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TOKES simulations to compare gas and pellet injection for disruption mitigation in ITER

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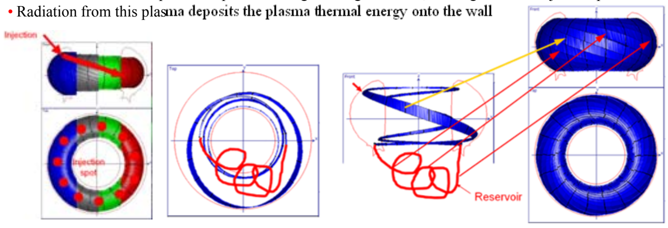
ABSTRACT

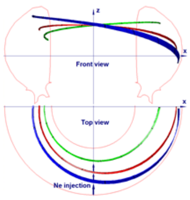
- Disruption mitigation by shattered Ne pellet injection (SPI) has been simulated using the 3D TOKES code
- Heating of the first wall from the radiation flash during TQ of the disruption initiated by the injected pellets has been assessed.
- The threshold pellet size for irradiation of the core energy has been found.
- The results of SPI and massive gas injection (MGI) simulations are compared.

TOKES APPROACH FOR POINT-WISE INJECTION

- TOKES simulates Ne plasma expansion along the magnetic tube, starting from the injection point.
- Radiation from this plasma deposits the plasma thermal energy onto the wall

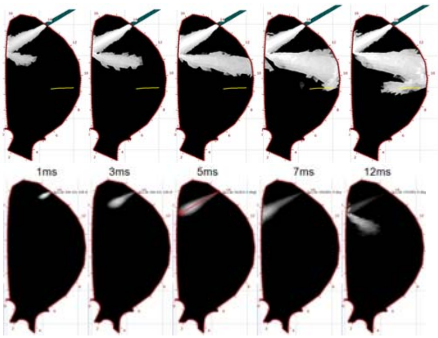


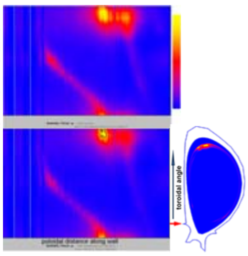
- TOKES core is subdivided into 'Radiator' and 'Reservoir'
- the 'Radiator' and the 'Reservoir' are the magnetic tubes
- D-T plasma fills both, the 'Radiator' and the 'Reservoir'
- Ne plasma expands and radiates inside the 'Radiator'
- The D-T plasma energy radiated onto the wall from Ne plasma spot
- The D-T plasma energy transported to the Ne spot along the magnetic field and radially, due to the disruptive cross-transport
- Radiation transport is 3-dimensional



SIMULATION OF NEUTRAL GAS AND PELLETS

- TOKES simulates injected Ne gas using Monte – Carlo technique
- Shattered pellet is simulated with Ne gas of artificially high density, which corresponds to the pellet density

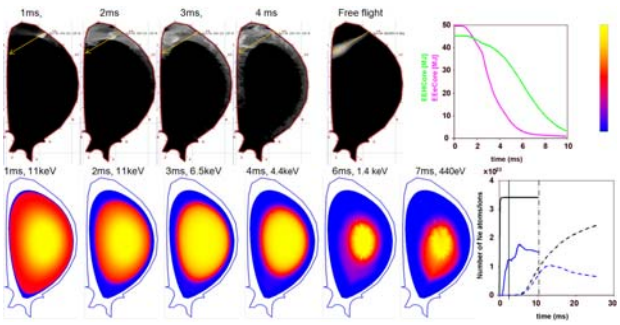




Poloidal distribution of the radiation source and corresponding wall heat flux and wall temperature

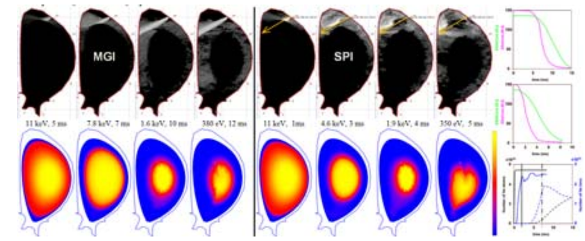
SPI SIMULATION RESULTS

- Dynamics of pellet (3.4×10^{23} Ne atoms) interaction with the core plasma.
- The Ne gas density (upper left) and T_e (lower left) are shown at different time moments.
- The TQ begins at 2.44 ms and finishes at ~5 ms, the ion thermal energy falling to zero ~10 ms.
- Time dependences of the total Ne injection (black lines) and of the Ne ions number in the core (blue lines).
- Solid lines correspond to SPI, dotted – for MGI.

