Introduction to Dense Plasma Focus (DPF)

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Outline of Presentation

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Z-Pinch

- Current generates B field in θ direction.
- $\mathbf{J} \times \mathbf{B}$ points radially inward.

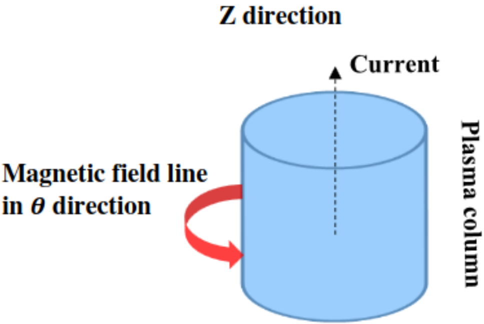


Figure 1: A Z-pinch in cylindrical coordinates. [3]

θ-Pinch

- Plasma current generates B field in z direction.
- Current in primary loop together with B field creates radially inward force.

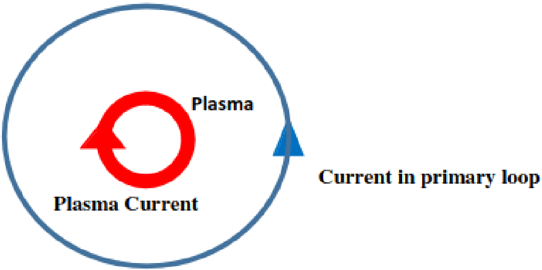


Figure 2: A Schematic of theta pinch configuration. [3]

X-Pinch

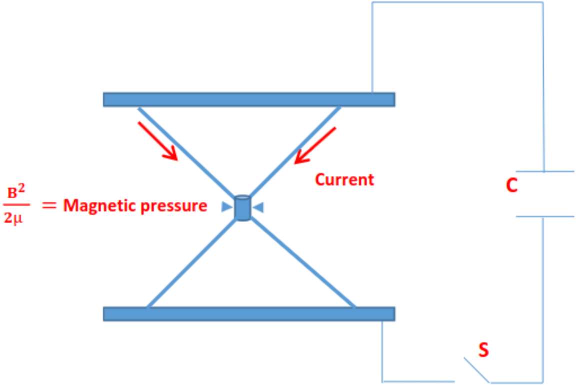


Figure 3: The configuration of an X-pinch device. [3]

Outline of Presentation

1. Pinch Effect
2. Dense Plasma Focus
3. Applications
4. Lee Model

Plasma Focus Device

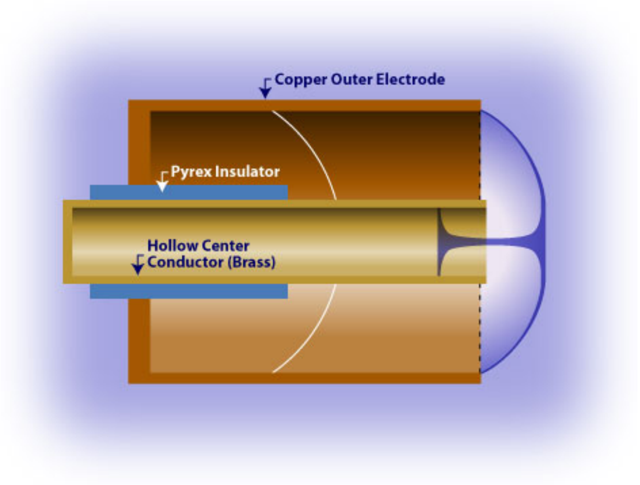


Figure 4: Plasma focus device (schematic). Source [1]

How It Works

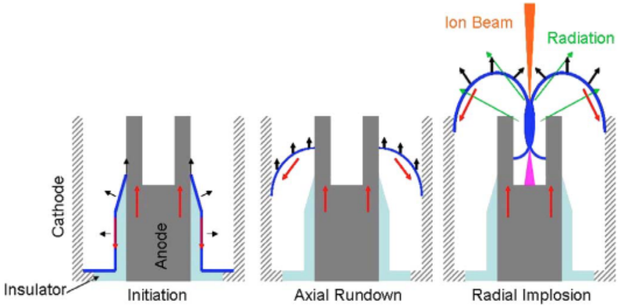


Figure 5: Three phases of a typical DPF current pulse: initiation via flashover of the insulator, axial run-down phase, and radial implosion of form beams and dense pinch. [4]

X-ray Radiation

- There are 2 well known mechanisms: line and continuum radiation.
- Line radiation: generated by a working gas, or from the interaction between the energetic electrons and impurities.
- Continuum radiation: recombination and Bremsstrahlung radiation.

Neutron Emission

- Two mechanisms: thermal and beam target.
- Thermal mechanism: collision of energetic deuterium ions.
- Beam target mechanism: interaction of accelerated deuterons with the plasma or background gas.

Outline of Presentation

Short-lived Radioisotopes (SLRs) Production

- SLRs: such as ^{13}N, ^{17}F, ^{18}F, ^{15}O, and ^{11}C.
- SLRs are used in medical applications.
- SLRs production: bombardment of an external solid (exogenous method).
- SLRs production: bombardment of a high atomic number gas (endogenous method).

