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A New Concept for a Wall Detector for Alpha Particles

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A new concept[1] for a wall-mounted detector is described here that would measure D-T alpha flux and corresponding pitch angle distribution in tokamaks (or related toroidal devices) (see Fig. 1). The sensing element is a conical Micro Channel Ring (MCR) coated with 1-2μ of ZnS scintillator (or possibly ZnO). The collimation of the α particles is provided by two circumferential slots at the wall surface. The alpha scintillation events on the MCR are transferred through the ring channels and coupled fiber optics bundle to an external processor. From the magnetic field vector at a given point on the device wall, a certain relation can be set up between the α-induced scintillation position on the MCR and its original pitch angle. (i.e., the angle between the α emission from the fusion reaction and the magnetic field vector) which is equal to the local pitch angle since the wall α flux is dominated by prompt losses.[2]

The measured local prompt α distribution as a function of the pitch angle may be translated into a spatial intensity distribution function for an assumed or measured plasma current profile. The reconstruction process using a multiple detector array is quite similar to the system suggested by Makowitz[3] for neutron based plasma imaging. The advantage of the proposed device is its simplicity and the possibility, for use at lower burn rates (i.e. lower power levels). In addition, other parameters like local current profile and instabilities may be imaged by using an appropriate reconstruction process.

The design takes advantage of the α's curved trajectories so that the entrance slots are curved, preventing a straight path between the plasma view

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region and the detector. This is a key feature which prevents penetrating UV and X-ray photons from inducing excessive noise in the detector. Also the space between the slots reduces space charge effects and absorbs the neutral flux due to multiple collisions.

Further shielding of the detector against x-ray radiation from the plasma is carried out by placing at least 2.5 cm of high-Z material in any view angle of the detector. This will prevent photons with energy up to 400 keV from striking the detector. Above that energy the scintillation cross section of the ZnS is negligible. The neutron flux will be only slightly modified by the shield, thus first approximation values for the direct dose level can be gained by assuming it is the same as the neutron flux at the first wall.

An α/neutron flux ratio of $\sim 10^{-5}$ can be expected on the sensing element under normal conditions. Fortunately this flux ratio can be tolerated with the thin ZnS layer due to the low macroscopic cross section for neutron interaction. However, the secondary radiation combined with slow neutrons reflected from the blanket will induce an additional noise level. Consequently, additional shielding is used. The secondary charged-particle emission is significantly reduced by coating the inner shield with a carbon layer which stops the (n,p) protons created in the high-Z shielding. The carbon (n,p) cross section is small over most of the neutron spectrum while the resulting secondary α and C^{+6} emitted fluxes are negligible. The thermal component of the neutron spectrum is removed by coating the blanket side of the high-Z shield with a ^{10}B layer. This coating removes most of the slow neutrons from the transmitted/reflected flux. The neutron and photon shielding for the ZnS scintillator was analyzed by using the Monte Carlo code MCNP.[4] The intensity and energy spectra of the neutron and photon fluxes incident on the detector shield were calculated by modeling the entire torus, with the neutron source including both thermal plasma and beam-target contributions. This incident flux was then used as a source for second step calculations which compared the effectiveness of different shielding arrangements. The MCNP code does not transport the secondary charged particles, but their production rate in the carbon layer was calculated. Then the resulting contribution to the noise was estimated.

These calculations show that the Si activation and resulting β^- radiation at the worst position on the wall (midplane inboard) is tolerable. The Cherenkov radiation in the fiber optic bundle has also been approximated using data from Ref. 5. The use of ultra pure silica fibers and MCR could reduce the background level even further.

In conclusion this design appears to offer unique opportunities for wall detection of α's in a device operating with D-T fuel. Calculations indicate that the noise level created in the proposed detector scheme is acceptable.

