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Pellet sublimation and expansion under runaway electron flux

The current concept of the disruption mitigation system in ITER relies on the cryogenic pellet injection. At the same time, as observed recently in DIII-D, the cryogenic pellets practically explode at the edge of the runaway electron (RE) beam, and the resulting RE dissipation rate is virtually the same for both the massive gas injection and the shattered pellet injection [1]. The similar overall effectiveness of the two injection methods calls for relevant physics interpretation.
For ITER-relevant parameters, this work provides a qualitative description and related estimates of the pellet sublimation and expansion with the following key points:
• The pellets available for mitigation of the RE current are transparent for the REs with energies of the order of or larger than MeV.
• The cryogenic pellet will likely be sublimated instantly at the edge of the RE beam. This was already observed in recent experiments [1].
• The injected pellet turns into a rapidly expanding gas cloud and spreads over the poloidal cross-section of a tokamak on a millisecond time scale. By the time it covers the poloidal cross-section, its temperature lies in a 1 eV range, and the ionization fraction stays low. Further ionization of the material is likely to occur during the toroidal expansion phase. As a result, the pellet acts similar to the massive gas injection.
• The expanding cloud is initially opaque and radiates as a black body. It becomes transparent to radiation only after it already covered a significant fraction of the poloidal cross-section.

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[1] D. Shiraki et al., Nucl. Fusion 58, 056006 (2018)

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