Progress of the PlasmaLab@CTU

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PlasmaLab@CTU [1, 2] is a laboratory focused on the fusion diagnostics methods and fusion technology. It reflects the importance of practical classes in the thermonuclear fusion technology, necessary for education of skilled experimentalists, both physicists and engineers. The aim is to contribute to the fusion community to cover the need for high level facility for training students of our home university as well as from abroad.

The laboratory was established in between 2017 and 2022 at the Czech Technical University in Prague in the scope of the Joint Degree programme with the Gent University [3]. It consists of two parts: one new with three workspaces, and the upgraded GOLEM tokamak [4]. The new part and Golem work separately, but closely collaborate. Some of the classes give the students the choice to work "upstairs" (new part) or "downstairs" (the tokamak), others divide them into two groups and they swap. Students' assignments projects usually run dominantly in one of the parts, often with knowledge and hardware interchange. This contribution is mainly about the "upstairs" part.

The new part of the laboratory (see Fig. 1) consists of ten main experiments plus a number of small devices and of accessories. The experiments are: Linear magnetic trap, Paschen curve, Discharge tubes, Resonance cavity (altogether Workspace 1 - Plasma); Magnetic stand,

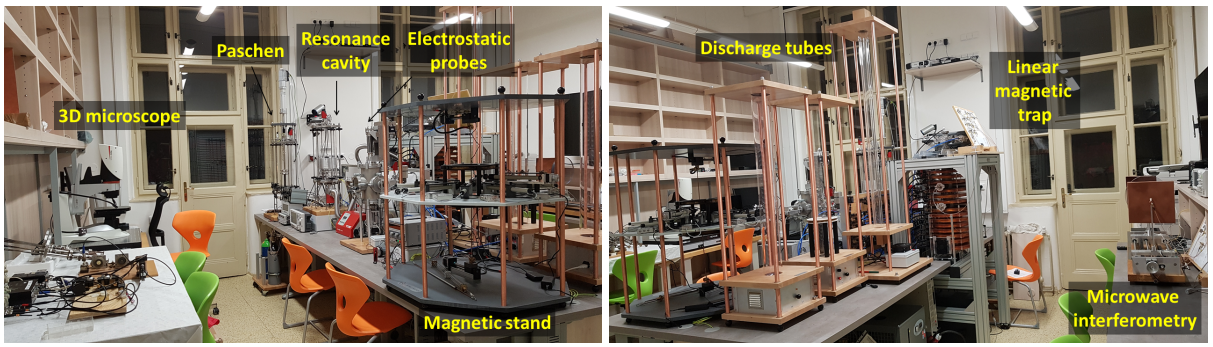

Figure 1: *PlasmaLab@CTU: look to the left and the right aisle of the laboratory. Two more experiments are behing the camera in a dark room.*

Electrostatic probes stand, Microwave interferometry (altogether Workspace 2 – Magnetic and electric fields); Laser spectroscopy, Sonoluminescence, 3D microscope (altogether Workspace 3 – Optics). Accessories are namely a Plasma MiniJet, a vacuum recipient, spectrometers, photo multipliers and others.

Teaching

Teaching is the main aim of the PlasmaLab@CTU. There are regular classes, theses, projects, seminars and such activities.

1. Regular classes

- Laboratory Work in Plasma Physics 1, 2 (PRPL): for the MSc students. The attendants are divided into two groups of their choice: one goes "upstairs", the other "downstairs" to the tokamak. The classes run two semesters, expecting students to show certain level of independence and creativity. It is focused on obtaining skills of experimentalists, beginning with critical thinking and planing of the work, through refining the culture of the flow, ending with requirement of decent reports. Students are expected to cover all the principals of measurements: put the hands on optics, electrostatic and magnetic probes, microwaves, and learn basics about vacuum handling.

- Laboratory of Plasma Diagnostics (UPP): for the Bc students. The attendants are divided into two groups which swap, half semester "upstairs", and half semester "downstairs". The idea is to present the lab work and the facilities rather than doing more serious work. The students are also required to put the hands on couple of experiments, but in smaller extent, and they are not required to produce reports.

2. Theses

- The first Bc thesis was on the magnetic diagnostic by Ondrej Bares (2021) [5]. Most of the experimental work was done remotely during the Covid lockdowns.

- The second Bc thesis was on the Resonance cavity by Daniel Svorc (2022) [6]. The student modified the cavity and made new antennas.

- The third Bc thesis was on Study of negative corona discharge and plasma jet for medical purposes by Laura Thonova (2022) [7]. It was performed mainly at the University of Chemistry and Technology in Prague with some measurements by the Plasma MiniJet in the PlasmaLab@CTU.

3. Projects and seminars

- Seminar on Plasma Physics (SFP): this seminar in the first year of Bc gives students their first contact with plasma applications. It includes a micro-project with a small presentation given in front of others. Micro-projects were conducted in the PlasmaLab@CTU in 2021, 2022 (resonance cavity), and in 2023 (magnetic stand).

- Research Project: one obligatory project for MSc students before they are given their diploma theses topics is being performed in the PlasmaLab@CTU. The topic is Microwave propagation in plasma (in the linear magnetic trap).

- Global Talent Mentoring project: a project in the scope of GTM was performed by Kalea Wen from USA, fully remotely. The topic was An Exploration of the Tokamak and MHD instabilities (Magnetic islands). She did her training on the magnetic stand before upsizing to the tokamak.

- High School students project: a nationally organised competition of high school students doing their research work at the universities, academy of sciences and other reasearch institutions. One of the students started his work on a discharge tube in the laboratory.

Research

PlasmaLab@CTU is furnished by high quality equipment which opens the door also for scientific publication. It is not only environment for education, but also a test bed for new ideas and a support structure for research performed at the University or elsewhere.

- Microscope: the 3D microscope Leica DVM6 belongs to the highest class of optical microscopy, going to the end of the visible light. The device is meant for material research, enabling 3D scans (changing the focal length and reconstructing the image) with a professional software which can measure patterns on the surface (depths, profiles, volumes etc.). Let us exemplify the scientific use of the microscope:

  - Detectors CR-39 of fusion protons from the pinches: plasma focus PF-1000, IPPLM, Warsaw, Poland; plasma focus MAIZE, University of Michigan, USA; plasma focus PFZ-200, CTU, Prague, Czech Republic.
  - Langmuir probes for the COMPASS tokamak: observing a plasma impact on the probes array after years of operation [8].
  - Calorimetry probe for runaway electron heat load measurements at COMPASS: assessment of the damage [9].

- Calibration of cameras: Number of projects were performed with the help of the PlasmaLab@CTU structure (optical table, vacuum recipient etc.). One of examples is calibration of tomographic cameras for the Golem tokamak [10, 11].

Online access

PlasmaLab@CTU is designed as a hands on AND an on-line laboratory. Most of the devices have at least the basic version of experiment remotely controlled. It yields from a long tradition of the tokamak Golem, fully remotely operated tokamak, and is inspired by the remote laboratory e-lab in IST, Portugal [12]. The lab is open to cooperation from abroad and would like to evolve in this strategy.

Conclusions

PlasmaLab@CTU is a modern laboratory devoted to education of experimentalists focused on fusion diagnostics and plasma physics. The structure is used also as a test bed for new research projects. With a high level of remote control, it is open for cooperation with schools abroad.

Acknowledgements

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