References

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ALPHA-PARTICLES DETECTOR UNIT

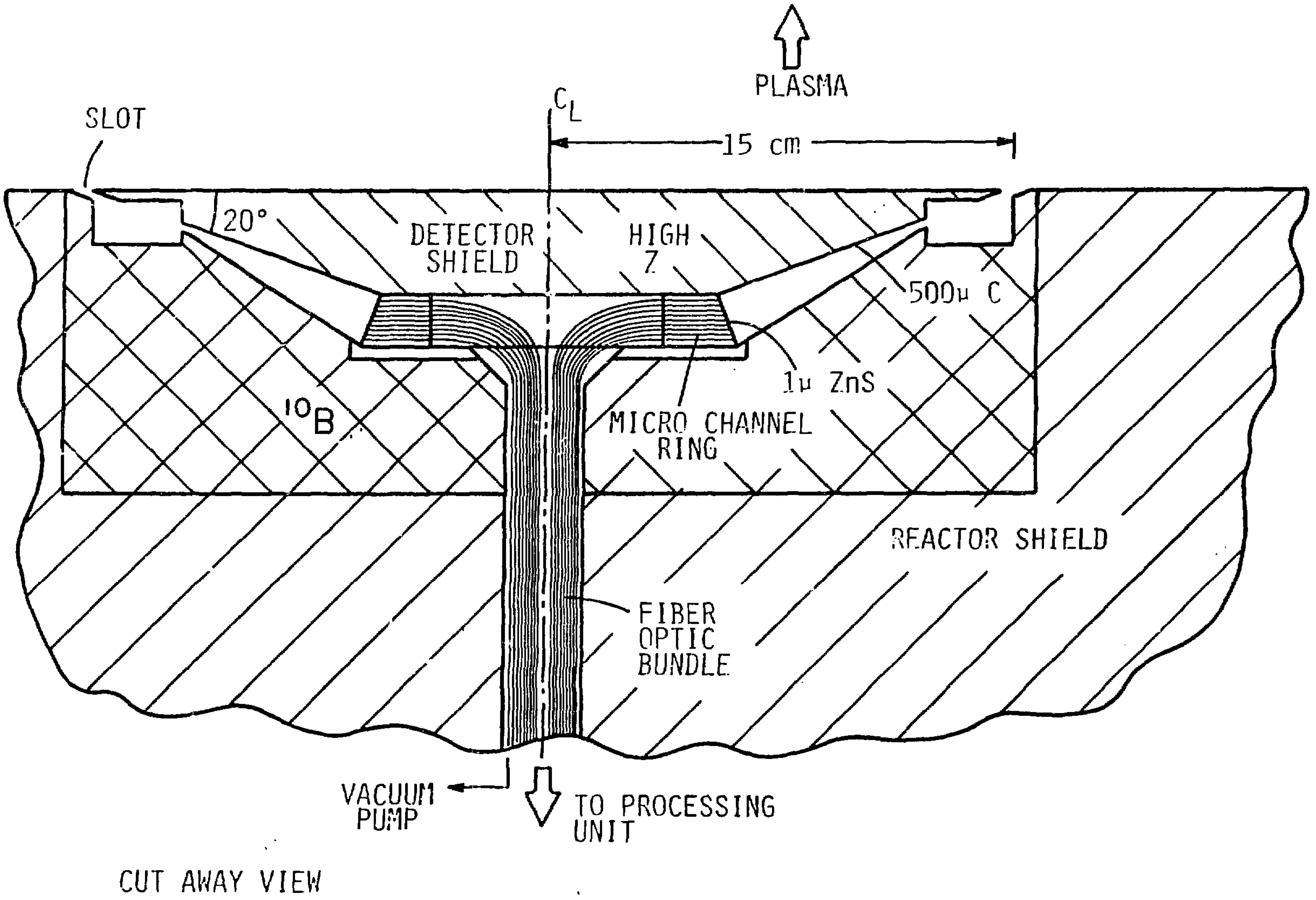

Figure 1.