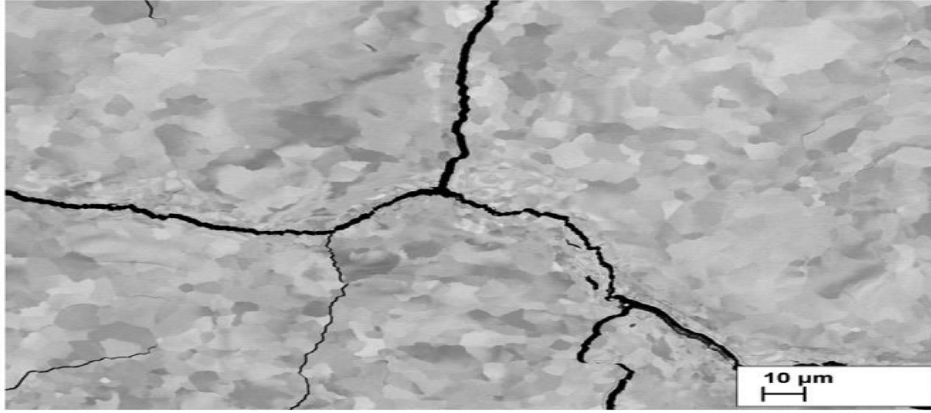
(b) 2 cross-sections of a sample of a Mo foil ($10 \times 10 \times 0.1\ mm^3$) taken before (above) and after (below) irradiation;

(c), (d),(e): cross-sections of the Ti alloy foil ($13 \times 13 \times 1\ mm^3$)

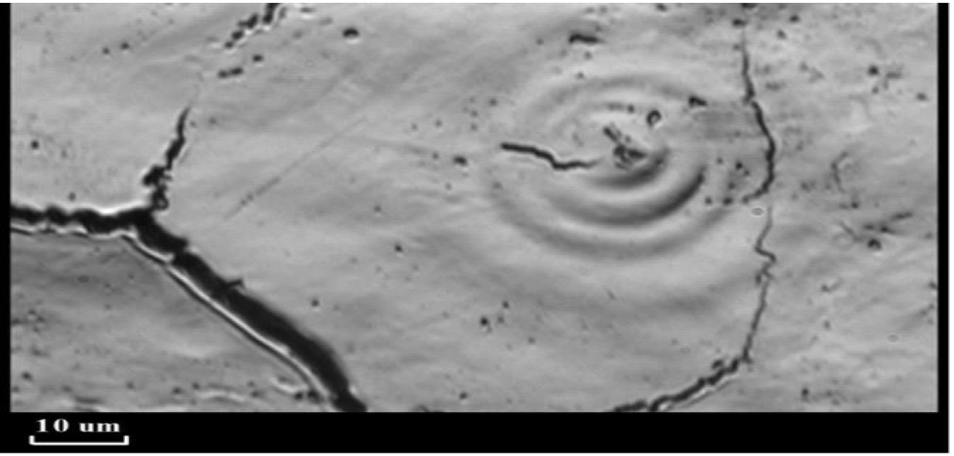
(c) before and after ((d) and (e)—with higher magnification) irradiation.



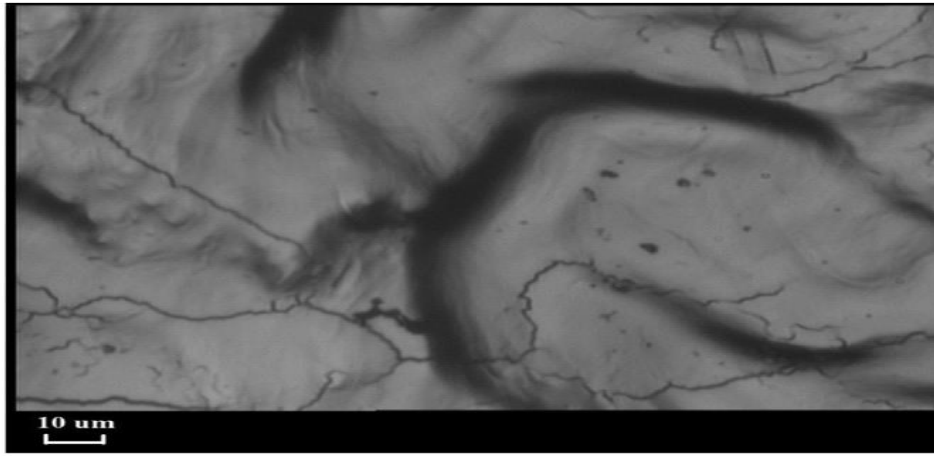
(a)



