Input to the FESAC Priorities Panel: RF Heating Technology

Submitted by
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Summary
A strong program of basic and applied research in enabling technologies must be a priority in a well thought out plan for development of Fusion Energy. A strong program of Electron Cyclotron Heating Technology is required to meet the challenges of present day programs, both for domestic devices and for ITER, as well as future program needs for DEMO. Technology development must go hand-in-hand with scientific advances in plasma physics research.

What is ECH Technology?
Electron Cyclotron Heating (ECH) and Electron Cyclotron Current Drive (ECCD) are used for plasma heating and current drive at the electron cyclotron resonance, requiring 28 GHz in frequency for each Tesla of magnetic field (i.e. 140 GHz for a 5T plasma). The high frequencies employed, and the high power necessary, require the use of gyrotrons as the source of the microwave radiation. Power produced by the gyrotron must be mode converted to a fundamental waveguide mode for transmission to the plasma through low-loss transmission lines. The power is typically launched into the plasma from a relatively simple antenna.

Why ECH Technology?
ECH has several very strong physics and engineering advantages for plasma heating including: direct coupling of waves to the plasma without mode transformation; highly localized wave absorption; demonstrated ability to suppress potentially dangerous Neoclassical Tearing Modes; easy modulation in time for studies of thermal diffusion; simple and small launching structures consistent with a reactor wall.

Where is ECH being used in the US Program?
The DIII-D tokamak at General Atomics has one of the world's largest ECH systems; it uses gyrotrons built by Communications and Power Industries (CPI) of Palo Alto and transmission lines built by GA. The US ITER Project led by the Oak Ridge National Laboratory is building 24 transmission lines for ITER, each rated for 2 MW of power under continuous operation.

Was ECH Technology Featured in ReNeW Needs?
Yes. Themes 1 (Burning Plasmas in ITER) and 2 (Creating Predictable, High-Performance, Steady-State Plasmas) require ECH Technology development. The ECH technology development is also crucial to developing an optimized and attractive fusion reactor (Theme 5).

Who Works on ECH Technology?

Basic research on ECH Technology within the DOE Virtual Lab for Technology is primarily conducted at three universities: MIT, Univ. Maryland and Univ. Wisconsin, with almost all of the funding going to support graduate students and postdoctoral associates. General Atomics and Communications and Power Industries are affiliated with the VLT program and benefit from its discoveries, but receive no direct funding for their technology research. The Oak Ridge National Laboratory is funded by the US ITER Program for their ITER ECH projects but not for basic research on ECH technology. Small businesses also contribute to ECH Technology development.

What's Exciting about ECH Technology?

Physics and engineering challenges of ECH Technology are at the forefront of modern physics and engineering research; the challenges stem from the very high microwave frequencies used and the extremely high output powers required. The gyrotron is a major area of research worldwide with current research aimed at the possibility of multi-megawatt sources; the detailed behavior of mode competition; and the ability to make multi-frequency and tunable gyrotrons. Gyrotrons operating at higher frequency and efficiency will be needed for DEMO. Transmission line research investigates the modes of corrugated waveguides and the losses at miter bends and polarizers; these research results are crucial for the success of ITER. The university based research groups provide support and a base of knowledge for the ECH components of the domestic magnetic fusion program on DIII-D leading to future installations on ITER and DEMO, without which it is unlikely that these devices can succeed. They do this while training the future scientists and engineers who will keep the U.S. in the forefront of technology generally and magnetic fusion research specifically.

What's Next?

The VLT ECH Technology program provides experimental and theoretical support for the ITER project. Graduate students working on ITER related activities cannot be directly funded by ITER because ITER funding is only provided year to year and must emphasize development over basic research.

What's the Problem?

Funding. In the President's FY13 budget request, ECH Technology is slated for a reduction from an annual funding level of $800k to $100k. This represents a closeout funding level under which the US will lose its capability to conduct an effective research program in this area. This funding proposal will take the U.S. from a world leadership position to one in which we are no longer able to match the capabilities of our international competitors. We decry our eroding capabilities in science and technology, yet we threaten not to support the very advanced research areas in which we are recognized as world leaders.

ECH technology should have a higher priority!