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Electron Temperature Measurements by Duplex Multiwire Proportional X-ray Detector on T-10 Tokamak.

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INTRODUCTION

Multiwire proportional chambers have been developed at CERN in 1968 by Charpak at al.[1] and have later been widely used in high-energy physics experiments for particle track measurements. The compact multiwire chambers with a similar construction were used on T-10 and TCV tokamaks for fast multichord soft X-ray emissivity measurement [2]. In this case the multiwire chambers were used as continuous-current X-ray detectors producing a continuous output current proportional to the incident x-ray intensity.

The duplex multiwire proportional X-ray (DMPX) detector is a new generation of the compact multiwire X-ray detectors. It uses the gaseous chamber feature of relative transparency for the higher energy X-ray photons. This allows to combine in series two multiwire chambers and to provide simultaneous measurements of the plasma X-ray emission in two spectral ranges using the first multiwire chamber as an absorber filter for the second one. The signal of the first multiwire chamber is suitable for measurement of fast and localized phenomena and can be used for the observation of magnetohydrodynamic activity, for characterisation of transport barriers or for determination of the electron cyclotron heating (ECH) power deposition profile [2]. The signal of the second multiwire chamber allows us in addition to provide fast multichord measurements of the plasma core electron temperature by the X-ray absorber foil method [3].

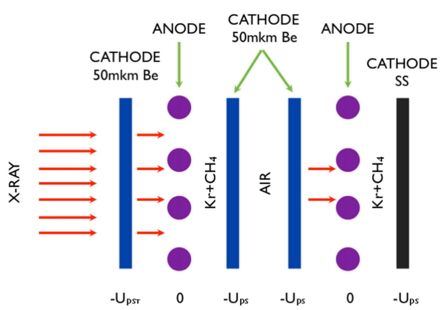

Fig.1 Schematic illustration of the DMPX detector

DUPLEX MULTIWIRE PROPORTIONAL X-RAY DETECTOR

The DMPX detector consists of two identical multiwire chambers which are similar to multiwire proportional chamber of the MPX detector (characteristics and principle of the MPX detector operation was described in [2]). Each multiwire chamber consists of parallel anode wires placed in a plane between two cathode plates (Fig.1).

The anode plane has 64 independent sensitive wires of 50μm diameter, made of gold-plated tungsten. Anode wires have sensitive length of 32mm and are stretched with a separation of 2mm. The distances between the cathode and anode planes are 4mm. Both cathodes of the first chamber are made of a 50μm beryllium foil and serves also as X-ray windows. The first cathode of the second chamber is also made of a 50μm beryllium foil; the second cathode is made of a stainless still. The multiwire chambers are filled at atmospheric pressure with 90%Kr+10%CH4 mixture. Both chambers are arranged in series in common aluminum case with the air-gap between chambers of 10mm.

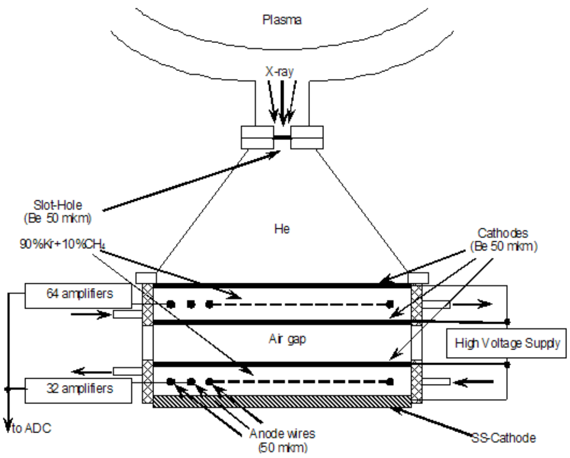

Fig.2 The implementation of the DMPX diagnostic on T-10 tokamak

IMPLEMENTATION ON THE T-10 AND DIAGNOSTIC DESIGN

The implementation of the DMPX diagnostic on the T-10 tokamak is shown in the schematic illustration of Fig.2. It consists of a vertically mounted pinhole camera and the DMPX detector mounted at the bottom end of the camera. The pinhole camera has a rectangular slit of dimensions 2x18mm^2. The slit is sealed by beryllium foil of 50μm which separate the vacuum vessel from the helium-filled camera. Beryllium cathodes of multiwire chambers separate sensitive volumes of the detector from the pinhole camera and atmosphere. The camera is filled at atmospheric pressure with helium. Thus the first multiwire chamber of the DMPX detector views the plasma through two beryllium foils 100μm overall thickness and the second multiwire chamber views the plasma through four beryllium foils 200μm overall thickness, 8 mm of 90%Kr+10%CH4 and 10mm of air. Therefore the first multiwire chamber (with air-gap and beryllium cathode of the second one) is an absorber filter for the second chamber.

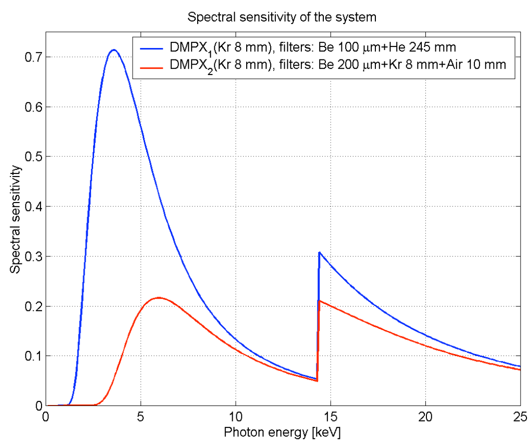

Fig.3 The DMPX detector efficiency versus photon energy

The efficiency of the detector, i.e. the probability to absorb a photon in the detection gas, depends on the incident X-ray photon energy, on the transmission of the input windows, on the gas layer thickness and on the composition of the gas mixture. The result of calculations of the diagnostic efficiency versus photon energy is shown in Fig. 3.

