ROYAL INSTITUTE
OF TECHNOLOGY

Course information

Experimental Fusion Plasma Physics (ED2220)

2011

ECTS Credits

6 hp

Department

Fusion Plasma Physics, Alfvén Laboratory, School of Electrical Engineering, KTH

Address

Teknikringen 31, KTH Campus

Coordination, lectures and examination

Per Brunsell, 08-790 6246, per.brunsell@ee.kth.se

Course administration and student service

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Course aim

There is currently a world-wide effort to develop a new energy source based on the nuclear energy that is released when light atoms are combined (fused) in a hot ionized gas (plasma). This has led to the growth of the research area *Fusion Plasma Physics*. This course gives an overview of the current progress in fusion plasma physics research and an introduction to experimental methods used in this field. The course is useful for students who which to become more familiar with fusion energy research in general or who wish to continue with experimental research in the field.

The course aims to make the student familiar with basic experimental and diagnostic techniques used in magnetic confinement fusion plasma physics research. The student will learn about techniques for generation of high temperature toroidal fusion plasmas and be able to understand the physics underlying the common fusion plasma diagnostics methods. Experimental techniques for generation of fusion plasmas will be exemplified by studying the systems at the EXTRAP T2R reversed field pinch device at KTH. In addition, the student will gain practical experience of using some diagnostics that are available at EXTRAP T2R and analyzing real measurement data. Physics concepts underlying the plasma diagnostic methods will be introduced and discussed during lectures, using a systematic approach from first principles. A number of plasma diagnostic applications will be introduced in more detail.

After passing the course, the student should be able to

- explain the principles and experimental techniques for generation of high temperature fusion plasmas,
- explain the underlying physics principles and technical features of some commonly used basic plasma diagnostic applications,
- demonstrate the practical usage of some selected plasma diagnostics that are available at EXTRAP T2R,
- write simple computer codes for acquiring, analyzing and plotting data from some selected plasma diagnostics using a commercial software packages that is commonly used in fusion research (MATLAB),
- perform common data analysis tasks, such as curve fitting, Fourier analysis and signal filtering using available software routines,
- present analyzed data in graphic form in short reports, that includes written material that describes the diagnostic setup and the data analysis methods used.

Contents

Experimental techniques for generation of high temperature toroidal fusion plasmas, including vacuum technology, magnets, energy storage, plasma control methods and data acquisition. Underlying principles for common plasma diagnostic methods such as magnetic measurements, measurements of plasma particle flux, measurements of plasma refractive index, electromagnetic emission by free electrons, electromagnetic radiation from bound electrons, scattering of electromagnetic radiation, measurements of ion processes. Some examples of basic plasma diagnostic applications; the selection of diagnostic applications is based on the systems available at EXTRAP T2R, and includes magnetic measurements, interferometer, Thomson scattering, spectrometers, bolometers, SXR camera, and electric probes.

Language

English

Prerequisites

Good knowledge of physics and electromagnetics.

Literature

Course book:
Experimental Fusion Plasma Physics, Per Brunsell, Alfvén Laboratory, KTH

Teaching

The course is given during period 1 and includes 16 h lectures, 8 h tutorials, and 16 h laboratory work.

Course outline

A series of lectures are given in order to provide an overview of the field of experimental fusion plasma physics, including technology aspects, experimental methods and plasma diagnostics. Some parts will be taught as home assignments, being distributed at the lectures. During tutorials, example problems will be demonstrated on the black board, and then students are provided with the opportunity to solve and discuss problems themselves in group work. Laboratory projects give the students the possibility to work in groups with real plasma diagnostics, data analysis and data visualization tools. Laboratory work is summarized in short written reports. Finally, students will have opportunity to participate in plasma experiments on the EXTRAP T2R device during an experiment demonstration.

Grades

A-F

Examination

The course is examined from home assignments, group work during tutorials, and laboratory projects.

Home assignments
A total of 4 individual home assignments will be given. Home assignments are given each week, and should be handed in the first lecture the following week. Home assignments provide maximally 4 points per assignment, and a maximum total of 16 points.

Group work during tutorials
There are 4 tutorials with student group work. Active participation in group work at a tutorial and handed in solution sheet provides maximally 2 points per group work, and a maximum total of 8 points.

Laboratory projects
There are 4 laboratory projects. Active participation and handed in project report provides maximally 6 points for each project, and a maximum total of 24 points.

Maximum total from all three parts of the course is 48 points. A minimum of 24 points is required for passing the course (grade A-E).

Grades are given based on total points as follows:

Grade	Total points
A	44 - 48
B	39 - 43
C	34 - 38
D	29 - 33
E	24 - 28

Lectures in Experimental Fusion Plasma Physics 2011

Place: Alfvén Laboratory, Teknikringen 31, Seminar room. (Use elevator, floor 3).

