PHYSICS STUDIES OF CRYOGENIC PELLET AND TRACER-LOADED PELLET (TESPEL) INJECTIONS IN THE STELLARATOR TJ-II

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ABSTRACT

- Cryogenic H_2 pellets and TESPELs[1] are injected into TJ-II using a shared system. Strong fluctuations are detected by magnetic pick-up coils during, and for a brief period after, a H_2 pellet is injected into microwave- or NBI-heated plasma. A brief reduction in broadband magnetic fluctuations (20 – 500 kHz) is observed after an injection.

BACKGROUND

- A variety of transitory effects are observed as a pellet travels through plasma in magnetic confinement devices.
- One observation is short-lived increased activity in magnetic pick-up coils.
- While such activity has been reported, the origin has not been considered.
- Such magnetic activity is seen for H_2 pellets in ECRH and NBI heated plasmas of the stellarator TJ-II. This is not seen for impurity pellets.

EXPERIMENTAL SET-UP ON TJ-II

TJ-II

A heliac-type stellarator, R = 1.5 m, B_0 ≤1.1, designed to explore a wide range of rotational transforms ($0.9 \leq \iota_0/2\pi \leq 2.2$), $\Delta\iota/\iota$ <6% ($\iota/2\pi$ = n/m (ι is iota value, n and m are toroidal and poloidal helical winding numbers)[2].

PLASMA PARAMETERS

ECRH: $\bar{N}_e \leq 1.2\times10^{19}$ m^{-3}, $T_{e0} \leq 2$ keV, $T_{i0} \leq 80$ eV, $t_{ecrh} \leq 300$ ms.

NBI: $\bar{N}_e \leq 5\times10^{19}$ m^{-3}, $T_{e0} \leq 0.4$ keV, $T_{i0} \leq 120$ eV, $t_{nbi} \leq 110$ ms.

PELLET INJECTOR SYSTEM

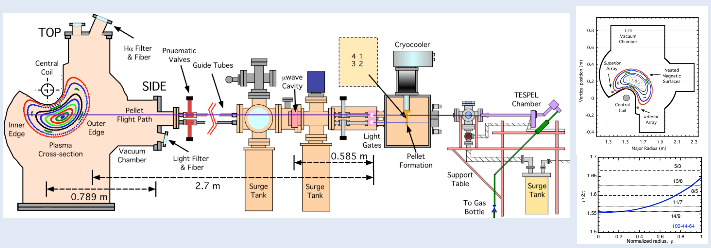
A 4-pellet pipe-gun type injector is available[3]. Only 0.66 mm ($\leq 0.6\times10^{19}$ H) & 0.76 mm ($\leq 1.2\times10^{19}$ H) diameter pellets are considered here.

A TESPEL (Tracer-Encapsulated Solid Pellets), -$(C_8H_8\text{-})_n$, injector is piggy-backed to the upstream end of 1 line[4]. Flight paths pass close to the axis.

DIAGNOSTICS OF INTEREST

2 new arrays of magnetic pick-up coils follow the helical field coil as it winds around the central field coil. Each one consists of 32 sets of equally spaced coils, each set containing 1 poloidal, 1 radial & 1 toroidal coil, that extend toroidally along 1 quadrant[5]. The arrays are positioned close to the plasma column, one called *Superior*, the other *Inferior*.

lhs: Sketch showing cryogenic & TESPEL injectors with guide tubes, diagnostics & ablation light systems. A flight path through the plasma (magenta) & closed magnetic flux surfaces for configuration 100_44_64 are shown. top rhs: Cross-section cut showing Inferior and Superior magnetic array positions in sector D7. Bottom rhs: Normalized plasma radius vs. rotational transform for 2 magnetic configurations. Principal rational surfaces are indicated.



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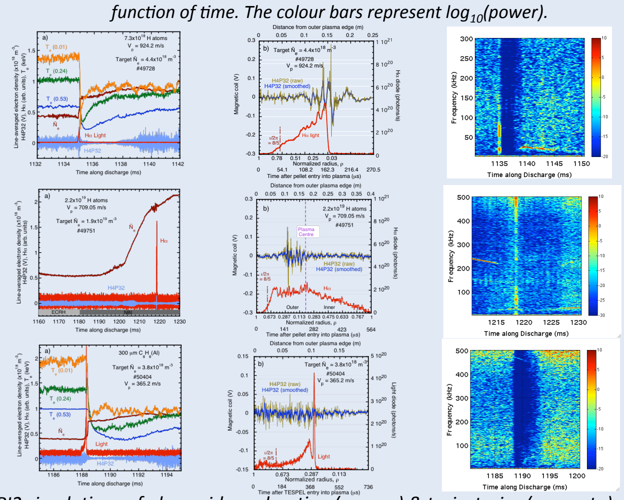
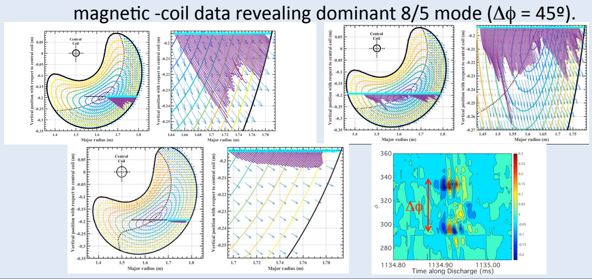
RESULTS

Top & Middle: H_2 pellet injection into ECRH & NBI plasma. Bottom: TESPEL injection into ECRH plasma. lhs: Time evolution of $\bar{N}_e$, magnetic coil, ablation light & T_e at several radii. centre: Ablation light emission plus raw & smoothed output from a poloidal magnetic coil (blue and olive) vs. time after pellet entry into plasma. rhs: Magnetic spectrograph as a function of time. The colour bars represent $\log_{10}$(power).



HPI2 simulations of plasmoid acceleration (arrows) & trajectories (magenta) showing poloidal cross-section at sector B2 & closed magnetic flux surfaces (100_44_64). top lhs: 7.3×10^{18} H injected into ECRH discharge #49728. Top rhs: 2.2×10^{19} H injected into NBI-heated discharge #49751. bottom lhs: 290 μm TESPEL injected into ECRH discharge #50404. bottom rhs: Singular Value Decomposition analysis of multi magnetic -coil data revealing dominant 8/5 mode ($\Delta\phi$ = 45º).



OBSERVATIONS

- Strong fluctuations (50 to 80 kHz) are excited in magnetic coils by H_2 pellets. Their presence is independent of the heating method.
- These occur as a H_2 pellet traverses the outer plasma region.
- Broadband magnetic fluctuations (50 to 500 kHz) reduce significantly for several milliseconds after injection of either pellet type.

FINDINGS

- Oscillations arise due to deceleration of outward drifting plasmoids, that detach in the core, near the 8/5 rational surface (ρ = 0.75). Analysis of magnetic array signals confirm that a 8/5 mode is excited. Abrupt steepening of the local pressure gradient gives rise to a short-lived magnetic instability followed by magnetic reconstruction once plasmoid homogenization is completed. HPI2 simulations support this argument[6,7].
- 2nd order enhanced ECC damping causes abrupt plasmoid breaking[6].
- Similar activity is not seen for TESPEL as plasmoids do not reach ρ = 0.75 due to reduced plasmoid outward acceleration.
- The reduction in broadband magnetic fluctuations appears to be related to the rapid drop in T_e. A similar effect is seen for electrostatic fluctuations.

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