CREATION, ACCUMULATION AND CONFINEMENT OF NON-NEUTRAL PLASMAS IN STELLARATOR MAGNETIC CONFIGURATION

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The experiments on creation, accumulation and confinement of non-neutral plasma in stellarator system are performed in Institute of Plasma Physics, NSC KIPT. The main goals of these studies are to investigate the behavior of non-neutral plasma in stellarator magnetic configurations, to compare transport in neutral and non-neutral plasmas, as well as to study the possibility of plasma confinement modification by active control of radial electric fields.
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1. INTRODUCTION

At present, the helical toroidal magnetic traps, most notable as the tokamaks and the stellarators, are the most successful plasma confinement devices for future fusion reactors. Economically acceptable fusion reactors requires steady-state and high-confinement plasma performances of such devices. Unfortunately, the presence of plasma electrostatic and magnetic turbulences causes the plasma confinement degradation and the heat conduction to be anomalously high. However, over last decade, in many helical type devices it has been observed that the turbulences are reduced in the so-called regimes with improved confinement (H-modes). Progress in the study of plasma turbulence and transport have shown that mechanisms which control the generation of the radial electric fields (Er) and the Er x B sheared flows to play a key role in formation of transport barriers leading to improvement of plasma confinement in H-modes [1]. Since radial electric fields can affect both anomalous and neoclassical transport, the development of methods to control the generation of electric fields is a very promising area of researches for modifying confinement in helical type devices [2]. Biasing electrodes [3] or limiters [4] is one of the methods used both in tokamak and stellarator devices to externally generate electric fields with the aim of achieving improved confinement modes of operation. The principal drawback of this technique, especially in high edge temperature devices, is the increased risk of radiation collapse due to either a massive entrance of impurities or to an increase in the impurity confinement time [5]. The other possible way to control the radial electric field is to change the plasma neutrality by injection of high energy electrons into plasma core. However, it is not easy to bring electrons into core region across a strong toroidal magnetic field. According to previous studies in tokamaks it is necessary to introduce an additional ripple magnetic field in order to transport electrons into core region along ripple trapped drift orbits [6]. On contrary, in case stellarators for electron injection, it is possible to utilized the existing loss cone orbit, which has reversible characteristic, to launch helically trapped particles from outside of the magnetic confinement volume and then transform them into blocked particles in the center of the confinement volume [7].

In addition to the studies in the context of thermonuclear fusion, more recently stellarators have become of interest as confinement devices for low density non-neutral plasmas [8]. Since stellarators confine plasmas over the full range of neutrality, from pure electron to quasineutral, they have unique advantages for laboratory confinement of positron plasmas, non-neutral electron plasmas, and antiproton – positron plasmas.

2. OBJECTIVES

The main objectives of the present project are to develop and to investigate a several possible methods of non-neutral plasma creation and radial electric field generation in stellarator magnetic configuration, to study the accumulation and confinement of externally injected charged particles within the confinement region of stellarator, to investigate the non-neutral plasma instabilities and turbulences as well as their influence on plasma losses across magnetic field, to investigate the possibility of plasma confinement modification by active control of radial electric fields, to compare the confinement of neutral ECRH (Electron Cyclotron Resonance Heated) plasma, non-neutral plasma created by electron injection, and ECRH plasma plus electron injection.

3. EXPERIMENTAL SET-UP

The experiments will be carried out in the small l = 2 stellarator (B_o = 0.09 T, R = 0.42 m, a = 0.04 m). The experimental set-up is schematically shown in Fig.1.

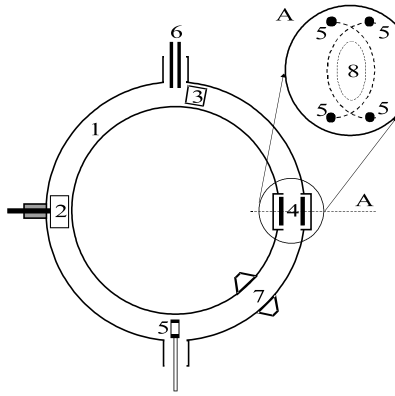

Fig.1. Schematic of an experimental set-up:
1 – stainless steal vacuum chamber, 2 – antenna of magnetron source, 3 – anode electrode, 4 – electron injector, 5 – heated cathodes, 6 – diagnostics probes, 7 – horn antennas of radiofrequency diagnostics, 8 – cross section of magnetic surfaces

The set-up includes four main parts: toroidal stainless steal chamber placed in stellarator magnetic configuration, magnetron source (f = 2.45 GHz) for ECRH plasma production, high energy electron injectors for non-neutral plasma creation and diagnostic equipment. To create the non-neutral plasma in close magnetic configuration of stellarator it is supposed to use a several methods of electron injection, as follows: electron injection from heated cathodes placed in edge confinement region; electron injection from auxiliary reflective discharge initiated not far from confinement region and electron injection through stellarator divertor. In run of experiments it is supposed to find experimentally the best points of electron injection into confinement region of stellarator, as well as to compare efficiency of varies methods of electron injection. The confinement of neutral ECRH plasma, non-neutral plasma created by electron injection, and ECRH plasma plus electron injection will be compared using microwave reflectometry. The radial profiles of electron temperature, plasma potential and density, as well as the fluctuations in plasma density and potential in plasma core and periphery will be measured by probe diagnostics. The charged particle flows, particle energy and their losses across magnetic field to will be studied by movable electrostatic analyzers.