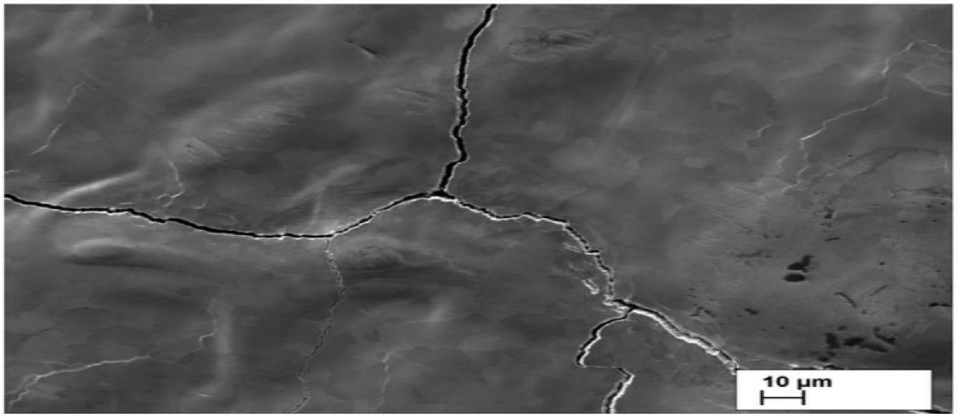
(b)



(c)

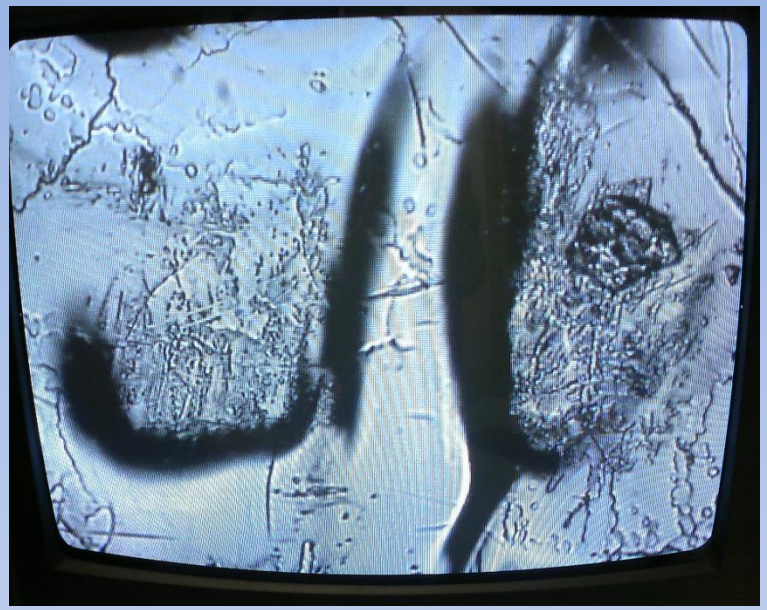


(d)

