ERASMUS+ KA220-HED-13A477C3

"Innovative Education & Training in Laser Inertial Fusion Energy"

IC1 – WP2 July 15-25, 2025

"Physics and technology of Inertial Fusion Energy"

Intensive program on plasma physics

University of Bordeaux

Pedagogical team (Univ. Bordeaux) :
Dimitri Batani, Emmanuel d'Humières, João Jorge Santos (coord.)

Confirmed Seminars by :
David Blackman (ELI-beamlines, Check Rep.), Gabriele Cristoforetti (CNR, Italy), Ioannis Fitilis (HMU, Greece), John Pasley (U. York, UK), Luca Volpe (EPM, Madrid)

Theoretical courses:

Chapter 1: Introduction and classification of plasmas + individual charge drifts in plasmas (3h, *E. d'Humières*)

- Main plasma parameters (Debye length, Landau length, ion/electron plasma frequency, ion/electron Larmor radius, ion/electron cyclotron frequency, ion/electron mean free path, collision frequency, …)
- Classification of plasmas (classical / coupled / degenerate / relativistic plasmas in temperature/density diagram)
- Examples of plasmas (natural plasmas, hot plasmas, cold and industrial plasmas)
- Drifts in a uniform magnetic field, crossed electric and magnetic fields
- Magnetic field gradient drift and magnetic mirroring (conservation of the magnetic moment)
- High frequency electric field, ponderomotive force

Chapter 2: Hydrodynamic description of a plasma (6h, *J.J. Santos*)

- Equations for the bi-fluid plasma model (continuity + Euler + EOS + Maxwell)
- Dispersion of electromagnetic waves and the critical density
- Dispersion of electron-plasma waves and of ion-acoustic waves
- Mono-fluid description of a plasma, extended-Magnetohydrodynamics
- Shock waves and relations Rankine-Hugoniot, blast waves, solution by Sedov-Taylor

Chapter 3: Kinetic description of waves and instabilities in plasmas (6h, *E. d'Humières*)

- Velocity distribution function and mean quantities
- Landau damping of electron plasma waves
- Beam-plasma instabilities
- Laser light propagation in non-uniform plasmas
- Parametric instabilities in laser-plasma interaction

Chapter 4: Radiative properties of plasmas (3h, *D. Batani*)

- Radiation emission from plasmas (bound-bound, recombination, bremsstrahulng, with some remarks on H-like and He-like spectra)
- Line broadening mechanisms
- Equilibrium in a plasma (Maxwell, Boltzmann, Saha)
- Photon absorption and opacity (in particular collisional absorption)
- Equation of radiative transfer and blackbody limit

Chapter 5: Principles of inertial confinement fusion (3h, *D. Batani*)

- Principles of inertial confinement fusion
- Nuclear fusion reactions, cross section and reactions rate
- Lawson criterion
- Fraction of burned fuel
- Energy spent in compression and in heating, energy balance
- Hot spot physics
- Radiative losses and thermal conduction losses
- Laser lighting, mass ablation and shock creation
- Setting in motion of the target, rocket model
- Implosion, stagnation, hot spot creation
- Temporal shaping of the laser pulse
- Hydrodynamic instabilities

Practical courses: *3 groups of 4 students: 2h experiments + 3x3h numerical training*

Laboratory session (LAB) (2h, *J.J. Santos + PhD student ?*)**:**

- Laser discharge at the surface of a solid target and propagation of a deflagration wave in air

Numerical sessions (3x 3h):

- **PIC simulations (PIC):** 2-stream instability and plasma expansion in vacuum exercises with code SMILEI
  (*E. d'Humières + PhD student ?)*
- **Hydro-rad simulations (HYDRO):** Laser-driven target implosion, shock formation, target gain
  (*E. d'Humières + PhD student ?)*
- **Plasma radiation simulations (RAD):** Spectral calculations with FLYCHCK
  (*D. Batani + PhD student ?*)

Seminars

Seminar 1: "Laser-based plasma diagnostics (optical diagnostics)" by Ioannis Fitilis (HMU)

Seminar 2: "Soft x-ray ablation and/or hohlraum physics" by John Pasley (Univ. York) – pref. 1st week

Seminar 3: "Theory of laser plasma instabilities in direct drive ICF" by David Blackmann (ELI beamlines)

Seminar 4: "Laser-plasma experiments and diagnostics on LPI…" by Gabriele Cristoforetti (CNR, Italy)

Seminar 5: "Ion stopping power: theory, experiments and diagnostics" by Luca Volpe (UPM, Spain)

Seminar 6: "…" by …

Seminar 7: "…" by …

Evaluation

Initial test (1h)

Final examination (1h30')

IC evaluation (online)

(tentative) Program planning: up to 24 students divided in three groups G1, G2, G3

July 15 - 25, 2025

Week #1

	Tuesday 15	Wednesday 16	Thursday 17	Friday 18	Saturday 19	Sunday 20
AM	**Students' arrival to Bordeaux**	**9:00 Evaluation test** **10:00 – 13:00 Chapter 1** *E. d'Humières*	Practical courses 9:00 – 12:00 G1a LAB G2 HYDRO G3 RAD	Practical courses 9:00 – 12:00 G2a LAB G3 HYDRO G1 RAD	**9:00 – 12:00 Chapter 4** *D. Batani*	**Touristic visit**
PM	**Students' arrival to Bordeaux** **18:00 IP introduction + Welcome party**	**14:30 – 17:30 Chapter 2** *J.J. Santos* **17:45 – 18:45 Seminar 1** *?*	**14:00 – 17:00 Chapter 2** *J.J. Santos* **17:15 – 18:15 Seminar 2** *?*	**14:00 – 17:00 Chapter 3** *E. d'Humières* **17:15 – 18:15 Seminar 3** *?*	**Free afternoon**	

Week #2

	Monday 21 July	Tuesday 22	Wednesday 23	Thursday 24	Friday 25
AM	**Visit to LMJ** **TBC**	Practical courses 9:00 – 12:00 G3a LAB G2 HYDRO G2 RAD	Practical courses 8:00 – 11:00 G1 PIC G2b LAB **11:30 – 13:00 Chapter 5** *D. Batani*	Practical courses 8:00 – 11:00 G3 PIC G1b LAB **11:30 – 12:30 Seminar 5** *?*	**Learning conclusions** **IP evaluation online** **Students' departure**
PM	**16:00 – 18:00 Visit to CELIA** **Webinar – Focused Energy**	**14:00 – 17:00 Chapter 3** *E. d'Humières* **17:15 – 18:15 Seminar 4** *?*	**14:30 – 16:00 Chapter 5** *D. Batani* Practical courses 16:15 – 19:15 G2 PIC G3b LAB	**14:00 – 15:00 Seminar 6** *?* **15:00 – 16:00 Seminar 7** *?* **16:15 – 17:45 Exam** **18:00 Farwell party**	