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Fast bolometric measurement on the HL-2A tokamak

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1. Introduction

Bolometer is indispensable diagnostic instrument for general radiation losses information, for example, the position and the evolution of the thermal radiation in the high temperature plasma. It's the base of controlling the radiated power fraction and the position of the radiation maximum in the tokamak. Both are key issues for the minimization of erosion and achievement high performance. Thin film metal foil resistors[1][2]and pyroelectric detectors are commonly used for these purposes due to non-selective sensitivity in wide spectral range of incident radiation, provided by thermal nature of their response. There low sensitivity, susceptibility to EMI noises and poor rise/fall time lead to serious limitations for the space/times resolution of multichannel systems.

Since 2003, three AXUV[3] arrays were installed to measuring the total radiated power and spatial profiles of the local radiation power density in HL-2A. Each arrays is equipped with an AXUV-16ELO linear array of 16 p-n junction photodiodes, characterized by a flat spectral sensitivity from ultraviolet to x-ray energies(1eV~10keV), a high temporal response (0.5 μ s), and insensitivity to lower-energy neutral particles emitted by the plasma. This high temporal resolution allows the study of transient radiative phenomena and will allow be an actuator of plasma radiation feedback control.

2. Bolometer design

Radiation induced current in semiconductor detectors is known to be independent on the incident particle energy in the range well above its energy bandgap E_g. Since plasma radiation losses spectrum is located with 20…5,000eV energy range, AXUV with E_g<2eV would be suitable because recent advance in Si technologies for eliminating the front dead layer and enhanced PD quantum efficiency. Taking into account a number of attractive features, AXUV

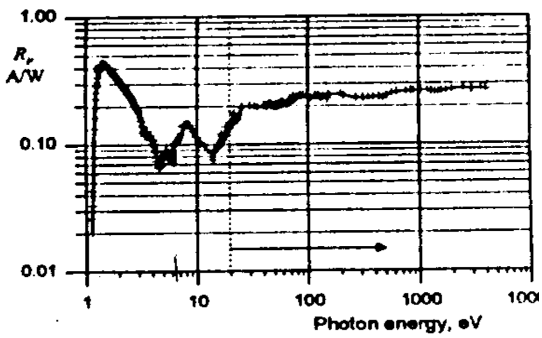

Fig 1: AXUV PD spectral response.

PD implementation to plasma radiation losses diagnostic seem to be worthwhile, although ~50% responsivity drop in 10~30eV energy range could result in some systematic errors of plasma radiation intensity absolute measurement (Fig1.).

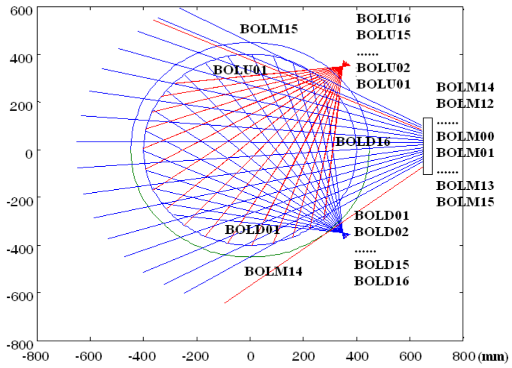

Fig 2: HL-2A bolometry arrangement.

The system consists of three pinhole AXUV arrays viewing the core plasma from the upper, lower direction of the ±45^0 poloidal angle and the third array in the middle plane (Fig.2). Each array contains Si PD array and 16-channel preamplifiers assembly to be placed inside the vacuum vessel. Stainless steel-made casing box is used to hold the detector and preamplifier and form the pine hole structure. Teflon and ceramic fixing elements provide high-voltage isolation.

The ADC/isolation unit was placed 5~10 meters apart from the port through the vacuum connect plug. In 2005 experimental campaign, the system was installed in HL-2A TOKAMAK for preliminary testing and plasma radiation profile evolution measurement. Temporal evolution of radiative collapses due to argon or neon injection is used to calibrate the absolute radiation power. No remarkable deviations in detector sensitivity along a year of operation have been observed after a number of vacuum vessel treatments including baking, cleaning discharges, siliconisation and more than 1000 shots.

3. Experimental results and radiation tomography

HL-2A is first middle-sized tokamak device with closed divertor (R=1.65m, a=0.4m) in China. 30% of the plasma facing area in the vacuum vessel (about 15m^2) is covered with CFC. The limiter is also made of graphite tiles. The main plasma parameter is Ip = 410 kA, Bt = 2.70 T and discharge duration 3s.

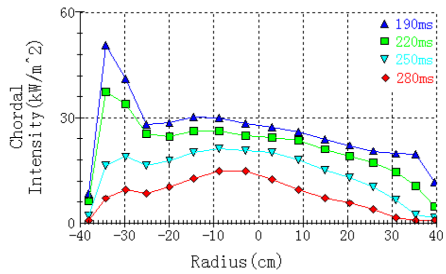

Fig3: the radiation profiles on the single null divertor operation on HL-2A. (shot 1654, flat top: Ip=139kA, ne=0.9*10^{19}m^3).

The plasma in HL-2A has a nearly circular cross-section, either in the limiter and divertor configurations. Firstly, the radiation profile in the single null divertor configuration shows strong poloidal asymmetric(Fig.3). An enhanced plasma radiative region exists around the X-point area. GDC and Siliconization are general wall cleaning and conditioning processes. The statistic result of the ratio of the radiated power to the total heating power P_{rad}/P_{ohmic} shows the core plasma radiation (P_{rad}/P_{ohmic}=40~70%) in limiter before siliconisation is larger than that in the divertor (P_{rad}/P_{ohmic} <50%). The ratio decreases to around 10~50% after each siliconlization in the HL-2A limiter discharges (Fig4).

