*32nd EPS Conference on Plasma Phys. Tarragona, 27 June - 1 July 2005 ECA Vol.**29C**, P-1.091 (2005)*

VACUUM PHOTODIODE DETECTORS FOR SOFT X-RAY ITER PLASMA TPMOGRAPHY

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The plasma tomography that utilizes a thermal X-ray plasma emission yields important information on the magnetohydrodynamic (MHD) activity of plasma in different plasma column. In facilities similar to ITER a D-T reactions gives rise to intense gamma and neutron radiation which makes impossible utilizing conventional semiconductor, scintillation and gas detectors.

Vacuum Photodiode Detector (VPD) [1] was proposed to perform ITER plasma tomography and imaging using the plasma own thermal X-rays.

For the ITER facility we had to develop VPD with a high sensitivity to the quanta with energies less than 100 keV (thermal radiation) and a low sensitivity to the quanta with energies greater than 500 keV (γ-radiation).The principle of proposed VPD operation is based on the conversion of a photon flux into electron flow as a result of interaction with photocathode atoms. As rules, such electrons divided into two groups, namely slow (with an energies of <50 eV) and fast (>50eV) electrons. The portion of the fast electrons rises and that of the slow one decreases when the photon energy rises. So the X-ray photons will produce mainly slow electrons and gamma rays will produce mainly fast electrons. If two electrodes – a cathode and an anode – are simultaneously irradiated with a photon flux two electron fluxes are produced: one from the cathode to the anode, and the other from anode to cathode. If the efficiencies of the photon conversion into electrons at these electrodes are different, the current between the cathode and anode starts to flow even if there is no electric field between them. One should also keep in mind that slow electrons emerge from a near-surface layer 40 to 50 Å thick, while fast electrons emerge from a much greater depth. Taking into account this facts the following design for a simple VPD cell has been proposed (Fig.1). Anodes 2, 100 μm thick, are made of Be. Two Ta layers 150 Å thick are deposited on both sides of Be plate 100 μm thick and serve as cathodes 3. Ammeter 4 is connected between anodes and cathodes. To eliminate the effect of charge-exchanging particles flow and UV radiation, Be filter 1 is installed at the

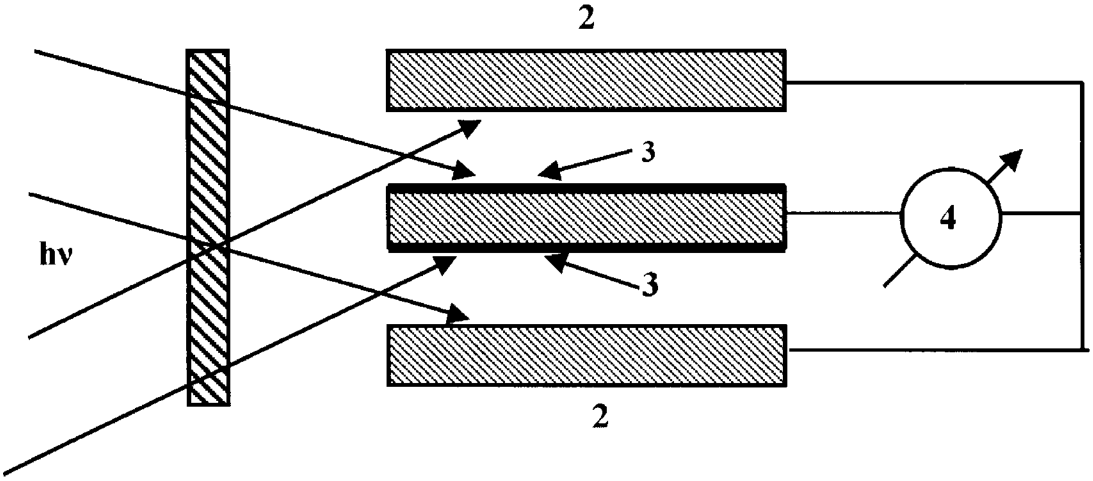

Fig.1.

