The Problem of Determining Temporal Fine Structure of the Neutron Source in a Large Plasma Focus

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The Problem…

- Time-of-flight separation of hard X-rays and neutrons equal to the duration τ of emission leads to loss of information about time-variations in neutron emission rate on the time scale of $\Delta t \sim \frac{\tau}{2}\frac{\Delta E}{E}$

- This information is correlated with details of plasma dynamics on the time scale of $\frac{r_p}{v_p}$

…Statement

- Can the temporal fine structure of neutron emission be resolved using a detector that does not require TOF for discrimination between X-rays and neutrons?

Proposed Detector

- UO_2 is an outstanding semiconductor
  - **Thomas Meek, Michael Hu and M. Jonathan Haire, "Semiconductive properties of uranium oxides", Waste Management 2001 Symposium, Tucson, Arizona, February 25–March 1, 2001.**
- Properties:
  - Band gap ~1.3 eV
  - Dielectric constant ~22
  - Resistivity similar to intrinsic single crystal Si

Proposed Detector

- Detector should be a charged transmission line segment of 50 Ω with UO_2 as dielectric.
- Polarization current introduced by fission fragments in UO_2 would generate a signal in matched impedance at the oscilloscope.
- Because of small range of fission fragments, the region of ionization would be small. Hence time-scale of charge release will be small.

Estimation of Signal Level

- Number of ion-pairs per fission~5×10^7
- Charge per fission ~8 pC.
- Fission Cross-section for U^{238} @2.5 MeV~0.54 b
- Signal voltage into 50 Ω from source producing S neutrons per sec placed at R cm from a detector having an active volume of W cm^3 is

$$V_S = 4.13 \times 10^{-13} \times \frac{S(n/sec)}{R^2(cm^2)} \times W(cm^3)$$

Discrimination against X-rays

- X-rays produce less ionization than fission fragments (How much??…)
- Signal levels from X-rays can be correlated with dosimeter measurements in hydrogen shots and can be used to demonstrate that the signal in deuterium shots is mainly from neutrons.

Detector implementation

- A 50 Ω parallel plate transmission line with UO_2 as dielectric would have height to width ratio of 0.622.
- Sintered poly-crystalline pellets 10 mm X 10 mm X 0.622 mm can be bonded with conducting adhesive between metal plates connected to a cable and encapsulated inside a metal tube to form an electromagnetically shielded triaxial structure.

Development issues

- Is polycrystalline UO_2 a suitable detector material?
  - Crystallite sizes >> range of fission fragments
- How to test the detector during development?
  - Fast pre-amplifiers ??…
- How to optimize the detector voltage?
- ….