Technical development for measurement of the plasma radiation on the EAST tokamak

*L.Q. HU, on behalf of EAST diagnostic team and collaborators**

Institute of Plasma Physics, Chinese Academy of Science, P.O. Box 1126, 230031, China

Introduction: As EAST (Experimental Advanced Superconducting Tokamak) device operated successfully with long pulse over 1 minute and at the plasma current of 0.9MA sustained by 1.2MW low hybrid wave (LHW) [1], it is required that diagnostics and internal components must be accommodated to working circumstance of continuous operation mode, high baking temperature of the first wall during the wall conditioning, harsh electromagnetic field and strong radiation from hard x-ray, γ-ray and even neutron, etc. However, long port of superconducting machine causes very poor accessibility to the plasma and forces some diagnostics have to be installed inside the port of the vacuum vessel so as to approach full poloidal view. It is needed further that those diagnostics have to be equipped with active water cooling to avoid damage during baking phase, and make efforts to decrease the bombardment from escaped particles. Such typical system is that of plasma radiation measurement. Herein, some techniques employed in the EAST are introduced, such as port plug structure with soft-x ray and AXUV diagnostics down viewing plasma through 3.5m long port and equipped with the de-ion cooling water system. In the meanwhile, R&D on ITER radial soft x-ray camera is also in study. Preliminary work on thin beryllium foil sealing, in-vessel preamplifier and detector selection are presented briefly as well.

Spectroscopic diagnostics on EAST: Measurement of energy loss caused by radiation of high temperature plasma produced during collisions between electrons and ions through the processes of bremsstrahlung radiation, recombination radiation, line radiation and cyclotron radiation, is an essential and standard way in the study of magnetically confinement plasmas, from which many plasma parameters can be got and the effects of impurities on plasma behavior can be determined. EAST device is aimed to achieve steady-state high-performance plasma sustained by intensive use of radio frequency heating and current drive, and to study relevant physics and technology [2]. Therefore, it is required that EAST diagnostics must be accommodated to working circumstance of the long-pulse discharge, high baking temperature of the first wall, different and frequent wall conditioning, harsh electromagnetic field and strong radiation from hard x-ray, γ-ray and even neutron, etc. In addition, long port length of the EAST tokamak machine due to its structure of full superconducting coils both in toroidal and poloidal magnetic field causes diagnostics poor accessibility to the plasma. Directly full poloidal view of the D-shaped plasma is very difficult even located in and viewed from the horizontal port, while vertical view to plasma is just of narrow angle of view because of 3.5m depth of the vertical port. And, those in-vessel systems have to suffer high surrounding wall temperature (usually 200-250°C at the case of the SiC doped graphite tile using as the first wall material) and sharp variation of the wall potential during the discharge. As a solution, the first mirror on the port wall is employed to collect light and help passive spectroscopic diagnostics enhance capability of covering divertor region and increase sightlines. To avoid coating during wall conditioning, protection shutter is also equipped, which is controlled manually at the present and will be upgraded to be controlled pneumatically.

To measure distributions of Ha/Da line radiation to study performance of the edge and divertor plasma, particle recycling and edge particle confinement, and investigate features of the EAST ELMy H mode, a photodiode linear array (PDA) with 35 channels and a Ha/Da filter is adopted together with the first mirror technique, as illustrated in Fig. 1. Two cameras inside the horizontal port view the upper and lower divertor regions reflectingly through the mirror and another one views down the outer lower divertor region and part of outer baffle through the vertical port. To study total spectrum and the behavior of impurities in core, edge and divertor regions, and wall conditioning effects, two OSMA (optical spectroscopy multi-channel analysis) spectrometers working in a wavelength range of 200 nm to 1000 nm employ the mirror in the same way by use of fiber bundle, as shown in Fig. 2, in which fine spatial resolution in two spectrometers is achieved with fifteen channels and eight channels for lower edge plasma, respectively [3]. Many spectroscopic diagnostics in the airside view plasma directly, shown in Fig. 1 and Fig.2, such as five UV-VIS monochromaters for light impurity of CIII, OII, LiI, BI and SiI, 8-channel visible bremsstrahlung array using photomultiplier for effective charge number, PDA cameras for CIII and ECE radiometer etc. Some spectroscopic diagnostics like soft x-ray camera for MHD activity, AXUV camera for power loss and balance, soft x-ray PHA array for spectrum of heavy metal impurity are required close to plasma by inserting into the port of the vacuum vessel as to get clear signal and more angle of view, while their supporting structures are connected to the window flange of the tokamak and confine accessible temperature of the detector cassette even in the baking state of the vessel due to heat conduction. But for those spectroscopic diagnostics located in the vertical port, port plug structure must be applied, as shown in Fig.3 and Fig.4, in which cameras are inside copper house 3.5m deep below the vacuum flange and cooled with active de-ion water to keep electrical isolation from the tokamak port, and maintain the detector at acceptable working temperature less than 60°C even while the surrounding port wall is baked up to 250°C. Metal bolometer array diagnostic is another example, which will present in this meeting (P1.055) as well.