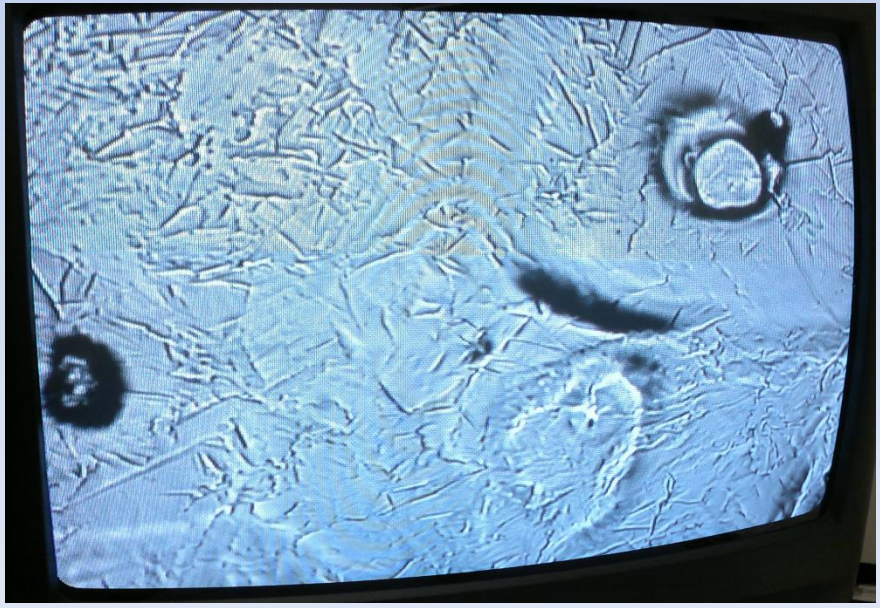


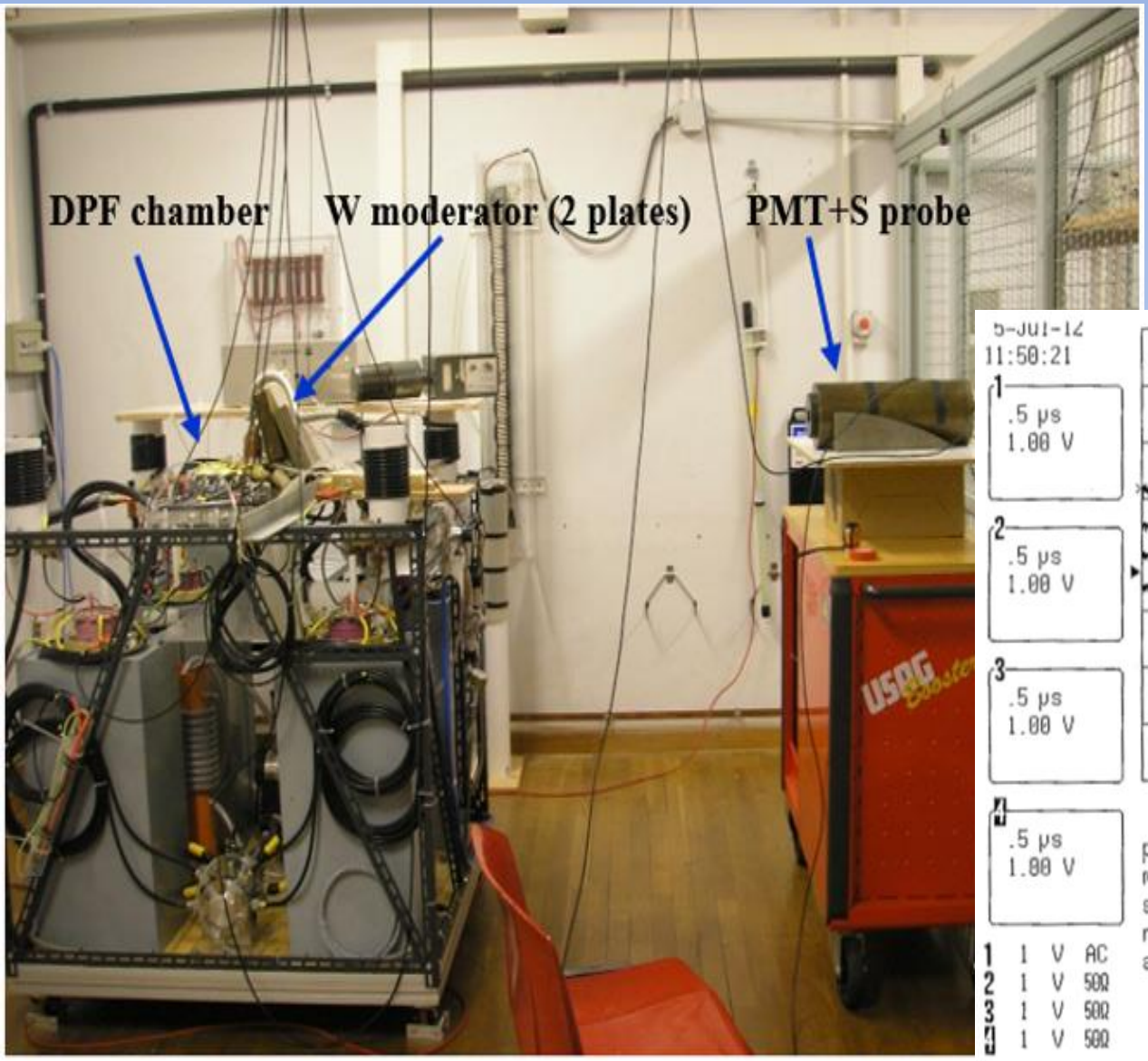
(e)

