Effects of Large Scale Magnetic Fields on Accretion flow in Sgr A*

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The suppermassive black hole in the Galactic center has a very low luminosity and accretion rate. The origin of such a low accretion state is still a matter of debate. On the other hand, the magnetic fields are strong in the Galactic center region, which may suppress the accretion rate significantly. In this talk I will discuss how the presence of a large scale magnetic field may affect the black hole accretion processes in a low density environment.

Non-conventional application of pulsed high energy density plasma for novel material synthesis

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In most industrial applications, plasma-based processes typically rely on low-temperature non-equilibrium plasmas for material synthesis and processing, though there is a growing adoption of higher-density thermal plasmas in specific sectors. The science and engineering behind low-temperature plasmas (LTPs), which operate at temperatures on the order of few eVs and densities ranging from 10ˆ6 to 10ˆ16 cmˆ-3, are well-established, making them a standard choice for precise material modification and fabrication. For instance, LTP-based plasma-enhanced chemical vapor deposition (PECVD) is essential for depositing thin films and coatings in microelectronics and semiconductor production, while LTP-driven plasma etching enables the precise patterning of silicon wafers for chip manufacturing. Additionally, LTPs are utilized to enhance textile surfaces, improving properties like adhesion, dye absorption, and water resistance without affecting the material’s bulk integrity, and they are also employed in sterilizing medical equipment by disrupting microbial cell structures and DNA. On the other hand, higher-density thermal plasmas, operating continuously, find applications in plasma arc welding and cutting, thermal barrier coatings in aerospace via plasma spraying, and high-temperature metallurgical processes in plasma furnaces. Meanwhile, pulsed high-energy-density plasma sources, such as the dense plasma focus (DPF), a Z-pinch, device generating plasmas with keV-level temperatures and densities of 10ˆ19-20 cmˆ-3 are emerging as promising tools for advanced material processing and nanoscale synthesis. However, DPF systems, being pulsed devices, often face skepticism regarding their controllability and reproducibility in material synthesis. In this plenary talk, I will explore the distinctive characteristics of the dense plasma focus as an innovative high-density, high-temperature pulsed plasma source and illustrate its potential for controlled, reproducible nanomaterial fabrication. I will present various strategies that we have developed and the results achieved, demonstrating that the DPF can serve as an effective, versatile, and dependable high-energy plasma tool for advanced material processing and synthesis.

Study of Tungsten Impurity Transport Mechanism in I-mode Plasma under the Full-Tungsten Divertor Environment of EAST

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The tungsten accumulation severely impacts the performance of magnetically confined fusion plasmas. Effectively controlling tungsten impurities is one of the key challenges for achieving steady-state operation in ITER and future fusion reactors. I-mode plasmas, due to their unique decoupling characteristics of particle confinement and energy confinement, have the potential for simultaneously achieving high confinement and effective impurity control, making them a candidate operation scenario for ITER and future fusion reactors. However, there is currently a significant lack of experimental and theoretical study on tungsten impurity transport in I-mode plasmas. Utilizing high-performance tungsten impurity spectroscopic diagnostics, the experimental studies on tungsten impurity transport in I-mode plasmas were preliminarily conducted on the EAST, obtaining statistical results on tungsten impurity particle confinement times. Moreover, based on TGYRO and STRAHL impurity transport simulation tools, the transport characteristics of tungsten impurities in typical H-mode, I-mode, and L-mode were compared and studied. This study clarified the contributions of neoclassical and turbulent transport to tungsten impurity transport in I-mode plasmas, leading to a physical understanding of tungsten impurity transport in I-mode plasmas, and provides important references for achieving real-time control of tungsten impurities and long-pulse steady-state high-performance operation in ITER and future fusion reactors under tungsten wall environment.

