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New Method for Driving Flows in Plasmas Demonstrated

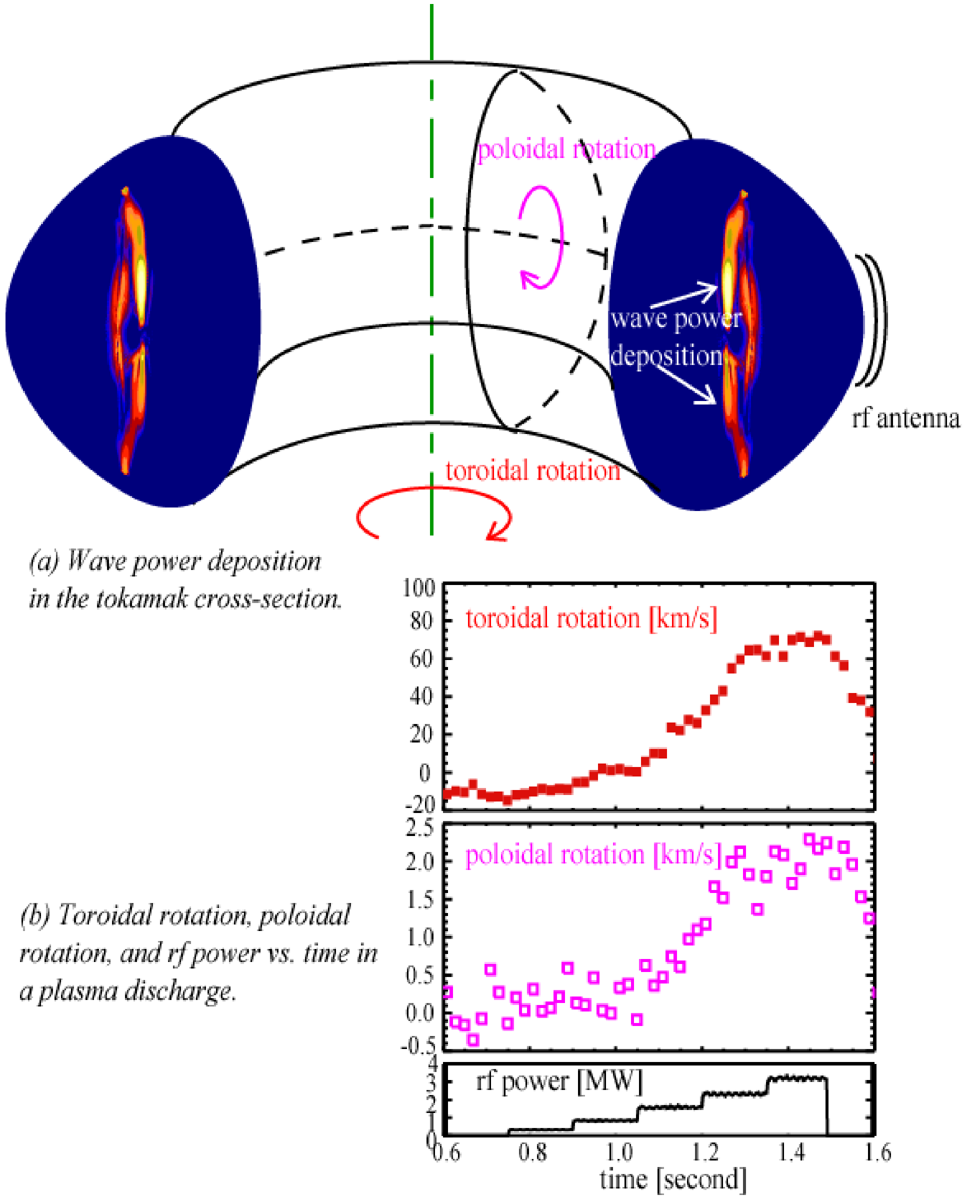
Plasma flows, driven by mode-converted waves in the ion-cyclotron range of frequencies, have been demonstrated for the first time.

In the latest experimental campaign of the Alcator C-Mod tokamak located at the Plasma Science and Fusion Center at MIT, we have demonstrated, for the first time, that significant toroidal and poloidal plasma flow can be driven by radio frequency (rf) waves. The experiments launched waves with a frequency of 50 MHz into plasmas consisting of deuterium and helium-3 (the isotope of helium with atomic mass of 3) and a magnetic field around 5.1 Tesla. The rf wave undergoes a process called “mode conversion” inside the plasma. During the mode conversion process, the launched rf wave slows down, its wavelength becomes shorter, and the wave is converted from the launched fast wave into a pair of slow waves, the so called ion cyclotron wave and ion Bernstein wave. When the amount of the helium-3 ions is at an optimal level, these shorter wavelength wave modes can interact with the plasma ions and generate plasma flow.

Toroidal and poloidal flows are beneficial in confined plasmas because they can suppress instabilities across a range of scales, reducing plasma turbulence and transport and allowing higher plasma pressures to be obtained. In most tokamak experiments, plasma toroidal flow is driven by externally injected neutral beams, though in some cases, flow can also appear spontaneously without direct momentum input. However, in reactor scale devices like ITER, the neutral beams will likely not be adequate to drive sufficient plasma flow to suppress turbulence. At the same time, spontaneous plasma rotation is not well understood and does not allow simple external control. Therefore, tokamak researchers around the world have been searching for other means to drive plasma flow, particularly via externally launched rf waves.

In the accompanying figure we show the time histories the poloidal and toroidal velocities. The toroidal velocity is peaked near the axis for $r/a < 0.3$. The poloidal velocity is peaked in the region of $0.3 < r/a < 0.6$. Power deposition calculated for the mode converted ion cyclotron wave on helium-3 ions are also plotted. The power deposition is obtained from a two-dimensional full wave simulation code, TORIC, and it shows a broad peak, approximately on the same location where poloidal flow is observed. The short wavelength modes, predicted by the simulations are shown in the figure and are observed experimentally as well.

The effect of the flows on plasma transport has been analyzed, suggesting that the flow shear is marginally sufficient to affect the turbulence. We expect that future experiments will provide more direct evidence of turbulence suppression and plasma performance enhancement. Such mode conversion process may be applicable to ITER using its ion cyclotron range of frequencies heating system. Using appropriately chosen plasma species, magnetic field, and plasma density/temperature, it may be possible to drive significant flows using similar mode conversion processes.



(a) Wave power deposition in the tokamak cross-section.

(b) Toroidal rotation, poloidal rotation, and rf power vs. time in a plasma discharge.

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Observation of ICRF Mode Conversion Plasma Flow Drive on Alcator C-Mod
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