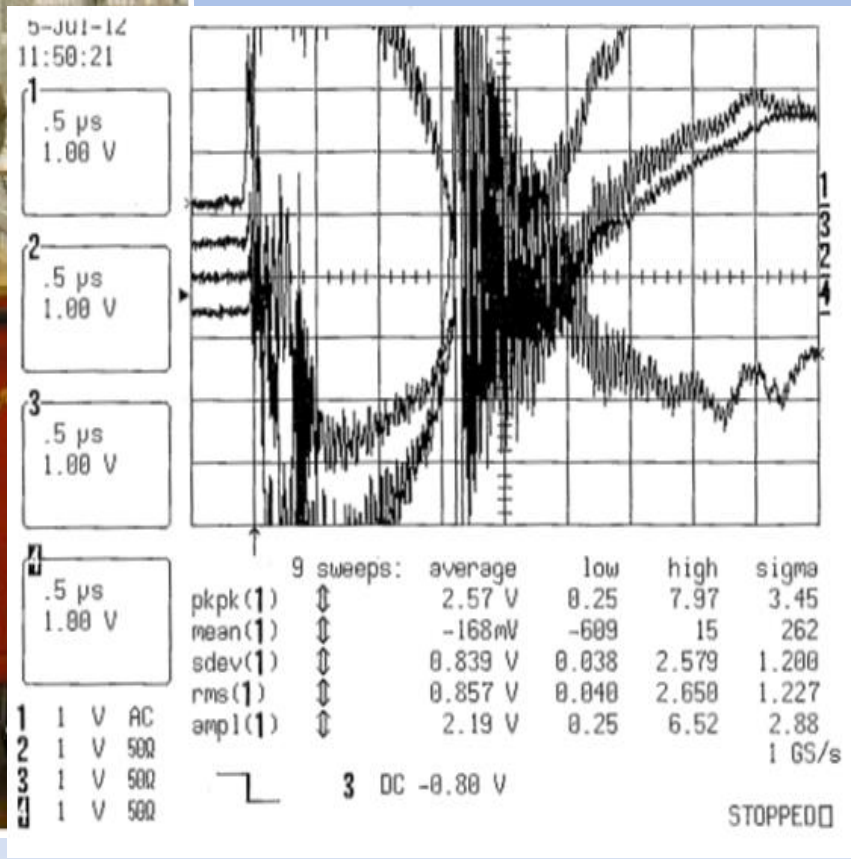

SABA

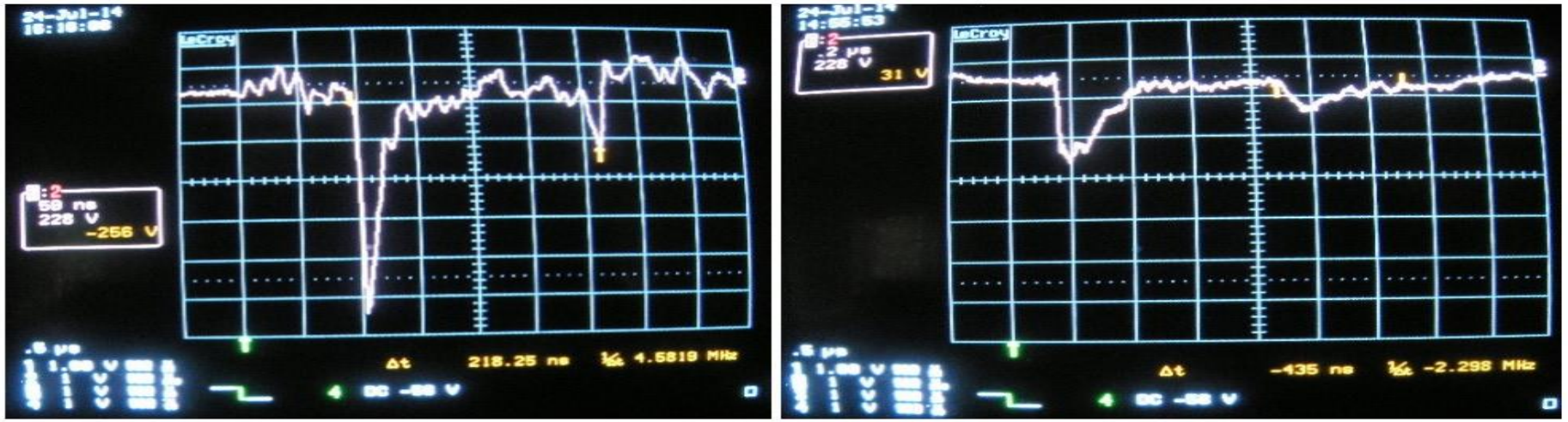



SABA



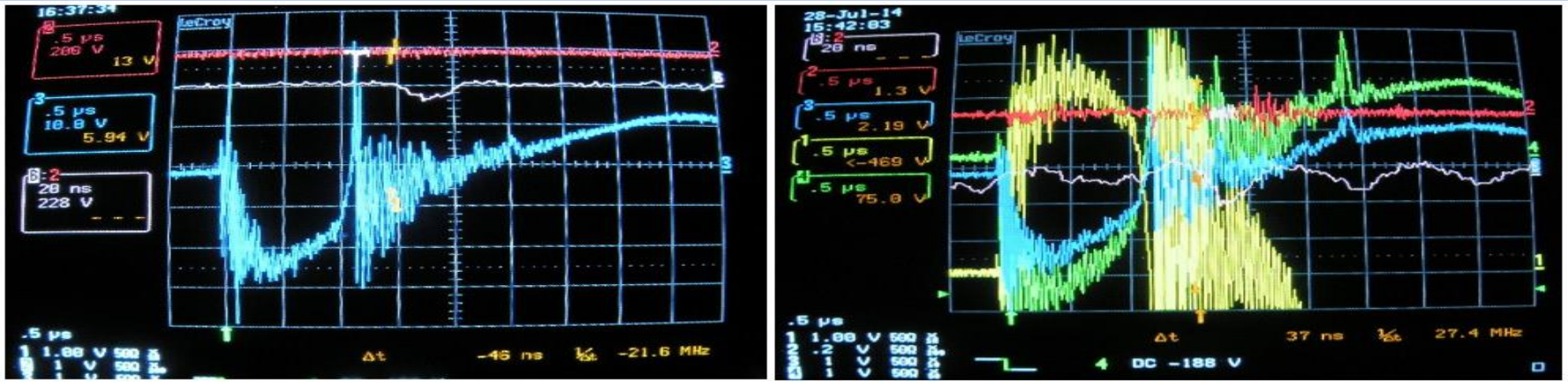

DPF chamber
W moderator (2 plates)
PMT+S probe


5-Jul-12
11:50:21
1
.5 µs
1.00 V
2
.5 µs
1.00 V
3
.5 µs
1.00 V
4
.5 µs
1.00 V
1 1 V AC
2 1 V 50Ω
3 1 V 50Ω
4 1 V 50Ω
9 sweeps: average low high sigma
pkpk(1) 2.57 V 0.25 7.97 3.45
mean(1) -168mV -609 15 262
sdev(1) 0.839 V 0.038 2.579 1.200
rms(1) 0.857 V 0.040 2.650 1.227
ampl(1) 2.19 V 0.25 6.52 2.88
1 GS/s
3 DC -0.80 V
STOPPED



a) b)