During the 2005 experiment, the fast radiation disturbulence after the general sawtooth corresponded to the Mirnov δB_θ, I_{sx}, I_{ha} before the disruption have been observed (Fig.5). Before the disruption, δB_θ was developed from small to large amplitude. In the same time, similar process is found in the bolometer signals. It shows the strong relationship between the radiation and MHD instability. They all change the profiles of temperature and current density. Its good space/time resolution may be used as actuators of the feedback control signal to suppress the disruption.

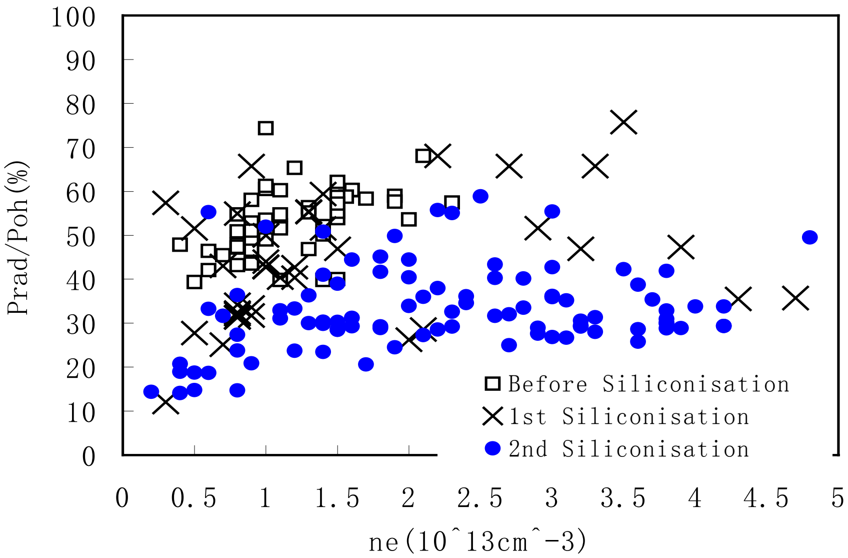

Fig4: the statistic results of the P_{rad}/P_{ohmic} over the line averaged density ne on the limiter configuration.

A improved tomographic algorithm[4] with taking magnetic flux surfaces as a basis of setting pixels, using a finite element tomographic algorithm and combined with Fourier expansion technique to invert the line integrated data[5]. The magnetic flux contours are derived from a field tracing code, and we may then expect either that the emission is constant along the contours, or that the deviation of the emission from its mean value is small and can be treated by allowing the emissivity within a pixel to vary in angular direction. This method

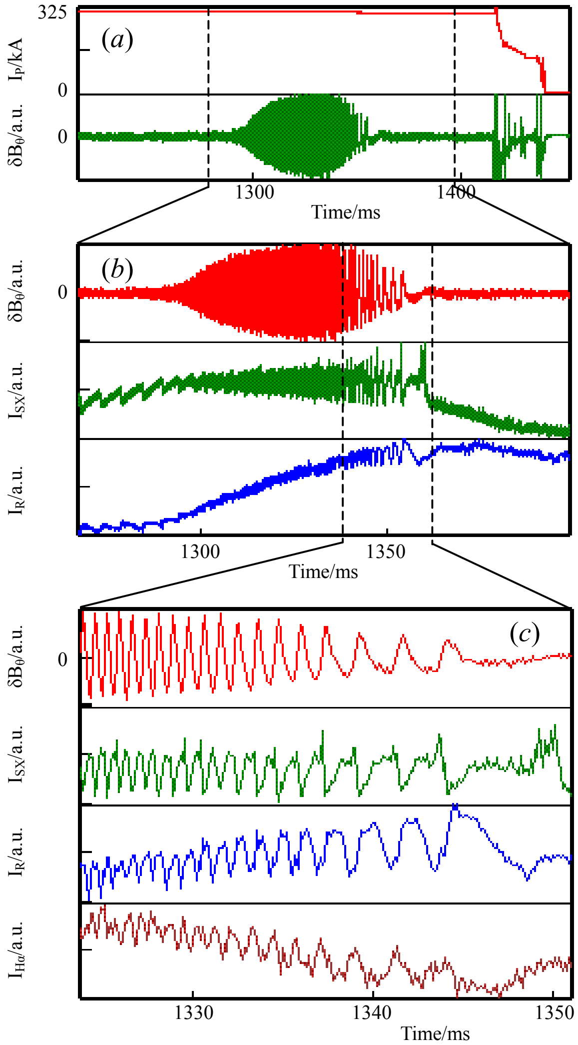

Fig5. Typical discharges before disruption. a) Ip and minrov signal δB_θ before disruption. b) responding I_{sx} from Soft X ray, I_{rad} from the bolometer and I_{ha} from Ha measurement before disruption.

has successfully been applied to the bolometer because the reconstruction is processed step by step from edge to plasma center. We perform a feedback technique to compensate the errors in the reconstruction, by which the quality of reconstructed image is significantly improved. Fig.6 is general image of bolometer which the most part of the plasma radiation exists in the edge region.

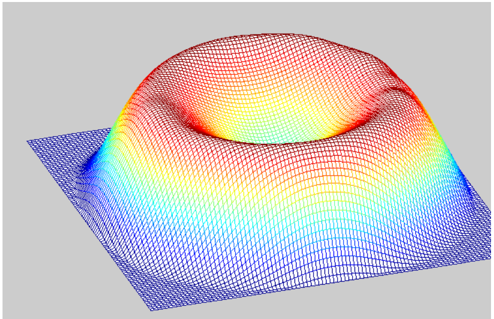

Fig6: the radiation reconstruction on

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