*34th EPS Conference on Plasma Phys. Warsaw, 2 - 6 July 2007 ECA Vol.**31F**, P-5.111 (2007)*

# The Bolometry Concept for the W7-X Stellarator

D. Zhang, L. Giannone, B. Klein and the W7-X-Team

*Max-Planck-Institut für Plasmaphysik, EURATOM Association, Wendelsteinstr. 1,*

*17491 Greifswald, Germany*

## I. Introduction

In view of the intrinsic three-dimensionality of W7-X[1], a multi-camera bolometer system is planned to diagnose the radiation loss distribution. The whole system consists of three subsystems - a bulk bolometer, a divertor bolometer and a supplementary one for providing additional information on 3D effects. According to their respective functions, they are located at appropriate poloidal and toroidal positions from a triangular to a bean-shaped plane, covering almost one half of a field period (see Fig.1).

The three subsystems will be stepwise installed on the machine, following a sequence according to the expected plasma-scenarios along with the experimental programs. At the first step, two bolometer cameras will be installed on the triangular plane to measure the bulk plasma radiation of relatively-low density plasmas in the start-up phase. The two cameras are already being under construction. The other two subsystems will be integrated later when the machine is ready for high density plasma operations. The realization of the bolometer system is complicated by the limited space in the available ports between non-planar coils. To handle a continuous thermal load of ~50kW/m$^2$ during steady state operation[2] presents an additional difficulty. Besides physics aspects, the paper presents and discusses also appropriate solutions to the technical problems.

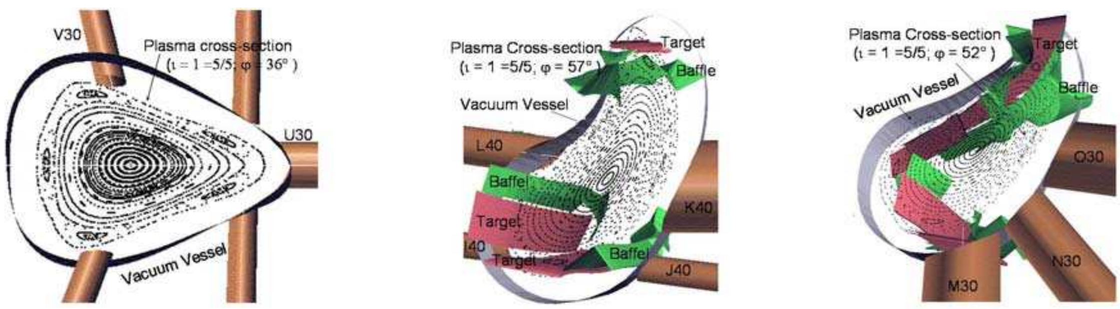


Fig.1: Locations of the bulk- , divertor- and the supplementary bolometer and the faced plasma cross-sections.

## II. Basic Concept of a Single Camera

The essential part of the applied bolometer camera is an array of four-channel miniaturized gold resistive-type detectors[3], viewing the plasma through a slit aperture. The detectors are uniformly arranged on a section of a circle centred by the slit for maximum flux reception.

The absorber of the detectors is made of a 4µm-Au-foil coated on a Kapton substrate. The sensitivity and absorbability of the 4µm-Au-absorber has been studied at the W7-X plasma conditions using the IONEQ impurity radiation code[4]. For most plasmas conditions of interest, the signal-noise ratio is larger than $10^3$ for a camera etendue around $10^{-4}$ $cm^2sr$. In addition, increasing the thickness of the Au-foil improves the absorbability only by 5% even for high temperature plasmas.

A secondary detector array is planned to be integrated to the camera later, located symmetrically around the slit axis with respect to the main detector array (see the insert of Fig.2 left). Different detectors can be chosen to form the secondary array, depending on topics of interest. For example, detectors using a Be-foil as an optic filter allow detection of high energetic photons, thus providing additional information on heavy impurity concentration in the plasma centre. Alternatively, blind channels can be used for eliminating offsets and drifts.