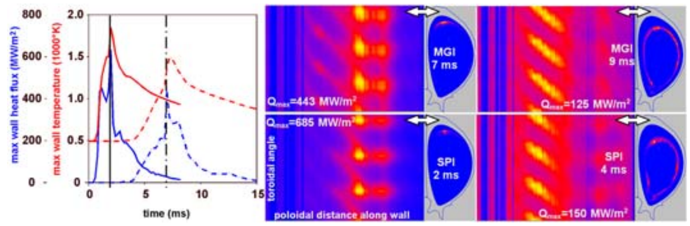


COMPARION OF SPI AND MGI SIMULATION RESULTS

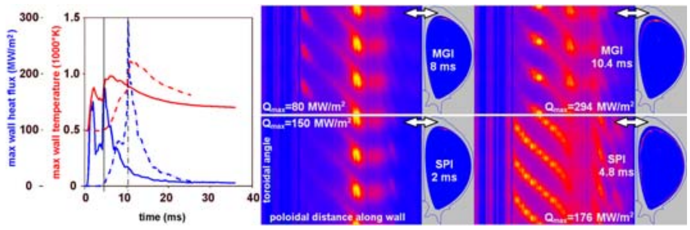
- Dynamics MGI and SPI interaction with the core plasma (3 up injectors with 5.4×10^{24} atoms each).
- The Ne gas density (upper panels) and electron temperature, T_e (lower plots)
- MGI (left group) and SPI (right group) results (time moments for upper and lower of plots are the same).
- The time dependences of electron (EEeCore) and ion (EEtHCore) thermal energy for MGI (upper) and SPI (middle). The lower plot shows the time dependences of the total Ne injection (black lines) and of the Ne ion number in the core (blue lines). Solid lines correspond to SPI, dotted – for MGI.



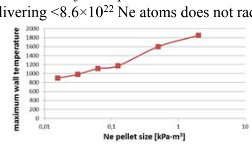
- Comparison of the wall heat flux and wall surface temperature for MGI and SPI for the same amount of Ne (3 upper injectors each with 5.4×10^{24} atoms):



- Comparison of the wall heat flux and wall surface temperature for MGI and SPI of the threshold amount of Ne: 3 upper injectors each with 3.4×10^{23} (MGI) and 8.6×10^{22} (SPI) Ne atoms:



- Maximum wall temperature versus the injected pellet size for SPI into an ITER discharge 280 MJ stored energy. Injection of pellets delivering <8.6×10^{22} Ne atoms does not radiate the total plasma energy:



CONCLUSIONS

- Disruption mitigation by shattered Ne pellet injection from three upper injectors has been simulated using the 3D TOKES code for an H-mode discharge with 280 MJ of stored energy.
- Shattered Ne pellet debris flying from injectors is simulated in TOKES by approximating the pellet as a gas of artificially high density, equal to the averaged pellet debris density.
- This approximation has been estimated to be adequate, although polarization and drift of the Ne plasma is not taken into account; the shielding due to pellet ablation is accounted for only rather crudely in this way.
- The simulations show that the maximum injection is excessive for both MGI and SPI: only a few percent of the injected Ne is ionized and ensures rapid radiation of the plasma thermal energy.
- The critical quantities required to ensure that the thermal energy is fully radiated are much lower than the actual injection capabilities: 3.4×10^{23} (MGI) and 8.6×10^{22} (SPI) Ne atoms.
- For these threshold quantities the wall surface temperatures are well below the beryllium melt temperature.
- The results of presented TOKES simulations, is a first attempt to derive heat fluxes and to compare between SPI and MGI. As a next step a pellet ablation model has to be implemented.

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