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# Microwaves Can Plug Leaks in Fusion Plasmas

Microwave heating significantly alters troubling Alfvén waves, offering insights into the physics of the waves themselves.

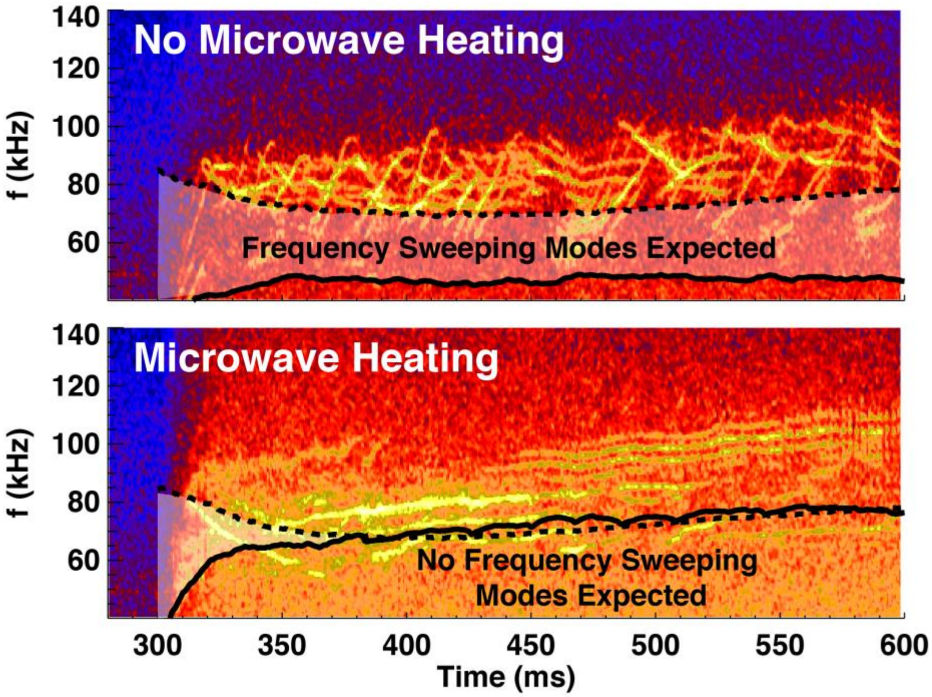


Image courtesy of M. Van Zeeland

Spectrograms showing the change in wave activity with and without microwave heating. With no heating (top), two types of Alfvén waves are observed. With heating near the wave location (bottom), no frequency sweeping waves are expected or observed. The black curves indicate that the electron heating leads to closure of a theoretically predicted window (gray shading) in which these waves exist. The plots show the frequency of the waves in kilohertz and the time in milliseconds.

## The Science

Powerful microwave beams, similar to those used to heat a cup of cocoa, can be steered into fusion plasmas causing heating at precise locations. Scientists found that microwave beams deposited near the location of Alfvén waves (another important type of wave that can cause the loss of high energy particles needed to heat the plasma) modify the wave activity significantly. In some cases, the microwaves completely remove Alfven waves. Unlike a type of constructive or destructive wave interference phenomena that may come to mind, here the microwave heating causes changes to the background plasma which increases the frequency of one type of Alfven wave to a point where it no longer exists.

## The Impact

Alfvén waves can cause redistribution or loss of the fast alpha particles as well as injected neutral beam ions that are needed to heat fusion devices. If these waves grow unabated, the resultant fast ion transport can reduce performance and potentially damage vessel components. These results provide new information about one of the few known tools (microwaves, or formally electron cyclotron heating) able to target and alter Alfvén waves in fusion plasmas. In addition, the research strengthens our basic understanding of the physics of the waves themselves.

## Summary

Localized electron heating by microwaves has been shown to be an effective tool for modifying Alfvén waves in DIII-D National Fusion Facility. Because localized electron heating can impact essentially all aspects of these waves, including mode drive, damping, and the actual eigenmode structure, a satisfactory explanation for this effect has been elusive and formed the basis of a joint experiment involving researchers from several devices worldwide. The researchers found that modification of the waves, specifically, reversed shear Alfvén eigenmodes (RSAEs), occurs through finite pressure effects via the microwave impact on the local electron temperature. The change in temperature gradient is the dominant factor in altering the wave spectrum in these experiments. The impact on frequency sweeping RSAEs is captured in a large collection of discharges by a simple model that is based on constraining the RSAE frequency sweep to be in a frequency range (or “window”) dependent on the plasma pressure profile and magnetic topology. This new understanding, coupled with the fact that discharges with reduced RSAE activity also have improved fast ion confinement, offers worthwhile and intriguing possibilities for Alfvén wave control applications.

## Contact

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## Publications

M.A. Van Zeeland, W.W. Heidbrink, S.E. Sharapov, D. Spong, A. Cappa, X. Chen, C. Collins, M. Garcia-Munoz, N.N. Gorelenkov, G.J. Kramer, P. Lauber, Z. Lin, and C. Petty, “Electron cyclotron heating can drastically alter reversed shear Alfvén eigenmode activity in DIII-D through finite pressure effects.” *Nuclear Fusion* **56**, 112007 (2016). [DOI: 10.1088/0029-5515/56/11/112007]

## Related Links

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