III. Bulk Plasma Bolometer

The subsystem consists of five cameras which are placed on a triangular plane, housed respectively in the five ports as shown in the left picture of Fig.1. At a first step, two of them are installed in the equatorial port U30 and the upper one V30, forming a basis of the bulk bolometer subsystem. They view the plasma horizontally and vertically with 32 and 40 lines of sight, respectively, covering the whole cross-section (see Fig.2 left and mid).The 32 sight-

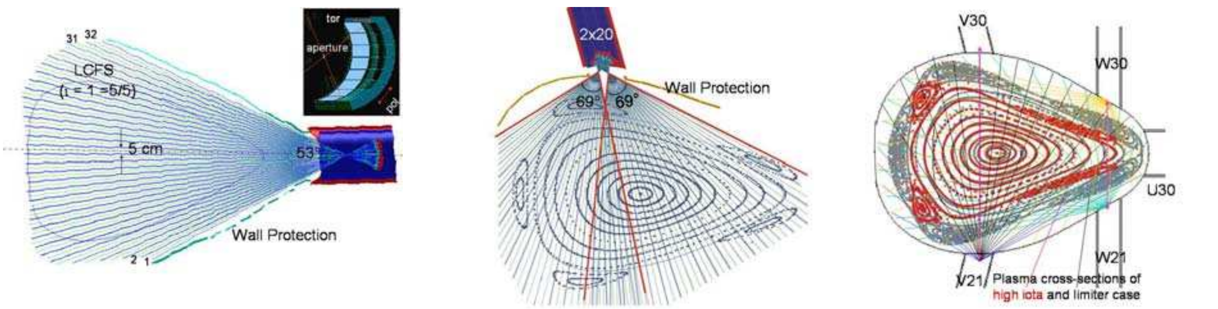


Fig.2: The 32-channel horizontal bolometer (U30, left) and the 40-channel two-aperture vertical bolometer (V30, mid) for monitoring the bulk plasma radiation. The insert of the left picture shows the paired detector array. The right part shows the proposed sightlines for a later step.

lines of the U30 camera are oriented up/down symmetrically and thus provide additional information about the plasma symmetry and possible vertical shifts of the plasma axis. The V30 camera has a much larger view angle range than the former because of the horizontally-elongated plasma shape. To realize the required large view range, the V30 camera is specially constructed by integrating two sub cameras with 20 channels each. They are optically shielded from each other, viewing different plasma regions through their individual slits (see Fig.2 mid). In order to avoid a smear-out effect, the toroidal view ranges of the cameras are restricted to ~±10 cm. Within this range, the corresponding changes in configuration cross-section are smaller than the spatial resolution of the cameras (~5 cm).

The cameras are designed to withstand a continuous heat flux of about $50kW/m^2$ on average during steady state operation. This high power load on the camera head will be removed by an active water cooling system. Additional graphite tiles clamped on water cooled CuCrZr structure will be used to shield the head of the V30 camera from charged particles. In order to minimize thermal drifts, the detector holder has to be cooled. Temperatures will be monitored using Pt100 resistor thermometers.

During a long pulse discharge, it is desirable to measure the offset or to perform in-situ calibrations[5]. For this, a shutter system is planned, with the detailed design being started soon. Another function of the shutter is to protect the detectors from contamination during wall-conditioning.

Owing to the unique fan-like sightlines of the U30 camera covering the whole cross-section, the total radiated power $P_{rad}$ can be derived by linearly extrapolating the bolometer signals from the viewed range to the whole torus, assuming that the radiation intensity distribution is a pure function of flux surfaces[6,7]. Under this assumption, a 1D radiation profile is also available from each of the two cameras. Their combination is even capable of reconstructing 2D tomography, with however poor spatial resolution. At present, different inversion methods[8-10] are being examined for this purpose. A significant improvement in spatial resolution is expected after adding another three cameras. The proposed lines of sight are shown in Fig.2 (right).

