PLASMALAB@CTU - NEW FACILITIES IN SUPPORT OF FUSION EDUCATION

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JOINT PHD IN FUSION

The joint doctoral programme "High Temperature Plasma Physics and Thermonuclear Fusion" [1], was proposed by Universitait Gent in Belgium and the Czech Technical University in Prague. The agreements were signed by the rectors of the Universities at the beginning of 2020. The students will be admitted by both the Universities. The joint training programme is supervised by international Supervisory Board that consists of lecturers from CTU, Universitait Gent, and external experts. Students must past within their studies at least six months at the partner University or in an institute or in the Participating Institution determined by the partner University. Every student must pass the state doctoral exam and the defence of the doctoral thesis according to the rules of both the Universities.

PLASMALAB@CTU

PlasmaLab@CTU [2] was established primarily as a laboratory to support the Joint doctoral programme. It's also determined to be used for other levels, including Bc and MSc. It consists of four main parts: Plasma, Magnetic and electric fields, Optics, and the GOLEM tokamak [3]. The first three parts are in a new room, while the tokamak is an established experiment which has been included and undergoes upgrades in the scope of the project. The goal of the laboratory is to teach fusion relevant basic physics and technology to the future fusion researchers.

Remote control

PlasmaLab@CTU aims to be a remotely operated laboratory. The GOLEM tokamak is a fully remote device which performs many international schools and campaigns. The new part of the lab follows this trend as much as the hardware and the idea of the experiment allow. Most of the devices is controlled by LAN or USB. Devices like step motors and some power sources are controlled by arduinos and/or Raspberry Pi. Devices with LAN are connected directly to the inner network. Each experiment is controlled by a Raspberry Pi, that controls and communicate with other components.

Plasma

The workspace Plasma includes four experiments: Linear magnetic trap, Paschen curve, Discharge tubes, and Resonance cavity. The trap (fig. 1) will study transmission of microwaves along and across magnetic field which will reach up to 100 mT in the centre of the chamber. Resonance cavity (fig. 1, 2) gives insight into resonators; plasma density can be established by the change of resonant frequencies with and without plasma. The trap, the Paschen and the cavity are fully remotely operated.

Fig. 1. From left: Paschen curve, resonance cavity, probes stand. Right panel: linear magnetic trap.

Fig. 2. From left: iodine tube, tube with variable pressure and one electrode; from top: set of spectral tubes, resonance cavity with plasma.

Magnetic and electric fields

This workspace includes three experiments. Magnetic stand (fig. 3 right) is in fact a simulation of a feed back system in tokamak, with different geometry. An electric current in a wire generates magnetic field which is measured with a ring of magnetic coils. With changing of the spatial distribution in the (adjusted) wire, phenomena of plasma current measurements are simulated. Electric probes stand (fig. 1) is a test bed for different designs of electrostatic probes. Microwave interferometry (fig. 3 left) consists of two antennas, an interferometer, and teaches basic physics of microwave transmission.

Optics

Optics part of the PlasmaLab include three ba-

Fig. 3. Left: interferometry, right: magnetic stand.

sic experiments and several independent components. The experiments are: Laser spectroscopy, 3D microscope, and sonoluminiscence. Apart of those, it posses two spectrometers in visible part of the spectrum, several detectors like a photomultiplier and photo diodes, a bolometric camera etc.

The 3D microscope (fig. 4) is Leica DVM6 which makes 3D pictures from reconstruction of scanned photos with different focal length. The LAS X software can measure parameters like depth, distances or volumes of the surface of the surveyed sample. 2350× magnification shows details down to 0.4 μm. The head can be tilted by 60°. Relatively large space between the lens and the table enables observe objects as large as e.g. tiles from a tokamak. This microscope is meant to train material physics, focused on damages caused by plasma-walls interactions.

Laser spectroscopy shows absorption and stimulated emission in rubidium vapors, using a tunable diode laser on 780 nm.

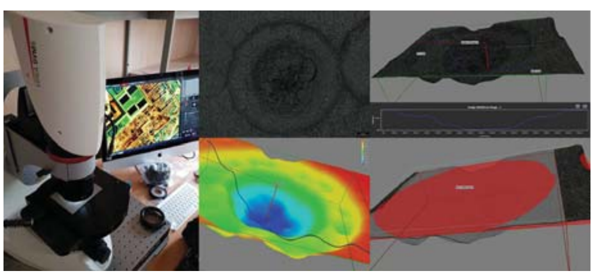

Fig. 4. The microscope with pictures of a 3D processed hole in a carbon target burnt by a laser. The depth is about 1 mm, the volume about 2.5 mm^3.

Common

The vacuum experiments have common vacuum and gas inlet system. Five experiments (Paschen curve, resonance cavity, probes stand, magnetic trap, and discharge tube with variable pressure) are connected to five gas cylinders (He, Ar, Ne, N_2, air) individually via the common gas inlet system in fig. 5. The board is fully remotely operated. These experiments will be connected to a common vacuum system. The Cube (fig. 5) is an extra vacuum recipient playing a role of a testing bed of various ideas for lab work. It has several ports and a big front door made of acrylic glass.

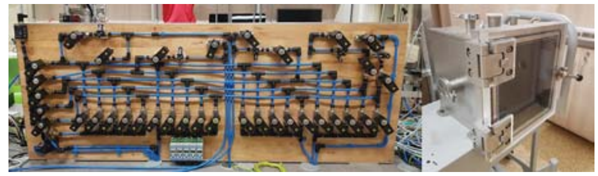

Fig. 5. Left: the inlet system, right: the Cube.

The GOLEM tokamak

The GOLEM tokamak is the first functional tokamak in the world. The original TM-1-MH from the Kurchatov Institute in Moscow was transported to Prague in 1977 and operated as CASTOR at the Czech Academy of Sciences. In 2007, CASTOR was transported to the FSNPE building, upgraded for fully remote operation, and renamed as GOLEM. Its main deal is to serve as an educational experimental device, but it also has a scientific programme, including Runaway and plasma edge physics studies.

Students in PlasmaLab

First lab works in the new part of PlasmaLab were in the academic year 2019/2020. It was a two semester master lab work, with 6 students. This year, three students are on the same course, and the first Bc student got enrolled.

CONCLUSIONS

A new laboratory for fusion education is being built on the FSNPE CTU in Prague. It consists from the GOLEM tokamak being upgraded, and a brand new part "upstairs" with basic experiments relevant to fusion research, mainly diagnostics, plasma, and vacuum physics. This part is preferentially for PhD students, but serves for all other levels - undergraduates and bachelor. It is being put into operation and first students have enrolled and passed through the lab works. Being a remotely operated laboratory, PlasmaLab has the potential of organizing remote educational campaigns; the GOLEM tokamak is a flagship of these activities.

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