Accelerating Fusion Research through Negative Triangularity Tokamak

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Fusion research attracts public interest through initiation of public-private cooperation and gain momentum from investment by private sectors as well as government funding. There are three pillars in fusion research - tokamak[1], [2], helical[3] and inertial confinement fusion[4]. Magnetic confinement fusion can be promising through search for symmetries, such as axisymmetry in tokamak and quasi-symmetry in helical [5]. Tokamak system continued to be most promising system due to its apparent symmetry but has difficulty in power handling by the existence of ELM, whose transient heat load is unacceptable and questioned for H-mode at my plenary talk in US-EU TTF[6]. ELM mitigation by RMP is a temporally measure and may not relevant for reactor operation due to its 3D nature. Negative triangularity tokamak (NT tokamak) as a reactor scenario is first proposed in 2013 by me as a possible solution for power handling in APPC-12 [7] based on TCV’s pioneering work[8]. NT tokamak based fusion reactor concept attracted interests at IAEA Fusion Energy Conference in 2018 in Ahmedabad [9]. Since then, NT tokamak research expanded worldwide and intensive research works were performed in TCV and DIII-D as reviewed by Marinoni in 2021 [10]. More recently in 2024, special issue on NT is published in PPCF[11]. All experimental results confirmed robust inhibition of H-mode entry in the edge while maintaining high confinement state as previously shown by Austin in DIII-D [12]. Based on these success, a NT-based Pilot Plant design is conducted in US [13]. Rapid growth in fusion private sectors such as CFS (https://cfs.energy/) in US, Tokamak Energy (https://tokamakenergy.com/) in UK, ENN (http://en.ennresearch.com/) in China, Kyoto Fusioneering (https://kyotofusioneering.com/) in Japan led to acceleration of fusion research. I am pleased to see foundation of NT-based fusion private sectors such as FIREFLY (https://fireflyfusion.energy/) in Europe and STARTORUS Fusion (https://www.startorus.com/, https://www.startorus.com/progress-news/300.html) in China. I will discuss NT concept, physics and its role in accelerating fusion energy research.

Potential Surface on an inhomogeneous dense plasma-half space

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This study examines how temperature inhomogeneity, surface charge, and surface mass densities influence the stability of charged surface waves at the interface between dense, incompressible, radiative, self-gravitating, magnetized electron–ion plasma and vacuum. In such plasmas, temperature variations follow an energy balance equation, and using the one-fluid MHD model, a general dispersion relation for capillary surface waves is derived, incorporating gravitational, radiative, and magnetic effects. The analysis identifies the conditions for interface instability. Without electromagnetic (EM) pressure, gravitational collapse occurs through Jeans surface oscillations rather than central contraction. EM radiation has significant effect on the dispersion relation and help to stabilize the Jeans instability. In specific cases, pure gravitational radiation can travel along the plasma–vacuum interface. The growth rate of radiative dissipative instability is expressed in terms of the wavevector, making the model relevant to both astrophysical and laboratory plasmas e. g., may have a strong influence on recent studies of target surface irradiation by intense laser light.

DSMC Simulation of the Effect of Metal Vapor Content on the Flow Field Characteristics of N2/O2 Cascade Arc Jet

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Arc jet is one of the typical methods for realizing ground simulation of the plasma sheath environment of hypersonic vehicles. It has the advantages of long duration, low cost, large plasma area, high temperature and high enthalpy. Currently, it is the mainstream approach for plasma sheath ground simulation and is widely adopted by international research institutions. However, electrode ablation is inevitable in high-power arc-jet devices. This results in the addition of metal vapors or ions to the ideally pure plasma flow field, which affects the accurate assessment of the properties of thermal protection materials. To address the issue of flow field contamination caused by electrode ablation in arc jets, this study developed a simulation model of the N_2/O_2 cascade arc jet flow field based on the direct simulation Monte Carlo (DSMC) method, and clarifies the flow field characteristics of the arc jet. The results showed that the jet shock wave expansion achieves a Mach number of 5.6, a temperature of 2277 K, and a flow velocity of 2376 m/s. Adding only 200 ppm of copper vapor reduced the Mach number by 12.5%, temperature by 4.9%, and flow velocity by 10.3%. Furthermore, an experimental platform for the N_2/O_2 cascade arc jet was constructed, and the simulated results of arc jet gas temperature showed good agreement with the experimental measurements. This study provides key insights for controlling flow field contamination in arc jet-simulated plasma sheath environments.

Effects of reversed magnetic shear on the plasma rotation stabilization of resistive wall modes in tokamaks

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Effects of reversed magnetic shear on the plasma rotation stabilization of resistive wall modes in tokamaks are investigated using the AEGIS code. MHD equilibria in toroidal configuration from circular cross-sections to realistic CFETR-like scenarios with various magnetic shear profiles are considered. Two critical aspects of the n=1 RWM are examined: the influence of toroidal rotation on the unstable regime and the toroidal rotation frequency thresholds required for complete stabilization. It is found that strongly reversed magnetic shear consistently broadens the unstable β_N window in both circular and CFETR equilibria when toroidal rotation is included. Furthermore, reversed magnetic shear significantly reduces the rotational stabilization, resulting in narrower stability windows and notably higher toroidal rotation frequency thresholds required for complete RWM suppression compared to the cases with positive shear only. These results clearly demonstrate that the reversed magnetic shear in the advanced tokamak configuration imposes more stringent requirement for the effective toroidal rotation stabilization of the n=1 RWM.

