Topics in Plasma Dynamics and Diagnostics

This group runs a small stellarator experiment (TJ-K) for the investigation of turbulence and transport. It is heated by microwaves and the main diagnostics are Langmuir probe arrays and microwave receivers. Simulations of microwave propagation and plasma dynamics on multiple scales are performed.

Characterisation of non-linear processes in microwave heating (parametric decay instability):

- different types of small antennas will be used to measure frequency spectra in microwave heated plasma
- compare measurements from small local antennas with distant horn antennas
- identify components in the frequency spectra by performing parameter scan

Influence of fluctuations on wave coupling processes in full-wave simulations:

- perform full-wave simulations of microwaves in magnetized plasmas
- study the influence of perturbations on wave mode coupling processes in the plasma
- compare with quasi-analytical models

Influence of plasma density perturbations on microwave propagation:

- perform full-wave simulations of microwaves in magnetized plasmas
- study the perturbing effect of plasma density variations on microwaves used for plasma heating or diagnostic purposes
- compare with simpler, numerically less demanding, models
Power distribution over turbulence scales (k-spectra):
• measurements of fluctuations in plasma potential and density with 64-pin poloidal multiprobe array
• compare poloidal k-spectra (real, local, wavelet) with respect to features like cascades, spectral indices, injection region, dispersion relation (optionally under imposed plasma rotation via biasing)
• compare poloidal and radial local k-spectra

Causality analysis between turbulent transport and zonal flows:
• test method of convergent cross-mapping on known systems of different complexity (e.g. 2D Hasegawa-Wakatani turbulence with modifications (curvature, zonal flows))
• apply method of convergent cross-mapping to transport and zonal potential
• compare with transfer entropy analyses

Classify equilibrium and turbulence via neural networks
• measure equilibrium profiles and turbulent fluctuations in plasma density and potential for different discharge parameters
• design artificial neural networks (ANNs) for classifying profiles and fluctuations
• test applicability of ANNs for plasma analysis purposes at TJ-K

Diagnostics for energy decay times:
• measure time dependent electron temperature by evaluating probe characteristics conditionally
• employ a spectral line sensitive photo diode diagnostic in addition
• compare decay times of Te and detected light intensity in modulation experiments

Development of a double probe system for time dependent Te measurements:
• check different probe concepts against conditional sampling technique
• analyse Te fluctuations in correlation with density and potential fluctuations
• analyse Te dynamics in power modulation experiments

**Analysis of plasma radiation**

• analyse spatially integrated plasma radiation with a bolometer and its dependence on different plasma scenarios

• deduce a spatial profile of the plasma radiation and compare with profiles of the plasma pressure obtained from Langmuir probe measurements

• perform energy balance studies

**Investigation of fast electrons**

• apply a pulse height analyser to analyse fast electrons in TJ-K

• investigate the occurrence of fast electrons depending on plasma configuration

• compare with numerical predictions

**Topics in Microwave Technology**

Our group is involved in the microwave technology for heating and diagnostics of the high temperature plasmas in the fusion experiments ASDEX Upgrade, Wendelstein 7-X, and TJ-K. The focus is on the design of advanced components and simulations of the propagation of microwaves in components and plasmas. We have developed several simulation codes for these applications.

**Design of a 20 kW calorimetric dummy load for a 28 GHz heating system**

• 28 Ghz gyrotron installation for TJ-K needs high power dummy load for testing and conditioning

• adapt existing design of cylindrical box with water-filled teflon hoses to this frequency

• build and test design
New Solvers for the fullwave reflectometry code IPF-FD3D

- for the 2D version
- hexagonal grid: finite difference time domain (FDTD) scheme exists for vacuum, need to add plasma effects, UPML absorbing boundary conditions
- 4th order methods: central differences in time and space AND coupling to plasma, simultaneous 4th order (simultaneous may not be possible)

Simulation of the impact of edge fluctuation on Doppler reflectometry

- probing near core, but high relative fluctuations at edge, moving at different speeds
- first slab geometry, then circular, full reconstruction of the Doppler spectrum
- synthetic turbulence

Investigation of super-linear scaling and non-linear saturation of Doppler reflectometry using the IPF-FD3D code

- scattered power in Doppler backscattering depends non-linearly on density fluctuation strength
- impact of saturation on Doppler spectrum, broadening, shifts, multiple peaks?
- forward scattering in case of super-linear scaling
- UH enhancement
- (speculative topic)

Numerical investigation of poloidal correlation reflectometry

- Microwave beam sent to plasma with several receiving antennas
- Each receiving antenna defines different beam geometry, probing a different poloidal position
- Correlation of signals from different positions yields poloidal rotation direction or the pitch angle of magnetic field lines
- Turbulence from codes can be used as input for realistic scenarios
3D Simulation of the ASDEX Upgrade Interferometer for the ICRF Launcher

- 3D plasma simulation with IPF-FD3D
- Interferometer beam with large transverse plasma density gradient
- Interferometer frequency near density cutoff
- Need for optimisation of sending and receiving antennas

Investigations for quasi-optical mitre bends

- Mitre-bends are the typical waveguide components for highly oversized waveguides because they are more compact than continuous bends
- For moderately oversized waveguides, diffraction effects can partly be compensated with quasi-optical designs
- Quasi-optical mitre-bends can accurately be calculated with PROFUSION.
- The work consists of parameter studies for different ratios of wavelength and waveguide diameter and the investigation of the broadband performance.

Investigations of the imaging characteristics of waveguides with a non-trivial cross-section

- Rectangular waveguides have imaging properties, which allow the design of remote steering antennas for the heating of fusion plasmas
- The angular range is, however, limited to about +/- 12°.
- By choosing a slightly deformed waveguide cross-section, the dispersion relation of the modes can be changed, leading to a possibly enlarged steering range.
- An eigenmode solver for deformed cross sections is already available and can be used for parameters studies.