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Preliminary investigation of impurity and radiation behaviors in the HL-2A tokamak

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1. Introduction

HL-2A tokamak (major radius R=165cm, minor radius a=38~45cm) has been successfully operated in limiter and single-null divertor configuration under good feedback control of plasma current and position in 2003 campaign. Parameters achieved under ohmic discharges with stainless steel wall and graphite limiter were as follows: toroidal field B_t=1.4T, plasma current I_p=168kA, plasma electron density $n_e=1.7\times10^{19}/m^3$, plasma duration time t=920ms. In last campaign, glowing discharge cleaning (GDC) is used as a conventional wall conditioning technology and titanium gettering is used occasionally in closed divertor chamber during SN configuration discharges phase.

As the startup phase of HL-2A operation and the first divertor tokamak device in China, it is important to identify the species of impurity, estimate the concentration of impurities and compare the different behaviors of radiation in limiter and divertor configuration. In the following, the present status of relevant diagnostics will be described and preliminary results will be presented.

2. Diagnostics for impurity investigation

The main diagnostics related to impurity investigation are indicated in Fig.1, showing their position on the torus and their lines-of-sight with respect to the vacuum vessel and limiter. During last campaign, four pairs of fixed graphite limiters and a pair of movable graphite limiters are used to define plasma boundary. The percentage of coverage of graphite is no more than 0.1% of the first surface.

A sixteen-channel horizontal bolometer array is used for measuring the integral radiation losses and local radiated power from the plasma. Visible spectroscopy utilizes light from HL-2A tokamak relayed by optical fiber-bundles to detectors in diagnostic room. Four channel fibers monitor the Ha line emission and six-channel observe bremsstralung

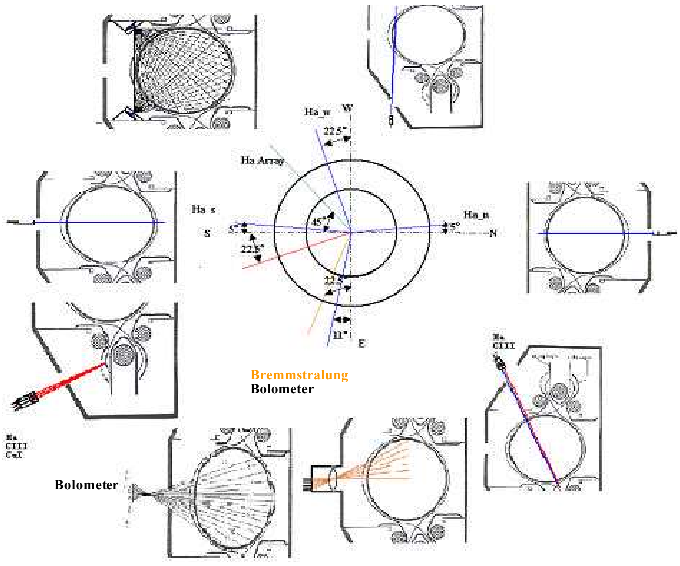

Fig.1. Layout and crosssection of relevant diagnostics

radiation by means of filters and photomultipliers. Another four fiber-bundles are connected to WDS-3 monochromater to monitor impurity line emission with low ionization states. Three of them can be used to measure the line emission from outer divertor region. SGV-50 VUV spectrometer with wavelength covering from 10nm to 200nm is used to monitor the changes of line emission with high ionization states, which usually exist near the plasma center.

3. Impurity identification

Spectral scans have been made to identify impurities by monochromator and VUV spectrometer shot by shot. Line emissions of hydrogen, carbon, nitrogen, oxygen, helium, iron, chromium, copper, ferrum, silicon, aluminium, titanium and molybdenum have been observed in last year's experiment. Line identification shows that most of the radiations are emitted by light impurities, especially by carbon and oxygen. Neutral lines of metal impurities appear demonstrating the existence of metal influxes from limiter or vacuum vessel. Fewer lines of high ionization states of metal impurities can be observed because of the lower electron temperature and density which are limited by the capacity of power generator. From spectral scans, it can be easily deduced that the radiation is mainly dominated by light impurities and high Z impurities have less influence on discharge quality within the parameter region of last campaign.

4. Estimation of carbon concentration

The carbon concentration can be simply estimated by intensities of line emission of carbon and hydrogen based on some atomic and molecular data and some calculations. From the statistic results of last campaign, the carbon concentration is mainly in the range of

2%~6% as shown in Fig.2. It is slightly higher than that in the startup phase of other

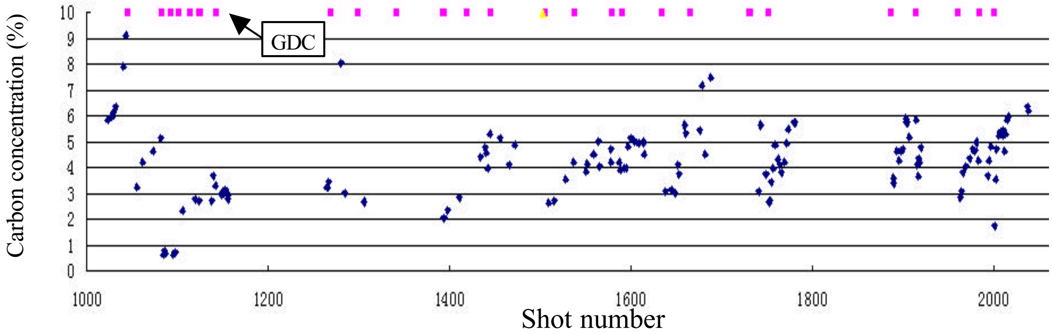

Fig2. The statistic results of carbon concentration in last campaign

tokamak device such as JET, but in the same level comparing with HL-1M. The statistic results also show that the carbon concentration has much dependence on GDC. After each GDC, the carbon content drops obviously.

