Plasma diagnostics in basic plasma physics devices and tokamaks: from principles to practice

January 30th - 2012 to Friday, February 3rd- 2012

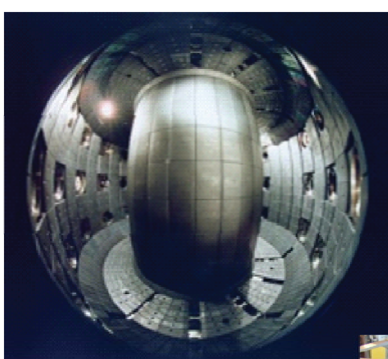
EPFL – CRPP, Lausanne, Switzerland

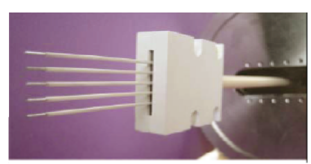
The course is a pilot programme in fusion education in the framework of the European FUSENET project (http://www.fusenet.eu/). The course lasts one week **(2 ECTS)** and is open to EPFL Students and also Students from other Universities and Institutes, including FUSENET Members. In this course, Ph.D. and Master Students learn specific aspects of plasma diagnostics with hands-on training on the TORPEX device and the TCV tokamak. The program allows Students to learn plasma diagnostics and data processing methods of modern fusion experiments and to bridge the gap between diagnostics theory and experimental practice. The course benefits from the combination of a small basic plasma physics device, TORPEX, which allows for excellent diagnostic access and easiness of data interpretation, with the TCV tokamak, in which Students have the opportunity to familiarize themselves with plasma diagnostics typical of high temperature plasmas.

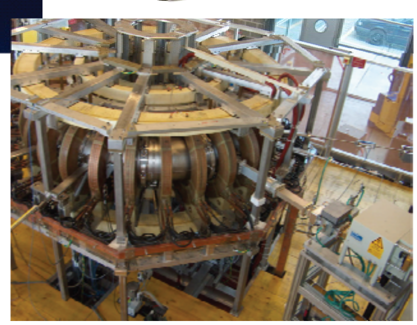
Prior knowledge required: basic knowledge of plasma physics and basic knowledge of Matlab language or similar (IDL,…)

For more information: ivo.furno@epfl.ch

For subscription refer to: http://crpp.epfl.ch/page-68266-en.html







Detailed program

(blue)	**Exercise session**
(orange)	**Practicum**
(pink)	**Ex cathedra lesson**

time	*Monday*	*Tuesday*	*Wednesday*	*Thursday*	*Friday*
8.30 10.15	*Introduction into Plasma Physics*	*Applications of magnetic measurements*	*Practicum III*	*Fast imaging techniques*	
	break	*break*	*break*	*break*	
10.30 12.15	*Visit of TCV and TORPEX*	*Practicum I Practicum II*	*Application of electrostatic measurements*	*Exercises III*	*Final exam*
	lunch	*lunch*	*lunch*	*lunch*	
13.30 15.15	*Theory of magnetic diagnostics*	*Data analysis I*	*Practicum IV*	*Practicum V*	
	break	*break*	*break*	*break*	
15.30 17.15	*Theory of electrostatic probes*	*Practicum II Practicum I*	*Data analysis II*	*Exercises IV*	
17.30 18.30	*Exercises I*		*Exercises II*		

Content details

Monday

Introduction into Plasma Physics (2 hours)

Introductory lecture

Visit of TCV and TORPEX (2 hours)

Students will be given a guided tour of the TCV and TORPEX experimental devices. Relevant diagnostics will be briefly illustrated with a particular focus on differences among the two installations (technology, constraints, etc...).

Theory of magnetic diagnostics (2 hours)

This lecture gives an overview of various magnetic measurements. It includes measurements of axisymmetric fields (flux loops and poloidal field probes), global plasma parameters (Rogowski-coil and diamagnetic loop) and deviations from axisymmetry (poloidal field probes and saddle loops).

Theory of electrostatic probes (2 hours)

In this lecture, we will review the theory of various types of electrostatic probes, including single, double, and triple probes, Katsumata, ball pen, emissive probes, Mach probes, energy analyzers, turbulent particle flux probes.

Exercises I: How to design an electrostatic probe (1 hours - Furno)

The students will learn the design principles of an electrostatic probe. Experimental constraints and requirements are discussed and possible solutions suggested.

Tuesday

Applications of magnetic measurements (2 hours)

The students will be introduced to the main applications of magnetic measurements, which includes the reconstruction of the current distribution in the plasma (ideal MHD equilibria) and the identification of instabilities.