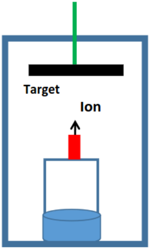


Figure 6: The bombardment of target by ion beam generated by plasma.

Thin Film Deposition

- Thin film deposition: create thin film coating onto a substrate material.
- Electron beam sputters target material.
- Sputtered material gets deposited onto the surface of substrate material.

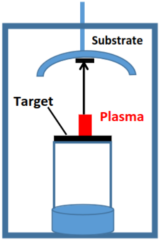


Figure 7: Schematic arrangement for thin film deposition in a plasma focus.

Detection of Illicit Materials and Explosives

- The neutron scattering and the gamma-rays allows us to determine the material.
- DFP is a good neutron source.

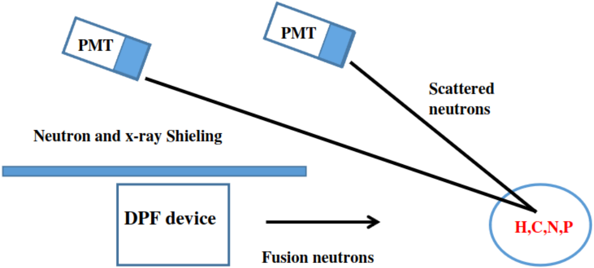


Figure 8: Schematic arrangement of illicit and explosive materials detection by a DPF.

Outline of Presentation

Lee Model

- Three phases: break down, axial, and compression phases.
- Compression phase: inward shockwave, reflected shockwave, and slow compression phase.

Break Down Phase

- Gas is ionized, and current layer formed

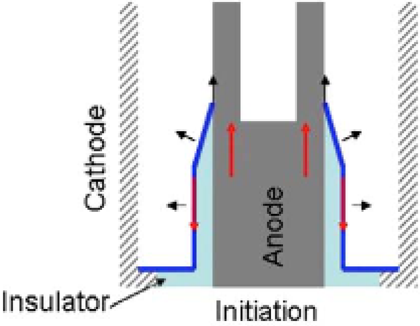
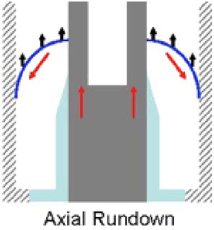


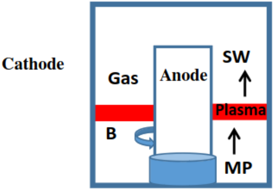
Figure 9: Initiation via flashover of the insulator. Break down phase. [4]

Axial Phase

- Current layer is accelerated by the $\mathbf{J} \times \mathbf{B}$ force in the axial direction.
- A shockwave (SW) is formed due to magnetic pressure (MP).



(a) Axial run-down phase. [4]



(b) The formation of plasma layer. [3]

Compression Phase - Inward Shockwave Phase

- When the plasma layer arrives at the top of the anode, the $\mathbf{J} \times \mathbf{B}$ force pushes them into the center of the anode.
- Plasma column with inner radius r_s and outer radius r_p will form on the top of the anode.
- Shockwave compresses gas in the center.

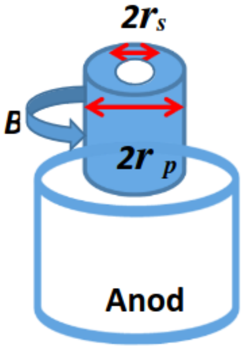


Figure 11: The inward radial shock wave in final stage off plasma focus.

- The shockwave will be reflected radially in the outward direction after hitting the center of the anode.

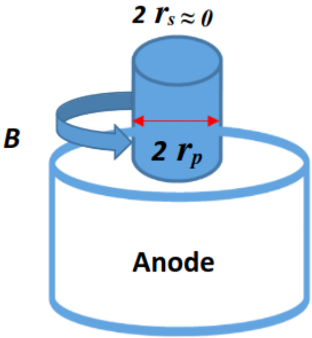


Figure 12: The reflected shockwave phase in plasma focus. [3]

Compression Phase - Slow Compression Phase

- Slow compression phase starts when $r_s = r_p$.
- The reflected shockwave produces a pressure in the opposite direction of the magnetic pressure.
- Plasma column will be compressed to its minimum radius.

Instability Phase

- When plasma reaches maximum compression, the plasma column may become unstable due to plasma instabilities.
- Instabilities make the plasma resistance anomalous.

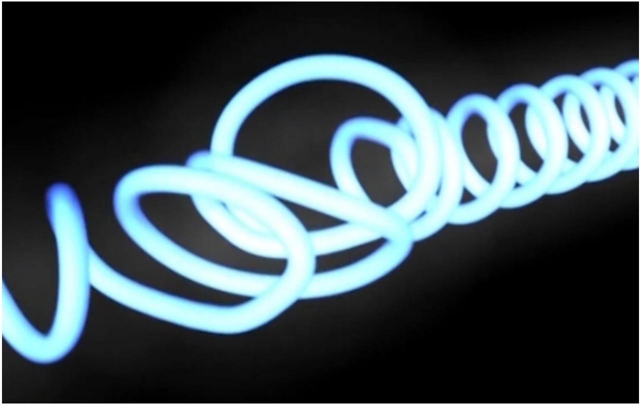


Figure 13: Plasma column is twisted in instability phase. Source [2]

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