Concept of pulse height analysis system (PHA) for Wendelstein 7-X

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Abstract. A new pulse height analysis (PHA) system is currently under design for Wendelstein 7-X (W7-X) stellarator for long pulse operation. The proposed diagnostic is intended to provide the spectral energy distribution with energy resolution better than 180 eV along a central line of sight. The system consisting of 3 single Silicon Drift Detectors (SDDs) operated with different filters will be installed on the horizontal port AEK50 on W7-X. Each detector will record an X-ray spectrum in three different energy ranges from 400 eV to 20 keV. In designing the PHA system for W7-X a specially developed numerical code, RayX, was used. The code allows to investigate the influence of a geometrical configuration of the diagnostic systems on the spectral intensity and shape. Moreover, it is used to calculate the detectable radiation from plasmas for different pinhole sizes, types of detectors, filter-materials and thicknesses, and simulates emission from different discharges characterised by widely varied electron temperature and density profiles. The results of the simulations allowed to develop the optimal diagnostic systems and decide on a first layout of a mechanical design.

1. Introduction

The investigation of the X-ray emission from fusion plasmas has become a standard diagnostic tool used on many different fusion experiments [1]. The measurements of X-ray intensities by using Si–detectors, which are sensitive to the total radiation above a threshold energy determined by thin absorber foils in front of the diodes, yield an excellent spatial and temporal resolution. The determination of the X-ray energy spectrum using pulse height analysis (PHA) systems requires sufficiently long acquisition times resulting in a poor temporal resolution. However, this method is particularly suited for long pulse operation envisaged for W7–X.

The combination of spectral data obtained along a single line of sight with broadband radial X-ray intensity profiles will provide a sufficiently good characterization of the impurity radiation in the plasma core. The measurements yield impurity survey spectra in the X-ray region above 0.5 keV allowing to identify the line radiation from all relevant impurities (with exception of elements lighter than nitrogen) and to determine their concentration in the hot plasma core. The slope of the hydrogen and low-Z continuum radiation is used to determine the central electron temperature. The intensity of the continuum radiation along with additional spectroscopic data allows to assess Z_{eff} values in the plasma center.

Computer simulations of soft X-ray emission for typical W7-X plasmas played an important role in designing of the diagnostic systems. As a tool for checking the performance of the PHA spectrometry system and optimizing filters and detectors, a special numerical code, named RayX [2] has been developed. A large number of simulations have been performed, the results of which allowed to decide on the positioning of the diagnostic components.

2. Concept of the PHA system for W7-X

The superconducting stellarator W7-X will operate with plasma discharges of up to 30 min duration at full heating power. Electron Cyclotron Resonance Heating (ECRH) is one of the main heating method for steady-state operation of the Wendelstein 7-X stellarator [3]. A heating power of 10 MW is required to meet the envisaged plasma parameters. A wide spectrum of requirements has to be considered during design and realization of the new X-ray diagnostics. Different ECRH heating scenarios, characterised by widely different electron temperature and density profiles have been taken into account. Figure 1 shows examples of electron density and temperature profiles for 8 MW of ECRH power, used as input data for simulations. The code allows to investigate the influence of a geometrical configuration of the diagnostic systems on the spectral intensity and shape. It also calculates the detectable radiation from plasmas for different pinhole sizes, types of detectors, filter materials and thicknesses.

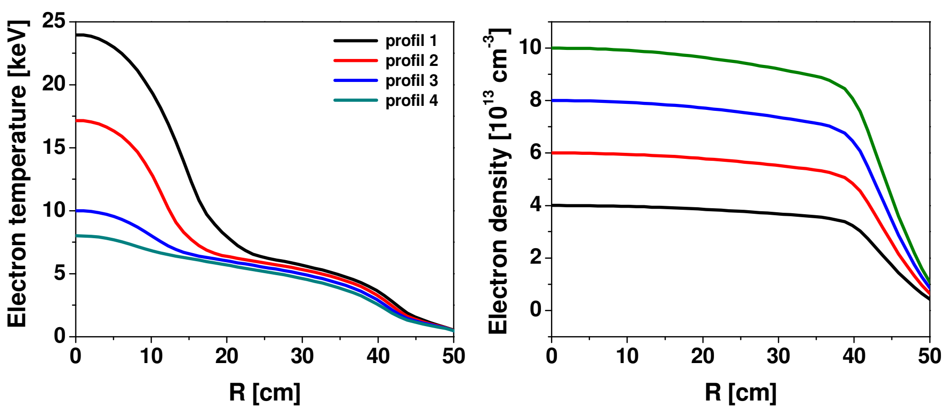

Fig.1. Electron density and temperature profiles for 8 MW of ECRH scenario with a=0.51 m, R=5.53 m, B=2.5 T

foreseen for W7-X, used in RayX simulations [4].

These simulations and the consideration of restrictions by the magnetic field effect on the individual elements of the system (e.g. turbomolecular pump) showed that the changeable slits must be placed at a distance of 6.5 m from the plasma center and the detectors 1 m behind the slits. A preliminary mechanical design of the PHA system is presented in figure 2. Details of the chamber (box) which contains three sets of movable slits with piezo drives and pinholes, and three interchangeable filter systems with a vacuum manipulator is presented in figure 2b. To collimate the plasma radiation and cut off ECRH stray radiation a plate with three fixed holes has been located in front of the chamber.