VPD input. As the efficiencies of slow electron production by Ta and Be are different we obtain a current between cathode and anode. The fast electron fluxes from anodes and cathodes should compensate each other. Since γ-radiation generates mainly fast electrons, one can expect that the signal from the γ-radiation will be appreciably lower than any useful signal from the thermal X-rays. The operating device consists of 28 simple cells. The dimensions of the electrodes are 20x100 mm^2, and the distance between them is 1 mm.

The experimental testing of VPD was fulfilled with the help of the radiation from the Mo-anode X-ray tube (XT). Let us call the ratio of the electron amount produced in VPD to the photon amount incident on VPD as the effective sensitivity η_{eff}. As VPD has 28 cathodes, the effective sensitivity depends not only on the photon angle-of-incidence at every cathode but also on the amount of cathodes crossed by a photon. As the Be electrodes thickness is 100 μm, the plasma thermal radiation photons can cross several electrodes thus raising the effectiveness of electron production. In Fig.2 the dependence of the η_{eff} on XT anode voltage U is presented. In this figure the points mark the experiment values of η_{eff}. During VPD effective sensitivity measurements XT radiation illuminates the whole VPD entrance.

One can see that when U rise, first, the effective sensitivity rises due to the rise in the amount of cathode with photons interact, but then it starts to fall because when U becomes greater than 20 keV the electrode system becomes transparent to photons and the energy dependence of sensitivity starts to play part. From Fig.2 one can see that for estimations it is possible to use $\eta_{\text{eff}} = 0.28$ (line in Fig.2).

In the further experiments we used the photon flux with the angle divergence equal to about 2^0 with the XT anode voltage U=30 kV. In this situation the electrode system is transparent to radiation.

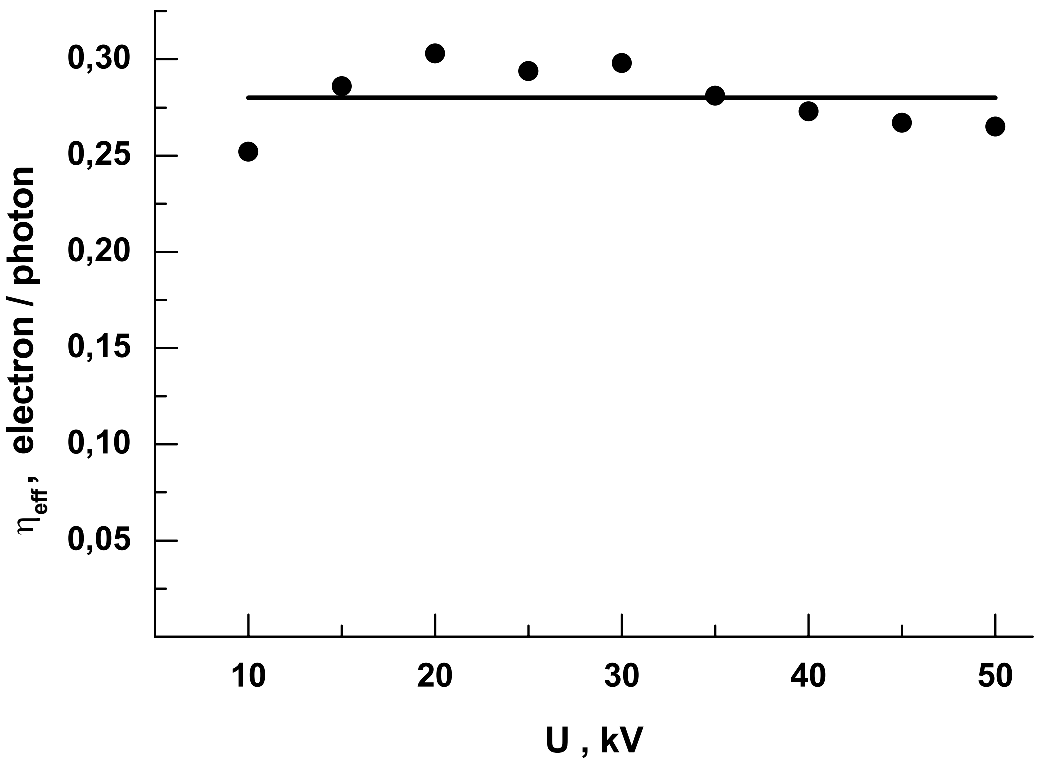

Fig.2.