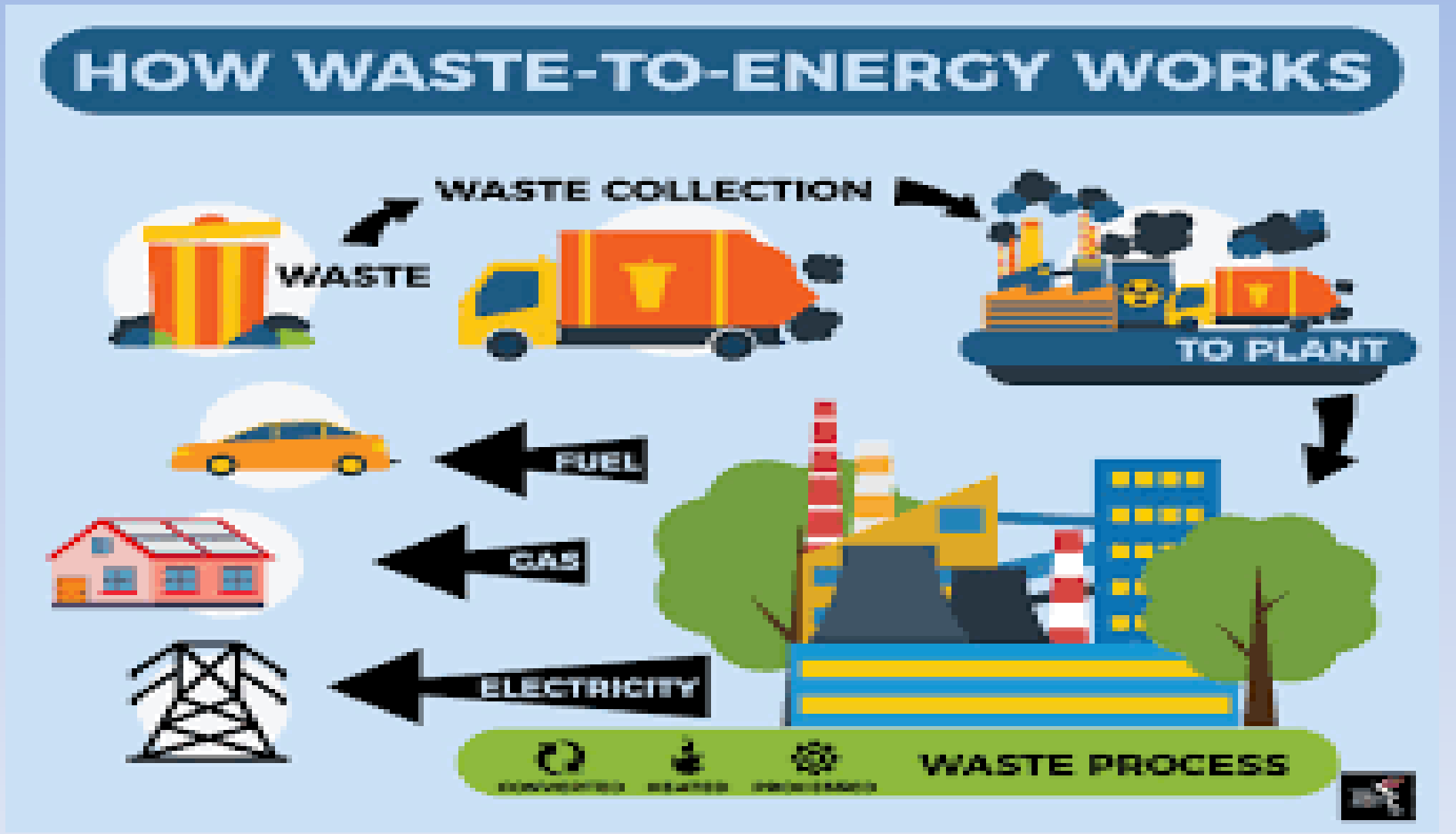
Oscilloscope trace of hard x-ray and neutron pulses in different conditions for the distance from the source to the PMT+S probe equal to 4.64m.



a) b)

Oscilloscope traces obtained for the distance from the source to the PMT+S probe equal to 8.89 m: a) - without tungsten blocks, b) with 2 tungsten plates of 84-mm total thickness.