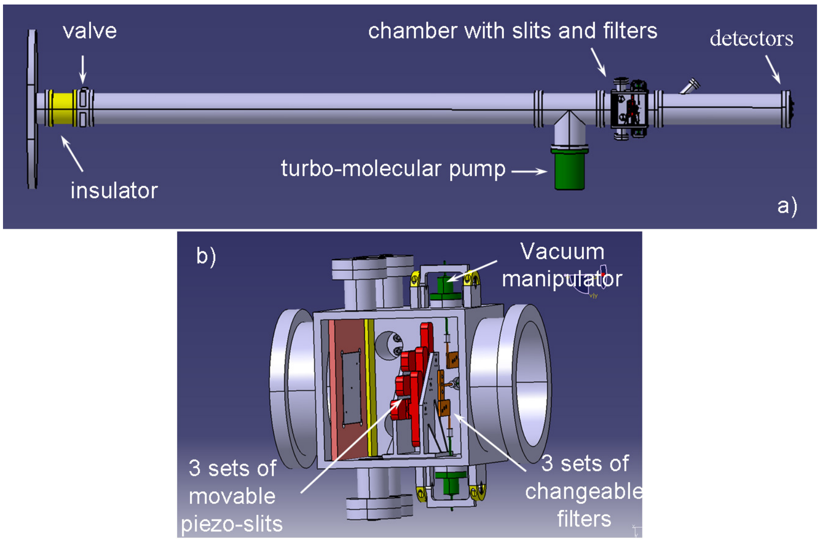

Fig. 2. Conceptual design of the PHA diagnostic system for W7-X a) diagnostic components connected to the W7-X port on the left side b) details of the chamber containing three sets of movable slits with piezo drives and pinholes, and three interchangeable filter systems.

The proposed PHA diagnostic is intended to provide the spectral energy distribution with energy resolution not worse than 180 eV along a central line of sight. The system will consist of 3 single Silicon Drift Detectors (SDD) each measuring along sightlines through the center of the plasma at the horizontal port AEK50 at W7-X. Each detector can be supplied with 3 changeable filters and is, therefore, able to record an X-ray spectrum in three different energy ranges (energy channels) from 400 eV to 20 keV. This will allow to enhance the sensitivity for particular impurity species and for the investigation of suprathermal tails in the spectra. In the standard configuration, the first channel will be equipped with a SD3 detector (from PNDetector GmbH) containing a polymer window and aluminum light protection, to cover the energy range between 250 eV-20 keV. The second and third channel will be equipped with standard SDD detector with 8μm thick Be windows, however for the third channel an additional thick filter will be used. This will allow to record spectra in the range of 1-20 keV and 7-20 keV, respectively. This fact is presented in figure 3.

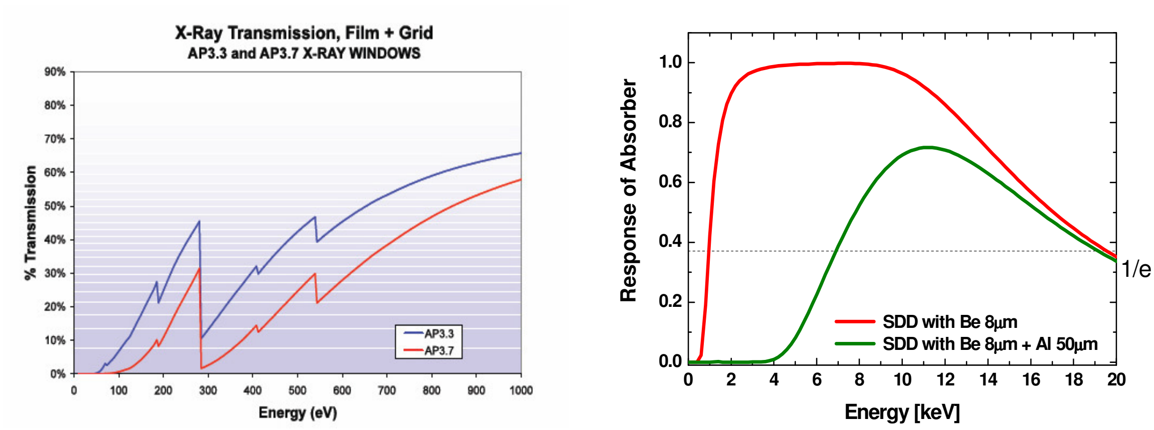

Fig.3. Proposed energy range for the first (left) (from PNDetector GmbH), second (right, red line) and third (right, green line) channel in the PHA system for W7-X.

All detectors will be accompanied by an individual control of pinholes size.

3. Conclusion

A number of computer simulations have been made to obtain a conceptual design of PHA diagnostics foreseen for the Wendelstein 7-X stellarator. The system will consist on 3 Silicon Drift Detectors (SDDs) covering different ranges of spectrum, all viewing the central plasma. The measurements will be taken along sightlines through the center of the plasma.

Acknowledgment

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