Comparison of private flux region gas injection vs. mid-plane gas injection in reducing divertor heat loads and halo currents during disruptions in NSTX

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ITER TSG & MS TSG

This work is supported by US DOE contract numbers FG03-96ER5436, DE-FG02-99ER54519 and DE-AC02-09CH11466

NSTX Research Forum for FY2011-12 Research
March 15-18, 2011
PPPL, Princeton, NJ

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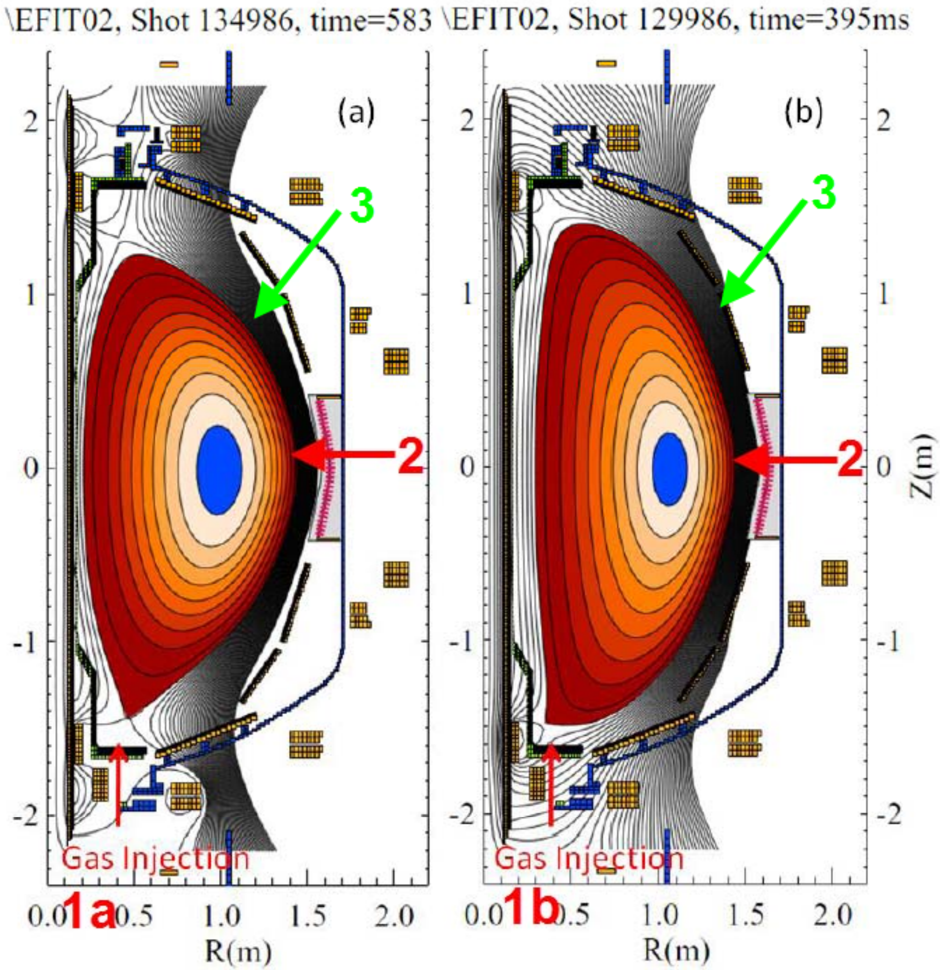
Motivation & Background

- Reducing the consequences of a disruption is a high priority task for ITER, as reflected by the ITPA Task MDC-01.
- Because of the higher toroidal field and current, runaway electrons could be an issue in NSTX-U, as noted by the PAC-29 summary recommendations.
- Massive gas injection (MGI) experiments will be conducted for the first time on NSTX to assess the benefits of this method in NSTX to reduce the negative consequences of a disruption.
- Two massive gas injections assemblies are being installed on NSTX. These will inject identical amounts of gas through a lower dome organ pipe and from the mid-plane location to assess the poloidal location variation for MGI.
  - Such a comparison study has not been conducted in tokamaks for disruption mitigation studies, and is expected to contribute to the development of suitable disruption mitigation systems for ITER and NSTX-U.

Optimum Massive Gas Injection Location for ITER

(R. Raman, S.P. Gerhardt, K.W. Kugel, T.R. Jarboe, et al.,)



1a: Private flux region 1b: lower SOL

2: Conventional mid-plane injection

3: Variation in poloidal location

Unique capability of NSTX:

Asses benefits of injection into the private flux region & the high-field side region vs. LFS mid-plane

- **Initial Experiments (FY11):**
  - -Compare MGI into private flux region to mid-plane and to SOL
  - -1000 Torr.L gas injection
  - -Ar + He + D2
- **Detailed Experiments(FY12):**
  - -Modify plenum size and valve throughput rates
  - -Consider other poloidal locations
  - -Simultaneous injection from multiple locations to maintain cold edge mantle and reduce poloidal asymmetries