Plasma as Green Energy



Plasma as Green Energy

- Wastes emerged to be an opportunity to generate valuable materials and products for human demands. Particularly in non-developed countries, recycling of resources have become a prominent revenue source for society. Numerous researches are conducting and developing to manage wastes by new technologies over the world day by day.

- **Plasma arc recycling:**

A relatively new type of waste treatment called plasma arc recycling (sometimes referred to as "plasma recycling," "plasma gasification," "gas plasma waste treatment," "plasma waste recycling," and various other permutations of the words plasma, gas, arc, waste, and recycling) aims to change all this. It involves heating waste to super-high temperatures to produce gas that can be burned for energy and rocky solid waste that can be used for building. Supporters claim it's a cleaner, greener form of waste treatment.

- **What kind of waste do we make?**

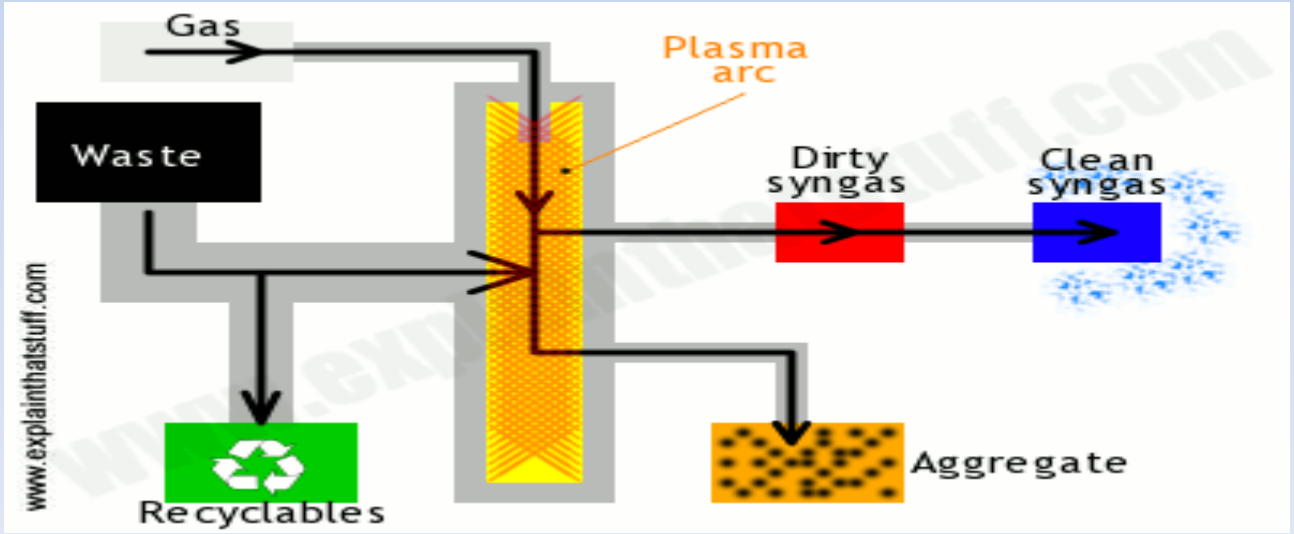
Plasma as Green Energy

1- The waste is burned in a closed container at extremely high temperatures (to destroy as many toxic chemicals as possible);