Practicum I - The real world: experimental data taking campaign (2 hours)

Students will learn specific aspects of electrostatic probes with hands-on training on the TORPEX device. The practicum will allow students to learn plasma diagnostics and data processing/storage methods of modern fusion experiments (i.e. MDS+) and to bridge the gap between diagnostics theory and experimental practice. The diagnostics will be setup by students and they will performed directly the following measurements on the TORPEX device:

- Using a single Langmuir probe, floating potential, ion saturation current, I-V curve.
- Using a triple Langmuir probe, time evolution of electron density, temperature and plasma potential.
- Using a gridded energy analyzer, electron distribution function.
- Using a fast framing camera to acquire visible light fluctuation measurements.

Practicum II: Calibration of a magnetic probe (2 hours)

The students will use a set of Helmholtz coils to measure the signal of a magnetic probe at various frequencies. The transfer function will be parametrized using MATLAB routines and the effective area extracted.

Data analysis I (2 hours)

In this lecture, different data analysis techniques will be reviewed with a particular focus on Fourier analysis (linear and higher-order techniques), statistical methods, conditional sampling techniques, and space-based techniques (structure identification, etc.).

Wednesday

Practicum III - Learning to interpret electrostatic probe data (2 hours - Furno)

Students will access and analyze data from the TORPEX device and the TCV tokamak using Matlab routines. In particular, they will analyze experimental data obtained in Practicum II. The following subjects will be covered:

- How to interpret ion saturation current and floating potential from a single Langmuir probe and how to deal with non ideal effects, such as bandwidth limitation.
- Building experimental I-V characteristics from swept Langmuir probes in TORPEX and TCV plasmas. How to interpret the I-V characteristics and extract time-averaged electron density, electron temperature and floating/plasma potential? How to deal with non-ideal effects such as probe contamination (hysteresis) and sheath expansion?
- How to measure time evolution of electron density, electron temperature and floating/plasma potential using a triple Langmuir probe. How to deal with non ideal effects, such as the finite size of the probe tips.
- How to measure the electron distribution function using data from a gridded energy analyzer.

Applications of electrostatic measurements (2 hours)

The students will learn various applications of electrostatic probes, such as, for example, how to measure a statistical dispersion relation to investigate electrostatic instabilities.

Practicum IV - Advanced use of electrostatic probes (2 hours - Furno)

Students will access and analyze data from the TORPEX device and the TCV tokamak using Matlab routines. In particular, they will analyze experimental data obtained in Practicum II. The following subjects will be covered:

- Using data from a single Langmuir probe and multiple Langmuir probes: identification of spectral (linear and higher order) and statistical properties (i.e. spectrum, correlation, dispersion relation, skewness, kurtosis, etc…). Discover plasma electrostatic instabilities and build the statistical dispersion relation.
- Using data from multiple Langmuir probes: application of conditional sampling and BOX-CAS analysis both on TORPEX and TCV data. Discover the blob propagation and ELMs in tokamaks.

Data analysis II (2 hours)

Various methods to analyse magnetic fluctuation measurements are introduced. The methods include mode identification using MHD spectroscopy and spectrograms. Toroidally distributed measurements can be analyzed using toroidal mode decomposition. The analysis can be generalized using a general least square fit. Capabilities of the Singular Value Decomposition are also highlighted.

Exercises II: Analysis of magnetic fluctuation measurements from TCV (2 hours)

The students will have access to TCV data. They will learn how to retrieve experimental signals and visualise them using MATLAB. They will analyse the signals using the methods introduced in *Data analysis techniques I & II*. Data access routines and basic analysis routines will be supplied.

Thursday

Theory of plasma emission - fast imaging techniques (2 hours)

In this lecture, the basic mechanisms of light/radiation emission from plasmas will be reviewed. Next, fast imaging techniques in plasmas will be introduced with a focus on CMOs/CCD cameras, fast framing cameras, streaked cameras, image intensifiers, and gas-puffing systems.

Exercises III: Interpretation of magnetic measurements (2 hours - Reimerdes)

The students will calculate magnetic signals using filament models. The modeled signals are then compared to measurements during the current ramp up in TCV.

Practicum V - Data analysis from fast framing cameras (2 hours)

Students will access and analyze data from fast framing cameras both from the TORPEX device and the TCV tokamak using Matlab routines. They will use techniques such as fft, conditional sampling, etc... to get insights into the physics of turbulence (waves, filaments, blobs).

Exercises IV: putting all together (2 hours)

The students will use magnetic data, LP data and fast imaging data to extract physics information in a TCV discharge.

Friday

Final exam and wrap-up discussion.