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EC-19

Summary of ECE Presentations at EC-19

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Abstract. At the EC-19 workshop there were ten presentations in the topic of diagnosing and heating plasmas with Electron Cyclotron Emission (ECE) and Electron Bernstein Wave (EBW). Innovations continue in designs of ECE systems while tried-and-true instruments still provide adequate data to explore new areas of research. Heterodyne radiometers and Michelson interferometers carry on as the bedrock of ECE electron temperature (T_e) measurements while ECE imaging systems continue expanding their capabilities. The design of the ITER-ECE diagnostic system is in its advanced stages; solutions are being found for challenges in the transmission lines and front-end calibration sources.

1 Introduction

The ECE topics at EC-19 were presented in three talks and seven posters. The topics naturally divide themselves into the primary type of instrument involved, Michelson interferometer, heterodyne radiometer, and ECE-Imaging instruments, with a separate section for ITER ECE systems plus a special related topic of EBW heating.

2 Measurement systems

2.1 Measurements with Michelson interferometers

Two papers dealt with the calibration of Michelson interferometers. A. Sinha reported on the calibration of the Michelson that will be used on the SST-1 tokamak. The system was calibrated at Culham before being sent to India. Two blackbody sources at 873 K and 77 K respectively were used, obtaining well-resolved response curves and verifying the stability of the instrument. M. Austin showed measurements of the variation of sensitivity of the Michelson instrument with humidity. For the DIII-D tokamak's system with the 18 m corrugated waveguide transmission line in air the results showed ignorable changes in response for low harmonic frequencies (70-300 GHz), less than 1% for relative humidity changes of 25% to 67%. But attenuation due to water vapor increases strongly with frequency such that the changes brought about at high frequency (300-1000 GHz) can be 5% or greater and hence need to be taken into account for data used in this range.

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2.2 Measurements with heterodyne radiometers

Three papers showed results from heterodyne systems. V. Siju summarized the radiometer diagnostics on the IPR tokamaks. The SST-1 system, eight channels covering 75-85 GHz, is providing well resolved T_e data. The ADITYA-U system is under construction; it will consist of 16 channels covering 75-94 GHz. S. Denk gave a talk discussing measurements in ASDEX-U of non-thermal ECE in the edge channels of that tokamak's 60 channel system. Forward modeling of the edge emission data has provided valuable information about the non-thermal distribution. Finally, M. Fontana presented data from the TCV tokamak heterodyne radiometer suite. TCV has multiple systems with a variety of flexible configurations. A highlight of the data was from TCV's Correlation-ECE system, that showed a strong reduction in T_e fluctuations for plasma discharges with a negative triangularity shape over an equivalent positive triangularity shape, indicating a causal relationship between the reduced turbulence and the improved confinement in the "backwards-D" configuration.

2.3 Measurements with ECE-Imaging

Results were presented from the ECE-Imaging system on KSTAR by M. Choi. The 2-D system was used to observe the onset of m/n=2/1 magnetic islands with various actuators. In the case of a density ramp actuation the 2-D contours closely resemble ballooning mode simulations. Mode structure was mapped out during the growth, crash, and recovery phases of both small and large minor disruptions. KSTAR now has a second ECE-I system located 22.5 degrees toroidally from the first system; this permits 3-D imaging of plasma T_e structures. This capability made possible observation of the modes of major disruption where the 2/1 magnetic island was seen to interact with a cold bubble which affected its growth. This could be one explanation for the explosive 2/1 island growth in a major disruption.

2.4 ITER ECE systems

There were three papers discussing ECE systems related to ITER. S. Danani gave a talk on the testing of a prototype receiver for the ITER high frequency radiometer. The receiver, which covers the 200-300 GHz range, was put through noise temperature and sensitivity checks and subsequently measured plasma signals at the DIII-D facility. The instrument met ITER requirements of 20,000 K noise temperature and 500 V/W sensitivity and was shown to make linear, frequency resolved measurements of plasma T_e when compared to simultaneous data from the DIII-D Michelson interferometer. R. Kumar presented data from the characterization of a high temperature blackbody source intended to be used in the ITER instrument room. IR measurements at 500 ˚C validated the high emissivity and good thermal conductivity of the silicon carbide source element.

G. Taylor gave an overview talk on the status ITER ECE diagnostic system. Good progress has been made in the design of interlocking systems that are shared between the US and IN-DA groups. The front end optics design is nearly final; recent changes were made to redirect the oblique view away from the ECH launchers and to accommodate improved neutron shielding. The hot calibration source (1000 K operating temperature) has been through several design iterations in order to meet tough requirements for shock loads, radiation loads, and overall robustness. The path of the transmission line (~45 m length) and the beam modification units (splitter boxes) are designed. The final details of the transmission line waveguide are awaiting testing of the two candidate options, smooth wall or dielectric wall, both which would be in circular metal tubing. The layout of the ITER ECE instrument hall, containing two Michelson interferometers (70-1000 GHz), a low frequency radiometer (122-230 GHz) and a high frequency radiometer (220-340 GHz) has been decided.

2.5 EBW heating

A. Koehn presented a paper on electron Bernstein wave (EBW) heating on the TJ-K stellarator. EBW techniques are a way to launch and receive waves in over-dense plasmas and in this case the heating and current drive aspects were investigated. Using a novel phased array antenna that steers via small frequency changes, heating was observed as the density was increased to the point where the O-X-B mode conversion for 2nd harmonic took place. Additionally, reduction of broadband turbulence was obtained when heating at high harmonic frequencies.

3 Conclusions

ECE continues to be a major diagnostic for T_e measurements in magnetically confined high temperature plasmas. Heterodyne radiometers and Michelson interferometers are still the major contributors for most experiments. Advanced versions of heterodyne instruments, such as correlation radiometers and 2- and 3-D imaging systems are exploring the finest details of electron temperature structures in plasmas. The design of the ITER-ECE diagnostic system is well along. Challenges are being found due to the machine size and nuclear aspects of ITER, particularly in the areas of hot source development, transmission line design. These challenges are being met and it is expected that the ECE diagnostic will be an important contributor to ITER plasma physics understanding.