The dependence of VPD effective sensitivity on the angle-of-incidence α_t is given in Fig.3. In this figure 1 marks the experimental data. When α_t varies from 0 up to $\pm\alpha_{\max}$ η_{eff} should remain constant because quantum yield is proportional to $1/\sin\alpha_t$ and amount of cathodes which photon crosses is proportional to $\sin\alpha_t$. When α_t becomes greater than $\pm\alpha_{\max}$ the η_{eff} mast change as $1/\sin\alpha_t$ (line 2).

Taking into account the data obtained one can estimate the signal value expected in ITER. If the plasma electron temperature is equal to 20 keV, the plasma density is equal to $1x10^{20}$ m^{-3}, the poloidal accept angle 2^0, the toroidal accept angle $\pm 20^0$ the useful signal could be about 10 μA.

The main problems which arise when using VPD in ITER are connected with background signals due to gamma and neutron radiation. The VPD tests were fulfilled with help of gamma radiation from ^{60}Co source. This source radiates two groups of gamma quanta of similar intensity, quantum energy being 1.17 and 1.35 MeV. During these experiments it was shown that effective VPD sensitivity to gamma-radiation is $n_\gamma = 7 \cdot 10^{-5}$ electrons/quanta.cm^2. Under ITER conditions the value of a background signal due to gamma radiation will not surpass 1% of a thermal radiation induced signal.

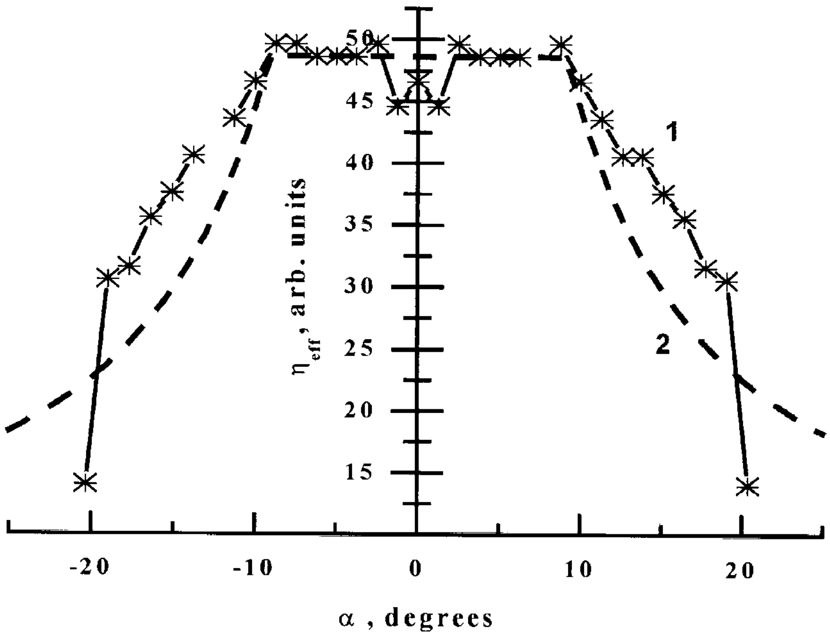

Fig.3

As to neutron radiation, it is known that the amount of electrons knocked out by neutrons is two or three orders of magnitude less than that of electrons knocked out by gamma radiation of the same energies [2].

1. .Barykov I.A., Gott Yu.V., and Stepanenko M.M., Instruments and Experimental Techniques, **No.2**, 242 (2004).
2. Kulakov G.V,.Malyshev E.K, and Schetinin O.I. *Vacuum detectors of radiation*. (Eneroatomizdat. Moscow. 1982).