L #	Date	Time	Book Ch.	Outline
1	31 Aug	13-15	1,2	Course introduction Principle of fusion energy: Fusion reactions, magnetic confinement Experimental fusion research: Experimental devices, an experimental fusion reactor - ITER Visit to EXTRAP T2R lab.
2	1 Sep	10-12	3,4	Vacuum technology: Gas flow physics, vacuum pumps, vacuum gauges, vacuum system components, cleaning and leak detection Magnet technology: Magnetic fields, forces on coils, circuit design, power and cooling, super conducting magnets.
3	7 Sep	15-17	5,6	Power supply systems: RLC circuits, field penetration, energy storage systems, ohmic heating circuit Toroidal symmetric configurations: Tokamak and RFP, equilibrium magnetic fields, beta value, experiments
4	8 Sep	10-12	7, 8	Radial equilibrium control: Equilibrium vertical field.Magnetohydrodynamic instabilities: Basics of magnetohydrodynamic model (MHD), Tokamak and RFP instabilities
5	14 Sep	13-15	9,10	Ohmic input power measurement: Stationary current and toroidal flux, time varying current or flux, RFP magnetic profiles. Magnetic diagnostics: Magnetic field measurements, Rogowski coil, flux loops, liner currents, RFP equilibrium measurement, MHD mode diagnostics.
6	15 Sep	10-12	11,12	Interferometry: Propagation of waves in plasma, refractive index measurement, principle of interferometer, heterodyne detection system. Electromagnetic radiation measurements: Bolometry, radial profiles from chord measurements, plasma spectroscopy, electron cyclotron emission, soft X-rays.
7	21 Sep	15-17	-	EXTRAP T2R experiment demonstration. Experiment operation, demonstration of diagnostics and data acquisition systems.
8	22 Sep	10-12	13,14	Thomson Scattering: Principle of Thomson scattering, Thomson scattering diagnostic system. Particle flux measurements: Electric probes, Neutral particle analyzers.

Tutorials in Experimental Fusion Plasma Physics 2011

Place Teknikringen 31, Alfvén Laboratory, Seminar room. (Use elevator, floor 3.

Goal During the class exercise, students solve problems which illustrate the theoretical concepts and methods introduced in the course.

Demonstration The teacher demonstrates various problem solving methods by a carrying out a few examples on the black board.

Group exercise After the demonstration, students solve selected problems themselves working in groups of 2-3 persons.

Solutions Solutions to the student work problems are handed in at the end of the tutorial. The solutions must be clearly written with comments explaining the method used on one solution sheet per group.

Examination Active participation in group work and handed in solutions sheets are part of the course examination.

T #	Date	Time	Book Chap.	Outline	Exercises
1	2 Sep	13-15	3, 4	Vacuum technology, Magnet technology.	3.1, 3.2, 4.1, 4.2, 4.3, 4.4,
2	9 Sep	13-15	5, 6, 7, 8	Power supply systems, Toroidal symmetric configurations, Radial equilibrium control, MHD instabilities.	5.1, 6.1, 6.2, 6.3, 7.1, 7.2, 8.1
3	16 Sep	15-17	9, 10, 11, 12	Ohmic input power measurement, Magnetic diagnostics, Interferometry, Electromagnetic radiation measurements,	9.1, 10.1, 10.2, 11.1, 11.2, 11.3, 12.1, 12.2, 12.3
4	23 Sep	13-15	13,14	Thomson scattering, Particle flux measurements.	13.1, 13.2, 14.1, 14.2. 14.3

Laboratory projects in Experimental Fusion Plasma Physics 2011

Place	Teknikringen 31, Alfvén Laboratory, EXTRAP T2R control room.
Time	To be decided together with students. Several possible dates and times.
Duration	Each project is estimated to require about 4 hours of lab work, including time for writing report.
Group work	Projects are carried out by students working in groups of 2-3 persons.
Goal	The projects are designed to introduce the student to various plasma diagnostic and data analysis methods. The projects are carried out in direct connection to EXTRAP T2R reversed field pinch experiment. Actual plasma diagnostics and experiment data are used.
Instructions	For each project, a short note will be handed out in advance with more detailed instructions on work procedure and requirements.
Preparations	Students are required to prepare for the lab project by reading the instructions notes and relevant sections in the text book prior to the project is started. Students must prior to the lab project be able to answer correctly a few questions in the instruction notes to demonstrate that they made sufficient preparations.
Report	At the end of each laboratory project, students are required to write and hand in a short report (2-3 pages). One report for each group and project is required. The report shall include a description of the diagnostic setup, data analysis method used and results. The results should be illustrated by selected data graphs, as detailed in the instructions for each project.
Examination	Active participation in laboratory projects and handed in project reports are part of the course examination.

Proj	Description
1	<u>Measurement of global plasma parameters.</u> Introduction to IDL software package used for data access and graph plotting. Diagnostics for plasma current, loop voltage, RFP equilibrium parameters. Measurement of ohmic input power for time varying discharge.
2	<u>Study of MHD instabilities with magnetic coil arrays.</u> Measurement of MHD mode spectrum using arrays of magnetic coils. Calculation of helical Fourier mode spectrum. Study of RWMs, and effects of active feedback control.
3	<u>Plasma particle density measurement with interferometry.</u> Corrections of experimental quadrature detector output signals. Corrections for two-pi jumps. Subtraction of base line drift. Analysis of data from two color interferometry system.
4	<u>Plasma radiation measurement with bolometer detector array.</u> Analysis of recorded data from bolometer detectors, assembly of radial profiles of plasma emissivity from an array of detectors, calculation of total plasma radiated power from absolutely calibrated bolometers.