Heating laboratory plasma to 100 million degrees

In magnetically confined fusion, the plasma needs to be heated to hundreds of million degrees. To achieve this, radio frequency (rf) waves are one of several techniques available to heat the plasma. In the Alcator C-Mod tokamak located at the Plasma Science and Fusion Center at MIT, 8 million watts of rf source power is available (typical FM radio stations have 0.05 million watts of rf source power). The radio waves are absorbed by hydrogen ions in the plasma core and these ions then transfer energy to the bulk plasma deuterium ions (an isotope of hydrogen and the fusion fuel) so that the entire plasma is heated. Like radio stations, an antenna is utilized to couple the power from the transmitter to waves that carry power into the plasma core (or to your car radio) and this antenna is placed near the plasma boundary.

The confining magnetic field isolates most of the hot plasma from the "room temperature" walls and structures outside the plasma boundary like the rf antenna. However, a small leakage of particles and power from the core does escape to the walls and strongly influences the transitional plasma (plasma between the hot confined plasma and the material walls). The plasma bombardment of the material walls causes erosion, much like rain causes soil erosion. The eroded material may be transported to the core plasma where it adversely affects fusion performance by through excessive radiation from the wall or antenna material. Operating the antenna near the plasma boundary can bring additional complications like increasing the erosion rate and the penetration of eroded material into the core plasma.

Several nations, including Europe, Japan, China, Korea, Russia, India, and the US are currently planning the construction of a large next-step burning plasma fusion experiment called ITER. The current ITER design utilizes a combination of carbon (low Z) and metals as first wall materials and plans to utilize rf to heat the plasma. Here at Alcator C-Mod we have developed a large knowledge base of the rf - plasma boundary interactions and their impact on the plasma core.

Through a series of experiments, we have observed that the rf enhances erosion away from the antenna at specific locations and this erosion is significantly higher than plasmas without rf. The application of rf also modifies properties of the transitional plasma magnetically linked to the antenna. This link suggests the fields from the antenna are playing a significant role in the modification of the transitional plasma properties. The solution to mitigating these rf affects will rely on understanding how the rf fields from the antenna impact the transitional plasma.

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