Visible Images Induced by the Three-dimensionally Complicated Structure of the Plasma Periphery in the Large Helical Device

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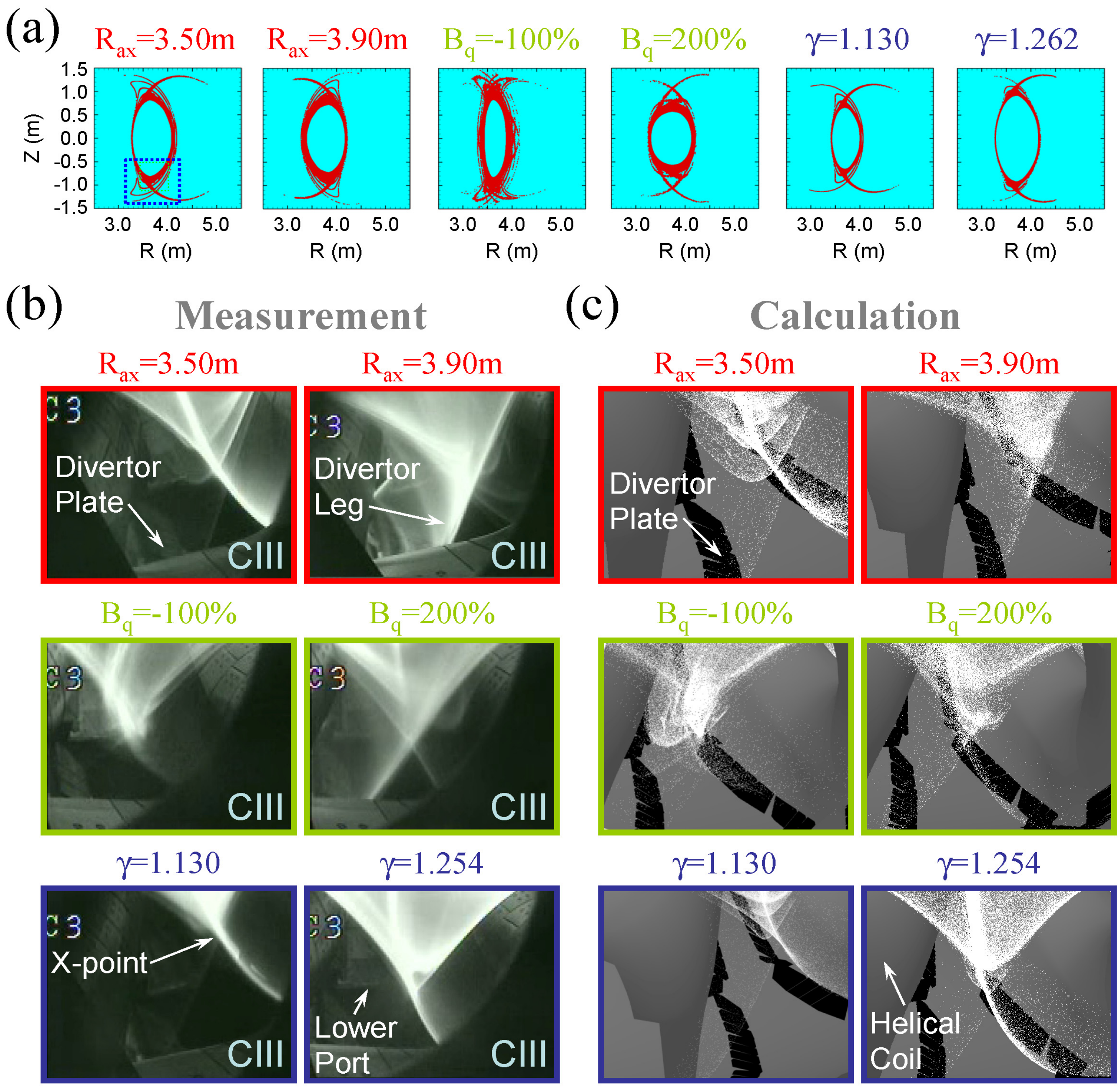

Fig. 1. Poincare plots of the magnetic field lines at a toroidal angle where the LHD plasma is vertically elongated (a), the measurements of the CIII line emission observed with a tangentially viewing CCD camera installed in an outer port (b), and the images of three-dimensional plots of the magnetic field lines in the plasma periphery (c) in various magnetic configurations where three magnetic parameter R_{ax}, B_q and γ are changed.