USING THE X-RAY ABSORBER FOIL METHOD FOR THE ELECTRON TEMPERATURE MEASUREMENT

Described construction of the DMPX detector allows us to provide measurement of the plasma core electron temperature profile by the X-ray absorber foil method. The local X-ray emissivity and the spectral composition of the radiation are determined by the electron temperature, the electron density, the impurity concentrations, and the charge state distributions of the impurities. The DMPX detector signal is proportional to the total X-ray emission power multiplied by chamber's absorption coefficient, integrated over photon energy and along the detector line of sight.

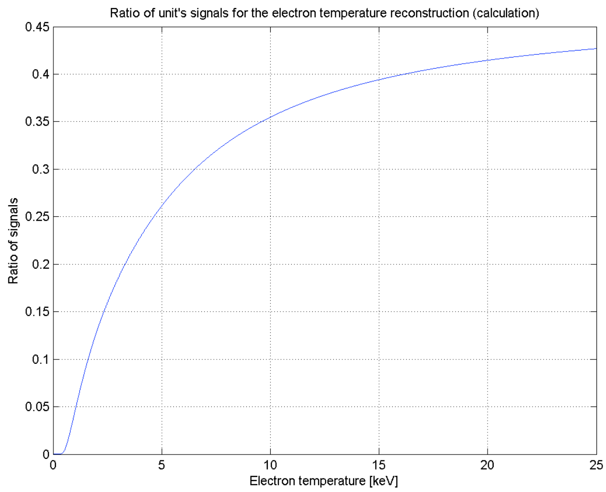

Fig.4 The ratio of DMPX signals as a function of T_e

The photon absorption of the first multiwire chamber differs from the second one. Therefore the ratio of chamber signals is a function of electron temperature only. Fig. 4 shows the calculated ratio of detector signals as electron temperature. From this graph the T_e can be reconstructed. For correct T_e reconstruction the local intensity of total X-ray emission needs. Thus we used one of Abel inversion algorithm for the X-ray local intensity calculation. The local intensity reconstruction was more detailed described in [4].

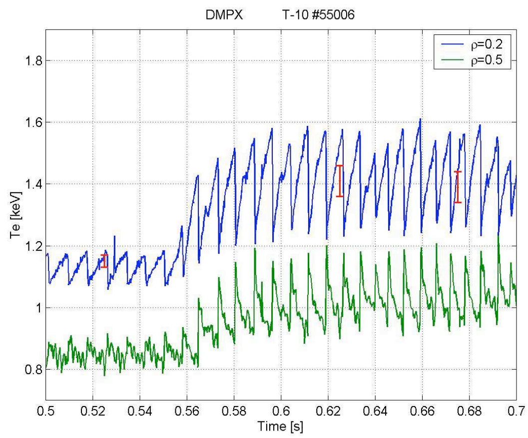

Fig.5 The T_e time traces calculated from DMPX signals

The Fig. 5 shows example of the T_e time traces calculated from the DMPX signals in the shot with on-axis ECH 0.5MW. The rise of T_e is also seen in the data of X-ray pulseheight analysis (PHA) diagnostic (red points on Fig.5). In observed shots T_e calculated from the DMPX signal was in good fit with the T_e measured by PHA system due to weak impurity K-lines radiation. The X-ray radiation spectrum for this shot measured by PHA diagnostic is shown in Fig. 6. Strong impurity lines radiation can affect the results and should be taken into account in calculations.

SUMMARY

A duplex multiwire proportional X-ray detector has been implemented on T-10 tokamak for the fast multichord soft X-ray emission measurement. Two multiwire chambers mounted in series view the plasma through the same rectangular aperture providing simultaneous measuring of the plasma X-ray emissivity in two spectral ranges (the first multiwire chamber serves as an absorber filter for the second one). The system permits in addition to soft X-ray measurements with the spatial resolution of about 1cm to provide measurement of the plasma core electron temperature profile with the spatial resolution of about 2cm and time resolution of less than 50μs.

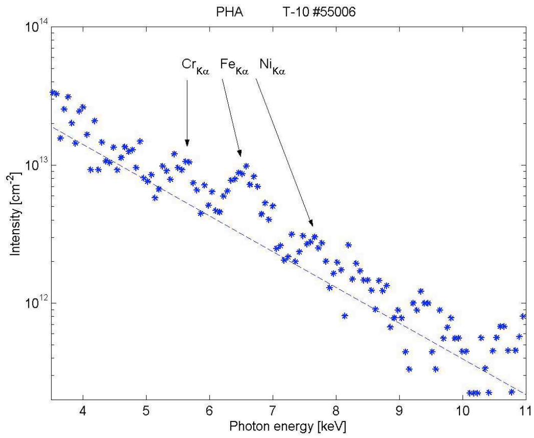

Fig.6 Typical X-ray radiation spectrum from T-10 plasma measured by the PHA diagnostic

The diagnostic allows improved spatial resolution of the T_e measurements and gives possibility to study fast T_e profile evolution during ECH and ECCD experiments in the vicinity of the electron cyclotron resonance previously inaccessible to researches.

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