4. PRELIMINARY EXPERIMENTS IN NSC KIPT

We have a large experience on electron injection into toroidal magnetic configurations. In our preliminary experiments [9] we have obtained and confined the non-neutral plasma in toroidal magnetic configuration at the expense of a high energy electron injection through toroidal divertor. The divertor cell for electron injection into toroidal magnetic configuration is shown schematically in Fig.2.

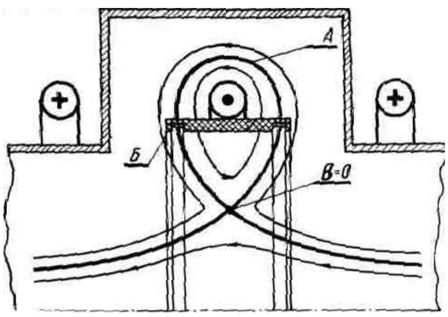

Fig.2. Schematic of the divertor cell: A – separatrix, B - high-voltage electrodes

The parameters of the non-neutral plasma entrapped were: the plasma density - $10^{11} < N_o < 10^{13}$ см $^{-3}$, the electron temperature - $T_e \approx$ 10-20 eV and the ion temperature T_i ~50 eV.

The oscillogram of (a) X-radiation and plasma potential, (b) the distribution of plasma potential along cross section of toroidal chamber and (c) the fluorogram of the cross section were shown in fig.3, respectively.

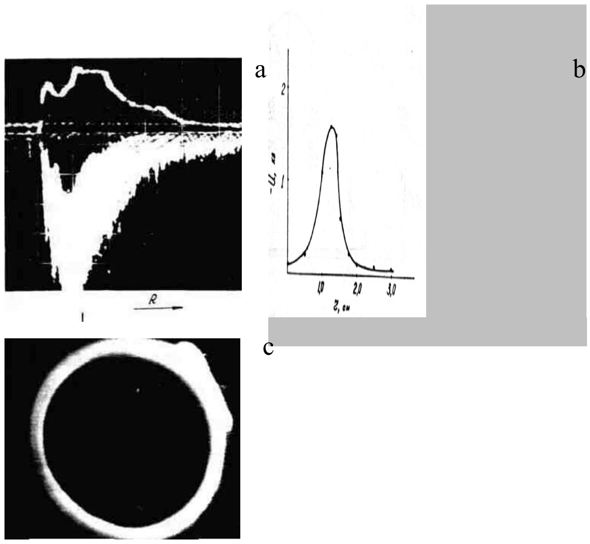

Fig.3. (a) the oscillogram of X-radiation and plasma potential, (b) the distribution of plasma potential along cross section of toroidal chamber and (c) the fluorogram of the cross section

5. CONCLUSION

Here we have presented the project of investigations on creation, accumulation and confinement of non-neutral plasmas in stellarator magnetic configuration. We suppose the results will be obtained can be used to create the non-neutral plasma and to control the radial electric fields in a large stellarator installations, for example such as URAGAN-3M and URAGAN-2M. Also, these experiments can be useful for the better understanding of behavior of non-neutral plasma in stellarator magnetic configurations, transport mechanisms, transport barrier formation and triggering of enhanced confinement regimes in helical type devices.

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СОЗДАНИЕ, НАКОПЛЕНИЕ И УДЕРЖАНИЕ НЕСКОМПЕНСИРОВАННОЙ ПЛАЗМЫ В СТЕЛЛАРАТОРНОЙ МАГНИТНОЙ КОНФИГУРАЦИИ

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Эксперименты по созданию, накоплению и удержанию нескомпенсированной плазмы проводятся в Институте физики плазмы ННЦ ХФТИ. Главные цели этих исследований состоят в изучении поведения нескомпенсированной плазмы в сталлараторных магнитных конфигурациях, а также в изучении возможности модификации удержания плазмы путем активного управления радиальными электрическими полями.

СТВОРЕННЯ, НАКОПИЧЕННЯ ТА УТРИМАННЯ НЕСКОМПЕНСОВАНОЇ ПЛАЗМИ У СТЕЛЛАРАТОРНІЙ МАГНІТНІЙ КОНФІГУРАЦІЇ

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Експерименти по створенню, накопиченню та утриманню нескомпенсованої плазми проводяться в Інституті фізики плазми ННЦ ХФТІ. Головні цілі цих досліджень складаються у вивченні поводження нескомпенсованої плазми у

стеллараторних магнітних конфігураціях, а також у вивченні можливості модифікації утримання плазми шляхом активного керування радіальними електричними полями.