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Taming Magnetically Confined Plasmas with RF Waves: A Historical Perspective[1]

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Heating and profile control by RF waves in magnetic fusion experiments has led to the development of a new area of physics, namely wave propagation and absorption in high temperature plasmas in complex magnetic field geometries. In addition, the development of high power microwave sources as well as novel antenna structures capable of handling high RF powers has also been necessary. In this talk I shall summarize the historical progression of relevant results in three frequency regimes, namely the ion cyclotron range of frequencies (ICRF), the electron cyclotron frequency and its harmonics (ECRH), and the lower hybrid frequency range (LHRF). In the ICRF regime breakthrough heating results were obtained in the 1980s in tokamaks with good confinement of energetic ions, such as PLT, TFTR and JET. In the period of late 1970s to mid 1980s the theory of RF current drive (LHCD, ECCD and that of fast wave, or FWCD) was developed. Soon thereafter efficient lower hybrid current drive was demonstrated in tokamak experiments such as Versator II, Alcator–C and PLT, and later JT60-U, Tore-Supra and JET. High harmonic FWCD has been also demonstrated on DIII-D and NSTX. Long pulse multi-MW LHCD experiments are now in preparation on the new superconducting tokamaks EAST (China) and K-STAR (Korea). ECRH results in the 1980s and beyond progressed rapidly with the development of gyrotron sources at the MW level and subsequently efficient heating and current drive was demonstrated on DIII-D, Asdex-U, JT-60U and TCV, including the stabilization of neoclassical tearing modes. Recent gyrotron tube development at the MW level at 170 GHz ensures the availability of ECH and ECCD on ITER. Finally, new results on RF induced transport phenomena have been discovered, such as enhanced plasma rotation and flow drive that hold promise for optimizing ITER performance.

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