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Observation of ELM mitigation by counter current direction NBI on EAST

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Abstract: *A non-stationary, effective edge localized modes (ELMs) mitigation/suppression regime has been recently obtained by counter current direction NBI heating on the Experimental Advanced Superconducting Tokamak (EAST). By scanning toroidal rotation with a combination of co-current direction NBI, counter-current direction NBI and radio-frequency heating, it is found the ELM-induced particle flux and ELM frequency decrease with increasing toroidal rotation in counter current direction. These results suggest a possible way to reduce energy and particle losses by ELMs and maintain quasi-stationary state by modulation of co-current direction NBI and counter-current direction NBI.*

Keywords: EAST; ELM mitigation/suppression; counter current direction NBI; toroidal rotation

1. INTRODUCTION

This presentation is devoted to introduce the recent result of a non-stationary, effective edge localized modes (ELMs) mitigation/suppression regime obtained by counter current direction NBI heating in the EAST experiments. This method of ELM mitigation has been demonstrated in JT-60U before [1]. Using the combination of four toroidal NBI sources (two in the co-current direction and the other two in the counter-current direction), we are able to scan the plasma toroidal rotation velocity by injecting different NBI torque in the EAST 2015 campaign

2. EXPERIMENTAL RESULT

The Experimental Advanced Superconducting Tokamak (EAST) is medium size fully superconducting tokamak which aims at steady-state operation. EAST has two beam units (each consist of two ion sources) for positive ion based NBI with a maximum power of 8 MW. A co-tangential unit at A Port（named "co-NBI"）and the other counter-tangential unit at F Port (named "ctr-NBI") can, respectively, inject toroidal momentum in the same direction as the plasma current and in the opposite direction to the plasma current. Lithium wall coating has been applied before the experiment everyday [2].

The core plasma temperature and toroidal rotation velocity are obtained by measuring Ar XVII spectra using a tangential viewing image X-ray crystal spectrometer (TXCS) [3]. The impurity content is obtained by measuring impurity line emissions using a fast-time-response extreme ultraviolet spectrometer (XUV) [4]. The central line-averaged density is measured by hydrogen cyanide (HCN) far-infra laser interferometer.

Two type of NBI combination shots are used in our experiment.

2.1 NBI modulation shot

In NBI modulation shot, co-NBI and ctr-NBI heating is modulated with frequency of 1 Hz and duty cycle of 50%. The ratio of co-NBI and ctr-NBI heating power is chosen that plasma stored energy remain constant in current flat top stage. In addition, plasma density feedback by super-sonic molecular beam injection (SMBI) is applied to keep the density constant. The D_α spikes (indicator of ELMs) indicated that the ELMs were greatly mitigated in ctr-NBI phase (Fig 1 (d-f)). Here the toroidal rotation velocity is presented in central toroidal rotation velocity, as edge rotation velocity data is not available. Note that the magnitude of the D_α spikes vary according to central toroidal rotation velocity.

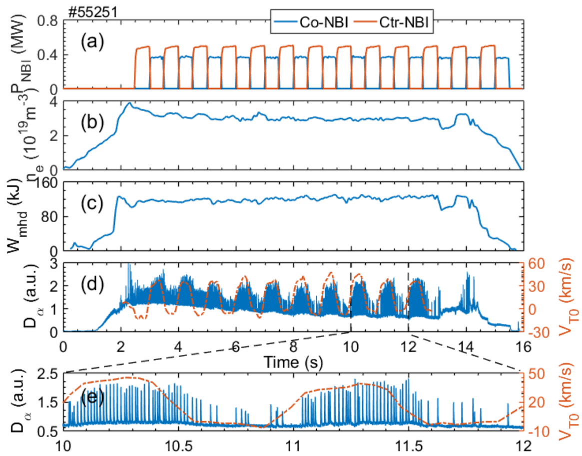

Fig. 1. Waveform of NBI modulation shot.

2.2 Non-NBI modulation shot

In non-modulation shot, four ion sources were utilized to ramp co-NBI and ctr-NBI heating power in step. In this shot, the auxiliary heating power is not constant, and there is no SMBI feedback control. It is found both the ELM amplitude and frequency was reduced with increasing P_(ctr-NBI)-P_(co-NBI), i.e. the counter-Ip NBI torque (Fig 2 (e-h)). After turning off co-NBI, ELMs were suppressed with ctr-NBI and ELM-free H-mode became non-stationary with density climbing up. List: Number the references (numbers in square brackets) in the list in the order in which they appear in the text.

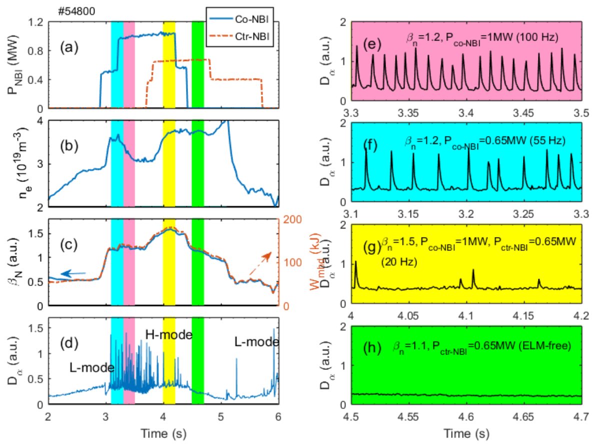

Fig. 2. Waveform of non-NBI modulation shot.

3. DISCUSSION AND SUMMARY

A major flaw of this ELM control method is that there is no alternative mechanism to provide essential radial transport. When ELMs are mitigated or suppressed with ctr-NBI, radiation power and impurity content began to increase (Fig 3). This often result in confinement degeneration and H-L back transition. An eclectic method is NBI modulation shot with appropriate duty time. It can reduce heat load in ELM-free H-mode with ctr-NBI, and expel impurity in ELMy H-mode with co-NBI.

In summary, we have found toroidal rotation can affect the ELM size in the EAST experiment. Possible explanation for ELM mitigation/suppression may be related to more negative edge radial electrical field by counter current torque. More experiment is required to validate the ELM dependence in controlled plasma parameters, as well as understanding its physics mechanism

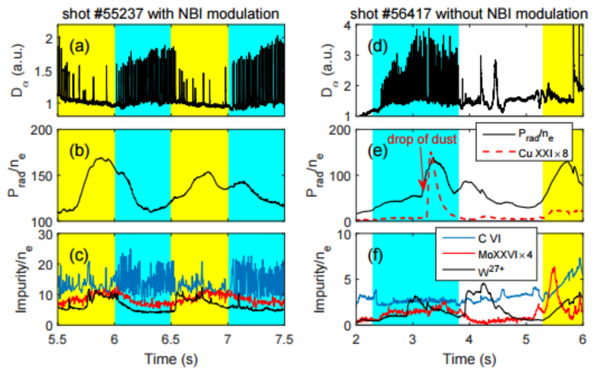

Fig. 3. Comparison of radiation power and impurity content between two shots

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