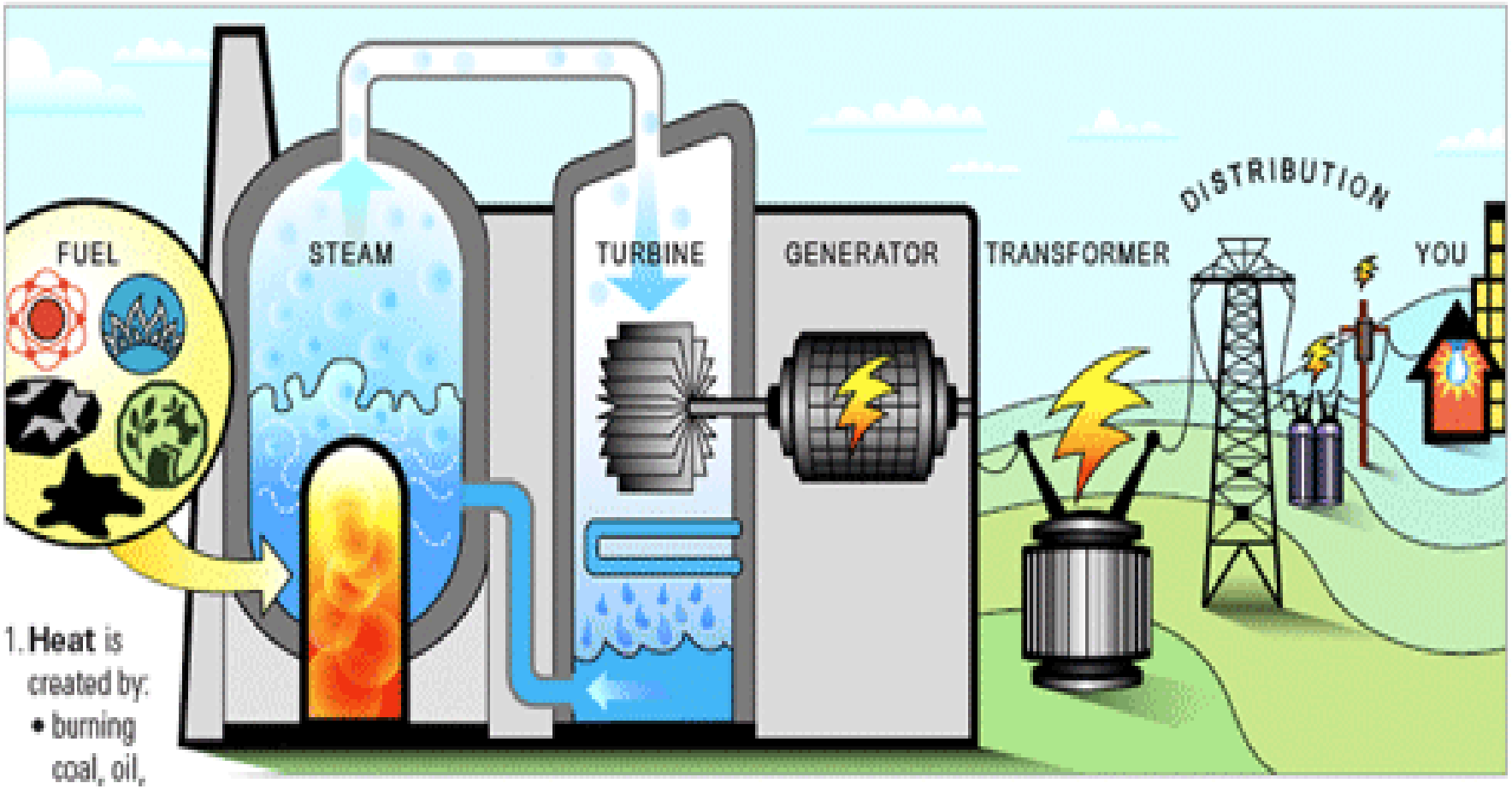
2- Pollution from the smokestack (chimney) may be trapped and "scrubbed" clean before it's released (using an electrostatic smoke precipitator);

3- A very tall smokestack is used, (theoretically) to disperse any remaining pollution in the wind;

4- The energy released by burning the waste is captured and used to boil water, drive a steam turbine, and generate electricity.



Plasma as Green Energy



Thank You