APPLICATIONS OF HIGH POWER MILLIMETER WAVES IN THE DIII–D FUSION PROGRAM

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First operation into a tokamak plasma of a new generation of MW level, 110 GHz generators (gyrotrons) for plasma heating and current drive applications on the DIII–D fusion experimental device has been achieved. The desire for high power, cw millimeter (mm) wave sources to support fusion research and development is just now beginning to be realized. The frequency required for fusion applications is related to the strength of the confining magnetic field. Plasma heating and current drive relies on the strong absorption achieved when the wave frequency matches the natural "cyclotron" frequency of electrons in a magnetic field or its harmonics. Recent progress in fusion experiments highlights the need for detailed control of the plasma for which mm wave systems are ideally suited. The importance of mm waves in these future directions will be described.

The vacuum transmission components necessary for transmitting, monitoring, and launching high power 110 GHz waves into a plasma have been developed at General Atomics (GA) and will be described. High power mm waves have a number of attractive technological features compared with other candidate plasma heating and current drive technologies. Millimeter waves can be transmitted with high power density over large distances with low losses by utilizing corrugated waveguides, so the generators can be sited remotely, facilitating maintenance and saving valuable space near the reactor.

The goal of producing clean, inexhaustible energy by the "fusion" of light elements is becoming a reality. Significant fusion power output (up to l0 MW) was demonstrated in two experiments over the past few years, one in the U.S. and one in Europe. Both experiments relied on a magnetic confinement geometry based on the tokamak concept which was originally developed by the Russians, but is now pursued by all of the major fusion research participants. Isolation of the hot plasma from the doughnut-shaped containment vessel walls in a tokamak is achieved by a combination of magnetic fields produced by an externally applied "toroidal" magnetic field plus a "poloidal" magnetic field generated by a current flowing in the plasma. Although single particles should be perfectly confined by these magnetic fields, collisions between particles produces some loss of particles across the magnetic "surfaces" to the wall. Decades of research have shown that the losses typically are much larger than expected due to "collective instabilities," but recent experimental successes have demonstrated regimes in which the "confinement" is closer to the expected level. An international effort is underway to design and build a device called the International Thermonuclear Experimental Reactor (ITER) which will demonstrate all of the essential elements of a fusion power plant.

The enormous progress which has been made in the magnetic fusion program over the past few years is due in large part to an improved understanding of the physics of the heating and containment of the plasma (hot ionized gas) in these doughnut-shaped confinement devices. Improved confinement regimes resulted in part from controlling the distribution of the current flowing inside the plasma, and theoretical understanding indicates further optimization of the plasma stability and confinement in tokamak devices can be achieved. This is an area where high power mm waves appear to be the key research tool! By launching waves directed along the torus, current can be driven inside the plasma and the detailed distribution of the current within the plasma cross section can be controlled. These ideas will be explored using the DIII–D tokamak at GA in San Diego, a DOE-funded national facility. The DIII–D device with its elongated poloidal cross section, its poloidal divertor, and its flexible heating and current drive features contains the main features envisioned for ITER and future tokamak reactors, so it is an ideal facility to investigate the detailed control of the pressure and current profiles in advanced tokamaks using mm waves. An ambitious mm wave program is planned for DIII–D with the ultimate level of 10 MW of 110 GHz power achieved in several steps, beginning with 3 MW experiments next summer.

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