Effects of neoclassical toroidal viscosity on plasma flow evolution in the presence of resonant magnetic perturbation in a tokamak

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The 3D non-axisymmetric magnetic field (NAMP) added outside the tokamak, such as error field and resonant magnetic disturbance (RMP), will affect the momentum transport and flow evolution of the plasma through plasma response. At the same time, the evolution of plasma response itself strongly depends on plasma flow. The neoclassical toroidal viscosity (NTV) torque generated under NAMP also participates in this complex physical process, and experiments and simulations have found that NTV has a significant impact on flow[1][2][3].

This work is based on the cylindrical error field theory under “free slip” condition[4][5], and coupled with the NTV torque to evaluate the effect of NTV on plasma flow evolution in the presence of RMP in a tokamak. Calculations show that the introduction of NTV has almost no effect on the flow on the resonant surface, so the locked or unlocked state on the resonant surface remains unchanged, but impacts the rotation profile in the core region. The toroidal, poloidal, and parallel flows in the core region are slightly reduced with uniform pressure. For non-uniform pressure profiles, the width of the saturated magnetic island decreases approximately 10% to 30% for different cases with increasing β, which is dominated by the pressure gradient effect.

Effects of external magnetic field ripple on FRC equilibrium

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The two-dimensional equilibrium of Field-Reversed Configuration (FRC) plasma in presence of an external ripple magnetic field is computed to show the emergence of multiple magnetic axes for hollow equilibrium current profiles. An increase in ripple amplitude reduces the hollowness threshold required for the development of multiple magnetic axes. For an intermediate range of the ripple axial period, the formation of multiple magnetic axes becomes the most likely. The ripple’s radial extension and the curvature of the axial field are the critical factors underlying the non-monotonic effect of ripple’s axial period. When the axial period increases from the lower range, the ripple’s radial extension gradually grows and enhances the chance of forming multiple magnetic axes. Once the ripple’s radial extension covers the entire radial domain, further increasing the ripple axial period decreases the ripple field curvature, which becomes the dominant factor for lowering the hollowness threshold for the formation of multiple magnetic axes.

Research on the Evolution of NTM during Plasma Current Ramp-up on J-TEXT

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One such macro-scale instability in tokamak driven by pressure gradients in high-beta operations is the neoclassical tearing mode (NTM), which will commonly appear and then degrade plasma energy and finally cause disruptions in future reactors.[1][2] Compared to classically current-driven tearing modes, NTMs are primarily driven by helical perturbations in the tokamak's bootstrap current. This drive arises from the flattening of the pressure profile within the magnetic island.[3]Although there exist many mechanisms of seed island formation, these seed islands, once generated and exceeding a size larger than the critical width of NTMs, will grow dominated by the effect of the perturbed bootstrap current.[4]Therefore, NTM and classical tearing mode shares topological similarities in magnetic island structures, but their physics mechanisms are fundamentally distinct.

On the J-TEXT tokamak, off-axis ECRH deposition was utilized to excite 2/1 NTM whose island width scales proportionally to the beta at the magnetic axis, as illustrated in figure 1 (a). Counterintuitively, core electron temperature increased during magnetic island growth, coinciding with the formation of an electron Internal Transport Barrier (e-ITB). [5] We postulate a potential connection between NTM dynamics and e-ITB development, wherein beta, island width, and ITB performance exhibit mutual proportionality—forming a self-sustaining positive feedback loop—as empirically demonstrated in figure 1 (a) and (b). And the e-ITB forms near the plasma core inside the NTM magnetic island aligns with recent theories on island-triggered transport barrier formation by enhancing sheared flows at magnetic island boundaries and suppresses turbulent transport .[5][6]

Recently on J-TEXT, we observed that NTM evolution exhibits abrupt increases when the plasma current ramps up and the edge safety factor qa decreases. The abrupt increases manifest as rapid increases in NTM frequency and amplitude. Our experimental evidence suggests a causal link between the observed abrupt amplitude/frequency increases and nonlinear coupling with transiently excited modes. Several promising experimental results have been observed:

1) Abrupt increases occurrences when qa ≈ 4. Abrupt increases are typically observed when the edge safety factor qa approaches values marginally above 4, as illustrated in figure 1 (c).

2) Frequency jump precedes island width surge. The abrupt increases manifests as rapid increases in frequency and amplitude, occurring on timescales of 2-10ms with a characteristic temporal sequence: frequency rise precedes amplitude growth, as illustrated in figure 1 (c)

In summary, J-TEXT experiments reveal that NTM magnetic island can trigger e-ITB, suggesting a potential mechanistic link between these. Additionally, we observe that current ramp-up induces abrupt increases in both frequency and amplitude of NTM when qa≈4.