II. Divertor Plasma Bolometer

This subsystem contains 6 cameras surrounding a bean-shaped plane where a divertor module pair resides. The main task of this system is to diagnose impurity radiation in divertor-relevant plasmas, i.e. under high-density, low-temperature conditions. A horizontal camera with 40 sightlines covering the whole plasma cross-section measures the total radiation. Two vertical cameras on the low-field side, like the V30 camera in the triangular plane, provide additional information for 2D tomographic reconstruction. The three low-field side cameras aim at providing a global, crude picture of the radiation distribution. More detailed localization of divertor radiation is resolved through combination with three additional cameras installed at the high-field side. Two of them share a common port, viewing respectively the upper and lower divertor regions. The third one will be placed in a port close to the lower target in order to improve the spatial resolution in the divertor region. With a ~2cm resolution around the X-point, this camera set is designed to detect strongly-localized radiation expected under detachment conditions.

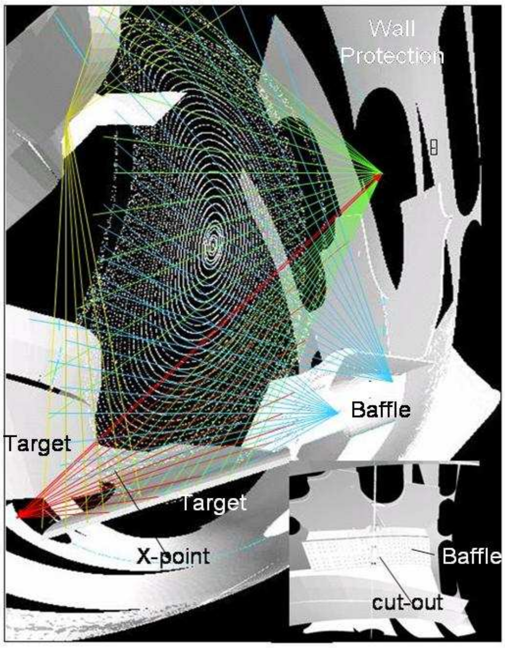


Fig.3: Overview of the sightlines of the divertor plasma bolometer. The insert indicates the cut-out in the divertor structure

Unlike the camera system at the triangular plane, the divertor cameras are exposed to the recycling neutral gas. The contributions of the neutral gas to the bolometer signals for individual cameras can be estimated using EMC3/EIRENE code[11]. Possible technical solutions are also being under consideration, for example, installing oppositely-faced channel pairs[12], as indicated by the thick red line in Fig.3.

III. Additional Bolometers

For examining 3D effects in the radiation distribution, three additional cameras will be arranged toroidally between the bulk bolometer and the divertor bolometer. Preliminary plans are: 1) A camera with similar geometry as U30, having fan-like sightlines covering the whole cross-section, to compare $P_{rad}$ based on the line-averaged intensity. 2) A wide-angle gold-foil resistive bolometer camera and 3) the infrared imaging bolometer developed and used on LHD[13].

Reference:

[1] H. Renner et al., Nucl. Fusion 40 (2000), p.1083-1093
[2] H.J. Hartfuss, R. König, A. Werner, Plasma Physics and Contr. Fusion, 48 (10), R83 (2006)
[3] K.F. Mast et al., Rev. Sci. Instrum. 62, 744 (1991).
[4] A. Weller et al., Report JET-IR-(87)10,1987
[5] L. Giannone et al., Rev. Sci. Instrum. 73, 3205 (2002).
[6] D.Zhang et al., PLASMA 2005, Opole, Poland 2005, AIP Conf. Proc. 812, NY(2006)
[7] L.C. Ingesson, Report JET-R (99) 06
[8] J.C. Fuchs et al., Proc. of the 21st EPS Conf. on Plasma Physics and Contr. Fusion, Vol 18B, Part III, P.1308-1311
[9] L. Giannone et al., Rev. Sci. Instrum. 68(1), p.762 (1997)
[10] K. Ertl et al., Nucl. Fusion, Vol. 36, No.11, p.1477 (1996)
[11] Y.Feng, Sardei F, Kisslinger J, J. Nucl. Mater. 266, p.812-818 (1999)
[12] L.C. Ingesson et al, Proc. of the 24th EPS Conf. on Plasma Physics and Contr. Fusion, 21A, Part I, P.113-116 (1997)
[13] B.J. Peterson, Rev. Sci. Instrum. 71, 3696 (2000)