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***Abstract* – The magnetic components produced by non-axisymmetric super-conducting coils in the Large Helical Device produce a complicated magnetic structure in the plasma periphery which strongly depend on the configuration of electric currents in the magnetic coils. A tangentially viewing CCD camera has observed line emission of doubly ionized carbon CIII. The dependence of the three-dimensional distribution of the CIII emission on magnetic configurations will be discussed.**

Large Helical Device (LHD) is the world's largest super-conducting heliotron which consists of two twisted helical coils and three pairs of poloidal coils for magnetic plasma confinement [1]. Helically twisted plasmas are formed by magnetic field produced by the both super-conducting coils. The radial position, the shape and the minor radius of the magnetic field for plasma confinement are controlled by the electric currents in the coils. The radial position of the magnetic axis ($3.50<R_{ax}<4.05$m) is moved by poloidal coil currents, the shape of the plasma is distorted by quadrupole magnetic components ($-200<B_q<200$%), and the minor radius is changed by a coil pitch parameter ($1.130<\gamma<1.265$) which is controlled by the combination of the electric currents in the three layers of the helical coils [2]. In a standard magnetic configuration for achieving good plasma confinement, the parameters of the magnetic field R_{ax}, B_q and γ are set to be 3.60m, 100% and 1.254, respectively.

The main plasma confinement region inside of the Last Closed Flux Surface (LCFS) is surrounded by an ergodic layer where the magnetic field line is three-dimensionally complicated [3]. The magnetic field lines are deviated from the ergodic layer at X-points where the magnetic field lines are bundled into four divertor legs. The divertor legs are connected to water-cooled divertor plates made of isotropic graphite (W250×D90×H15mm). The divertor plates are installed along the space between the two helical coils to protect the vacuum vessel (stainless steel). Figure 1 (a) illustrates Poincare plots of magnetic field lines in the plasma periphery at a toroidal angle where the plasma is vertically elongated in different magnetic configurations in which the parameters R_{ax}, B_q and γ are independently varied from the standard configuration. The structure of the magnetic field lines depend on the three parameters.

A CCD camera (SONY DXC-LS1, 30fps, exposure time ~2ms, sensing area 3.2×2.4mm) with an interference filter (λ_0=465.4nm, $\Delta\lambda$=1nm) for CIII line emission measurement is installed in an outer port for directly monitoring carbon impurity production on the divertor plates and the impurity transport in the plasma periphery. The camera tangentially observes the ergodic layer, divertor legs and the divertor plates around a lower port. Figure 1 (b) shows the measurements of the distribution of the emission in various magnetic configurations. The measurement area corresponds to a blue rectangle in a Poincare plot (R_{ax}=3.50m) in Figure 1 (a). The distribution of the CIII emission depends on the parameter R_{ax}, which shows the change of the position of the emission on the divertor legs. The emission is bright on the right divertor leg for R_{ax}=3.50m, while it is observable on the left divertor leg for R_{ax}=3.90m. The distribution of the emission near the X-point is more complicated for B_q=-100% than that for B_q=200%. The position of the X-point is shifted down with the increase of the parameter γ. Figure 1 (c) is the images of the three-dimensional plots of magnetic field lines (white dots) which are traced from the uniformly distributed positions (totally ~7000 points) on the LCFS in the three-dimensional model which includes the detailed geometry of the divertor plates and the vacuum vessel [3]. The images are consistent with the measurements of the CIII emission in various magnetic configurations because of the transport of the ionized impurity ions along the magnetic field lines on the divertor legs (n_e~1.0×10^{18} m^{-3}, T_e~20eV).

The position of the strike points is basically calculated by the magnetic field line tracing onto the divertor plates from the LCFS. The calculations indicate that the position of more than 85% of the strike points locate on the divertor plates when R_{ax}=3.50~4.05m, B_q~100% and γ~1.26. In the other magnetic configurations, the most of the strike points locate on the vacuum vessel. The calculations of the position of the strike points strongly suggest that high heating power or long pulse discharge operation in non-standard magnetic configurations ($B_q\neq$100% or γ<1.20) should be carefully tried for protecting the LHD vacuum vessel.

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