The relationship of carbon concentration with plasma current and electron density is illustrated in Fig3. It is clear that the carbon concentration measured just before GDC is much higher than that measured just after GDC in the same plasma current and electron density. The result also validates the good effect of GDC for removing light impurities. Under similar wall conditions and the same plasma current, the carbon concentration has slight decrease with electron density. But it has increasing tendency with plasma current under the same electron density. These results may relate to the producing rate of impurities by interaction mechanism between edge plasma and limiters under different plasma parameters.

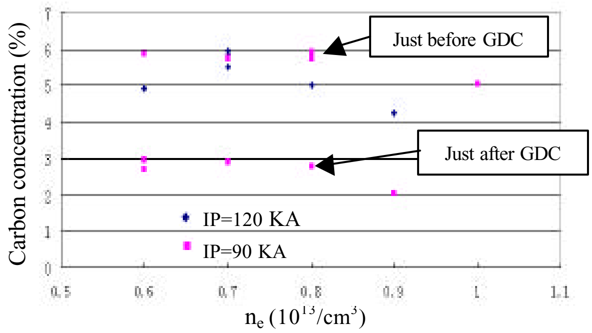

Fig.3. Carbon concentration vs. electron density

5. Radiation behaviors in limiter and divertor discharges

Chord intensity profiles measured by bolometer array show the different shapes in limiter and divertor configuration, seen from Fig.4 and Fig.5. In limiter discharges, the radiation profile is symmetry. But in SN divertor discharges, asymmetry radiation profiles have been observed and an enhanced radiative region of plasma existed near the X-point area. From measurement results in limiter discharges (seen from Fig.3), the radiation profiles have a little different in the same plasma current when the position of the movable limiters changes from a=38cm to a=40cm. The radiation profile with a=38cm is much more peaked than that with a=40cm, Which can be understood by the interaction between plasma and limiters. When the minor radius of plasma is small, the channel of plasma current will become narrow, which could enhance the interactions between plasma and limiters and produce much more impurities from the limiters by physical sputtering. The above results also can be validated by VUV signals, in which the intensities of OVI line emission at a=38cm are higher than those at a=40cm in the same plasma current. After calibration, total radiation power can be calculated by signals of bolometer. By statistics, the main chamber radiation ratio of P_{rad}/P_{ohmic} in limiter discharges is about 45%~80%, which is much higher than that in the divertor discharges (less than 50%). It is consistent with the result that intensities of line emission of OVI, CIII, Ha and bremsstrahlung radiation in main plasma during SN configuration are much lower than those during limiter one in the same discharge.

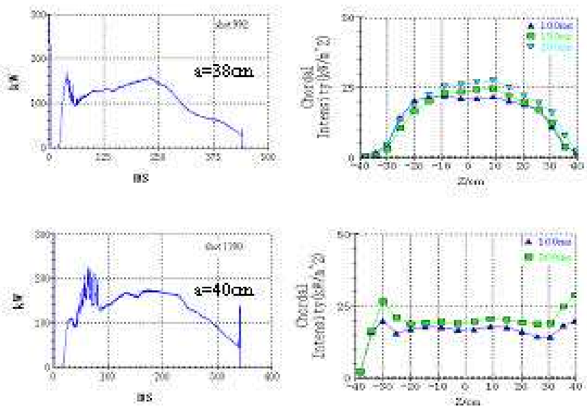

Fig.4. Chord intensity profiles (right) and total power evolution (left) in the same plasma current Ip=100kA and different limiter position (a) a=38cm (b) a=40cm.

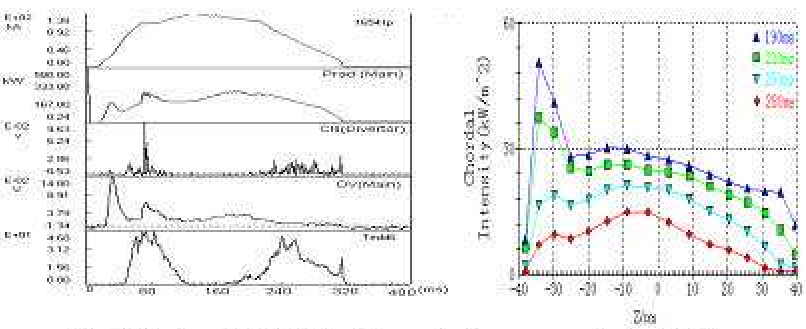

Fig.5. Chord profile (right) and the main plasma parameters in HL-2A

6. Conclusion

The above results identify that divertor operation has a good effect to minimize the interaction between plasma and wall and to reduce impurity content and recycling. The carbon concentration was in the range of 2%~6% in last campaign and it was affected by wall conditioning. The asymmetric radiation profile existed during SN configuration.