Electron internal transport barrier induced by NTM in the ECRH plasma on J-TEXT

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Understanding the electron thermal transport is essential for the magnetic confinement fusion plasmas, since the fusion-born alpha particles mainly heat the electrons in a fusion reactor. For more than a decade, it has been believed that magnetic island structure can be responsible for the trigger of internal transport barrier (ITB) at rational surface and hence improves plasma confinement [1]. In the ECRH plasmas on J-TEXT, the increase of neoclassical tearing mode (NTM) amplitude has been observed to induce the reduction of the core electron thermal transport with the formation of an electron internal transport barrier (ITB) [2] just inside the island inner separatrix.

At medium NTM amplitude, the ITB is formed with a dithering phase, i.e. plasma transitions from no transport barrier to ITB or vice versa quasi-periodically. With NTM amplitude further increasing, the dithering ITB transitions into a steady ITB. The steady ITB can last for over 0.3 s (limited by the discharge duration), which is more than 2.5 times current diffusion time. The electron temperature gradient inside ITB increases with NTM amplitude.

The trigger of ITB and further enhancement of ITB performance are also demonstrated by locking the island via applying a resonant magnetic perturbation (RMP) field. The confinement energy with improved ITB can recover to the level prior to the appearance of the magnetic islands. The reduction of density fluctuations in ITB region is observed and indicates the turbulence suppression during ITB formation. The ITB can also be triggered with the formation of 3/2 locked island due to the penetration of 3/2 RMP [3]. By applying external rotational transform field [4], the rotating NTM can be suppressed while the ITB is maintained with significant increase of core Te. These findings offer new insights for understanding ITB formation and robust ITB control.

Progress in the development of the high-power electric propulsion systems in ASIPP

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To meet the demands of deep space exploration missions, the Hefei Institutes of Physical Science, Institute of Plasma Physics, Chinese Academy of Sciences (ASIPP), has developed a high-power electric propulsion system named the Superconducting Tunable Acceleration Rocket (STAR). STAR is a Variable Specific Impulse Magnetoplasma Rocket (VASIMR)-type device, which consists of three major stages. The first stage employs a helicon plasma source to generate high-density plasma. This is followed by an ion cyclotron resonance heating (ICRH) stage for ion energization. Finally, thrust is produced in the magnetic nozzle through the conversion of plasma azimuthal velocity into axial velocity. Regarded as one of the most promising propulsion technologies for future space missions, STAR is designed for ground-based demonstration of high-power and high-thrust capabilities.

This work presents the development and key operational results of the STAR system. The design and experimental testing of critical components, including the helicon plasma source, ICRH section, magnetic nozzle, and plume diagnostics, are described in detail. STAR achieved first plasma in November 2021. Through experimental optimization, the system successfully reached the blue core helicon mode and demonstrated efficient coupling of ICRH power into the helicon plasma. Preliminary thrust performance evaluations indicate that STAR can deliver up to 1.19 N of thrust at a maximum input power of 60 kW. Additionally, an overview of other linear plasma devices developed by the research group for various applications is provided.

The Magnetic Diagnostic System for the CFQS-T Quasi-axisymmetric Stellarator and Preliminary Studies on Plasma Energy Confinement

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The construction and experimental operation of the China First Quasi-axisymmetric Stellarator (CFQS) is divided into two phases. The first phase (Mar 2024 - May 2025), located at the Jiuli Campus of Southwest Jiaotong University, involves the assembly and testing of the main device, validation of the quasi-axisymmetric configuration at a low magnetic field, and conducting low-parameter plasma discharge experiments (magnetic field < 0.1 T, heating power < 30 kW). This stage is designated as the "CFQS Test platform" (CFQS-T). In the second phase (starting Apr 2026), the entire device will be constructed in the Tianfu New Area to achieve high-field, high-parameter operation (magnetic field = 1 T, heating power = 500 kW) [1-4]. This poster introduces the magnetic diagnostic system for CFQS-T and presents preliminary research results on plasma stored energy and energy confinement time based on these magnetic measurements.

Currently, the magnetic diagnostic system on CFQS-T includes a 3D magnetic probe array for measuring magnetic fluctuations, another 3D magnetic probe array for measuring the magnetic field, three diamagnetic loops for measuring stored energy, three Rogowski coils for measuring plasma current, and nine Rogowski coils for measuring the magnet coil currents. These magnetic diagnostics have been successfully implemented in plasma discharge experiments.

By utilizing the signals from the diamagnetic loops and Rogowski coils, the stored energy during argon and hydrogen plasma discharges on CFQS-T is calculated. From this, the energy confinement time throughout the discharges is further computed and summarized. A preliminary scaling law for energy confinement time under the low-parameter operating conditions of CFQS-T has been derived using standard regression analysis.