Integration of Diagnostics and Resulting data

Thomson scattering, EFIT, neutral pressure gauges

Physics of gas penetration (fraction that penetrates separatrix)

H-alpha array, neutral pressure gauges

System response time (gas trigger time to first detection of injected gas interacting with the plasma edge)

Multi-color Soft X-ray, H-alpha, Ip, EFIT, Thomson scattering, Mirnov coils

Delay in current quench after the gas contacts plasma edge

Rate of current quench and vertical dynamics of the plasma

3-D MHD response to the whole equilibrium and MHD activity

Thermal quench evolution & pedestal collapse

Bolometer array- Core radiated power dynamics

Halo current sensors- Dependence on halo current amplitude on gas assimilation (Mitigated vs. beta limit and a VDE disruption)

Two color divertor fast infrared camera and Eroding thermocouples

Spatial distribution of Thermal loads & fast heat flux measurements

Locked mode, RWM mode - n=0 mode detectors - Precursors to disruption

Provide data to groups involved in NIMROD, KPRAD, EIRENE-SOLTPS

Run Plan (0.5 to 2 days)

- For all cases the primary objective is to obtain data for lower dome injection and mid-plane injection using the same amount of gas and by keeping all other conditions identical.
- The time of gas injection will be varied as the q-profile is evolving and this would provide physics information on the importance of the time and spatial dependence of the q=2 surface for initiation of the thermal quench. The toroidal field could also be varied to alter the q evolution.
- The comparisons that are being made are:
  - Private flux region injection vs. LFS mid-plane
  - High field SOL vs. LFS SOL
- Combination of gas mixtures will be used
  - Typically 10% Ar, 90 Torr.L He, 4000Torr.L D2
  - Initial experiments would begin with pure D2 or He with NBI valves closed
  - Final data will be obtained using 4 and or 6MW NBI heated discharges

Run Scheduling

Probably the best time to schedule this would be early in the run even before a serious HHFW campaign

Based on the results obtained, a final set of measurements would be obtained (towards the end of the NSTX run using smaller plenums and perhaps faster valves, and improved gas combination)

See Abstract for details on run breakdown

Detailed Run Plan

Step-1: [Deuterium-only, No NBI] – 3 hours [To assess impact on machine and diagnostics]
Day-1 (3 hours): Run an Ohmic plasma such that the private flux region is over the organ pipe opening to the vessel. During the flat-top of these discharges inject up to about 5000 Torr.L of D2 from the lower dome and then from the mid-plane MG injector. These tests carried out in steps would provide needed information on the impact of large quantities of gas injection on diagnostics and recovery for the subsequent shot.

Step-2: [Ar, He and D2, No NBI] – 6 hours [Settle on a gas composition and examine impact of large amount of He vs Deuterium as large amount of He may not be possible in Step 3]
Day-2 (2 hours): Repeat with a mixture of 10% Argon and 90% He (Ohmic plasmas) and with the NBI gate valve closed. Do this early during the run so that HHFW is able to scrub any Argon trapped on the walls, and before introducing too much Li in the vessel.
Day-3 (2 hours): Repeat with a mixture of 10% Argon, 90 Torr.L He and the rest D2 (Ohmic plasmas). Then, induce a VDE without MGI to obtain reference data.
Day-4: (2 hours): Run an Ohmic plasma so that the organ pipe is over the lower SOL region. Inject a mixture of 10% Argon, 90 Torr.L He and the rest D2. Then, induce a VDE without MGI to obtain reference data.

Detailed Run Plan-2

Step-3: [Ar, He and D2, With NBI] – 4 hours – This is the main experiment, but probably cannot be run as the first step

Day-4 (1 hour): Repeat with 4MW NBI heated H-mode discharge at 800kA (NBI valves will be open). 10% Argon, 90 Torr.L He and the rest D2. Obtain halo current data by disrupting this discharge by inducing a VDE. [Private flux region over organ pipe]

Day-5 (1 hour): Repeat with 4MW NBI heated H-mode discharge at 800kA (NBI valves will be open). 10% Argon, 90 Torr.L He and the rest D2. Obtain halo current data by disrupting this discharge by inducing a VDE. [SOL region over organ pipe]

The first priority is to obtain the comparison data. The VDE experiments could be done on a separate day.

Day-6 (1hour): Repeat with 6MW NBI heated H-mode discharge at 1MA (NBI valves will be open). 10% Argon, 90 Torr.L He and the rest D2. Obtain halo current data by disrupting this discharge by inducing a VDE. [Private flux region over organ pipe]

Day-7 (1hour): Repeat with 6MW NBI heated H-mode discharge at 1MA (NBI valves will be open). 10% Argon, 90 Torr.L He and the rest D2. Obtain halo current data by disrupting this discharge by inducing a VDE. [SOL region over organ pipe]

The first priority is to obtain the comparison data. The VDE experiments could be done on a separate day.

Additional time would be needed to obtain missing data and to run some cases with less gas injection from the organ pipe injector or with different gas species combination. Because the required time is in small 1 to 2 hour time increments, these could be included in the schedule as a time window opens up.