R&D of ITER radial soft x-ray camera: Since ITER radial x-ray camera must be in the separately secondary vacuum system sealing with thin Beryllium foil, some preliminary R&D work on sealing technique with mechanically pressured method is tested, in which the structure of two opposite stainless-steel knifes and Beryllium foil in between is used to realize vacuum sealing by turning tight manually. So far, 60μm Beryllium foil with a diameter of 30mm successes to reach vacuum sealing with a leakage of 10^{-10} Pa.m^3/s, further trials for higher finished product and test for reliability, lifetime and durability such as withstanding vibration are on-going. To help detector selection, calibrations using stable optical light source with a luminance up to 10^4 cd/m^2 are tried as well. The results suggest that a more precise positioning mechanism to overcome the inhomogeneity of the standard luminance and usage of Pyroelectric x-ray generator for higher energy are necessary, which will be implemented soon as to improve calibration methodology.

Acknowledgments: The author would like to thanks all members of EAST diagnostic group, all attendee from domestic and international facilities for their contributions to EAST project. This work is undertaken partially under the support of Chinese Nature Science Funds by Grant

No.10935004 and National Magnetic Confinement Fusion Science Program by Grant No. 2008GB109003.

References: [1] J.P. Qian, X.Z. Gong, et al, Plasma Science and Technology, Vol.13, No.1, p.1, 2011.

[2] B.N. Wan, etc., 23rd IAEA Fusion Energy Conference, OV1-2, October 11-16, 2010, Daejeon, Republic of Korea.

[3] Liqun Hu, etc., Plasma Science and Technology, Vol.13, No.1, p.125, 2011.

*Domestic and international collaborators for the EAST: Donghua Univ., South West Institute of Physics, USTC, Tsinghua Univ., Peking Univ.; General Atomic, FRC Austin, PPPL, Tri Alpha Energy in USA; NIFS and JAEA in Japan; Association Euratom-CEA in France, NFRI and KBSI in Korea, etc.

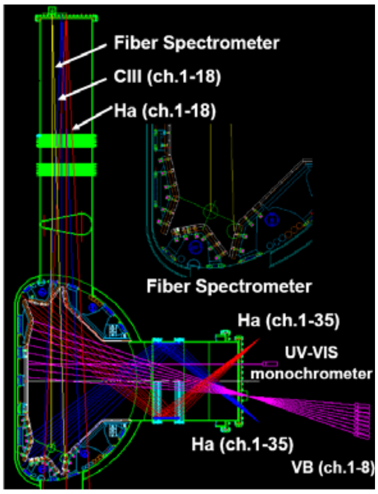

Fig.1 Arrangement of Spectroscopic diagnostics

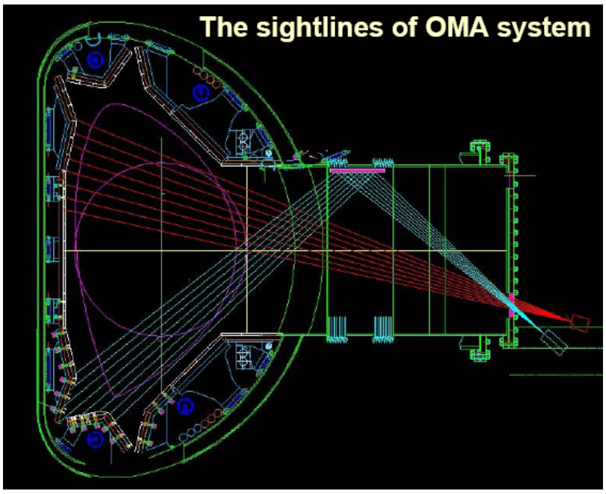

Fig.2 The sightline of the OSMA spectrometer

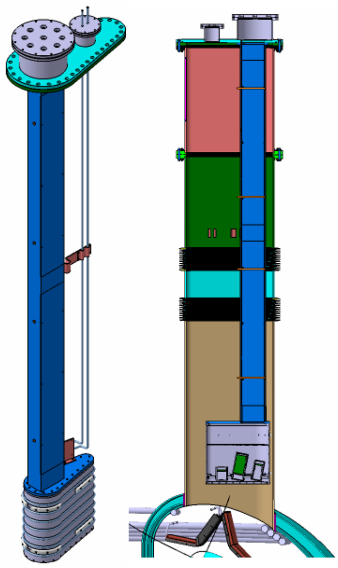

Fig.3 Structure of the vertical port plug for diagnostics

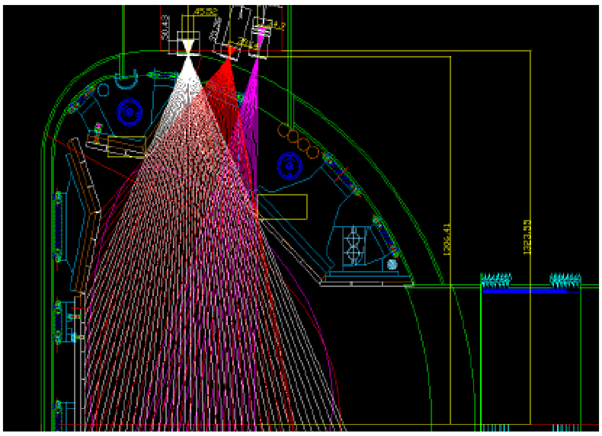

Fig.4 sightlines of cameras in Fig.3