Status of the self-modulation experiment at PITZ

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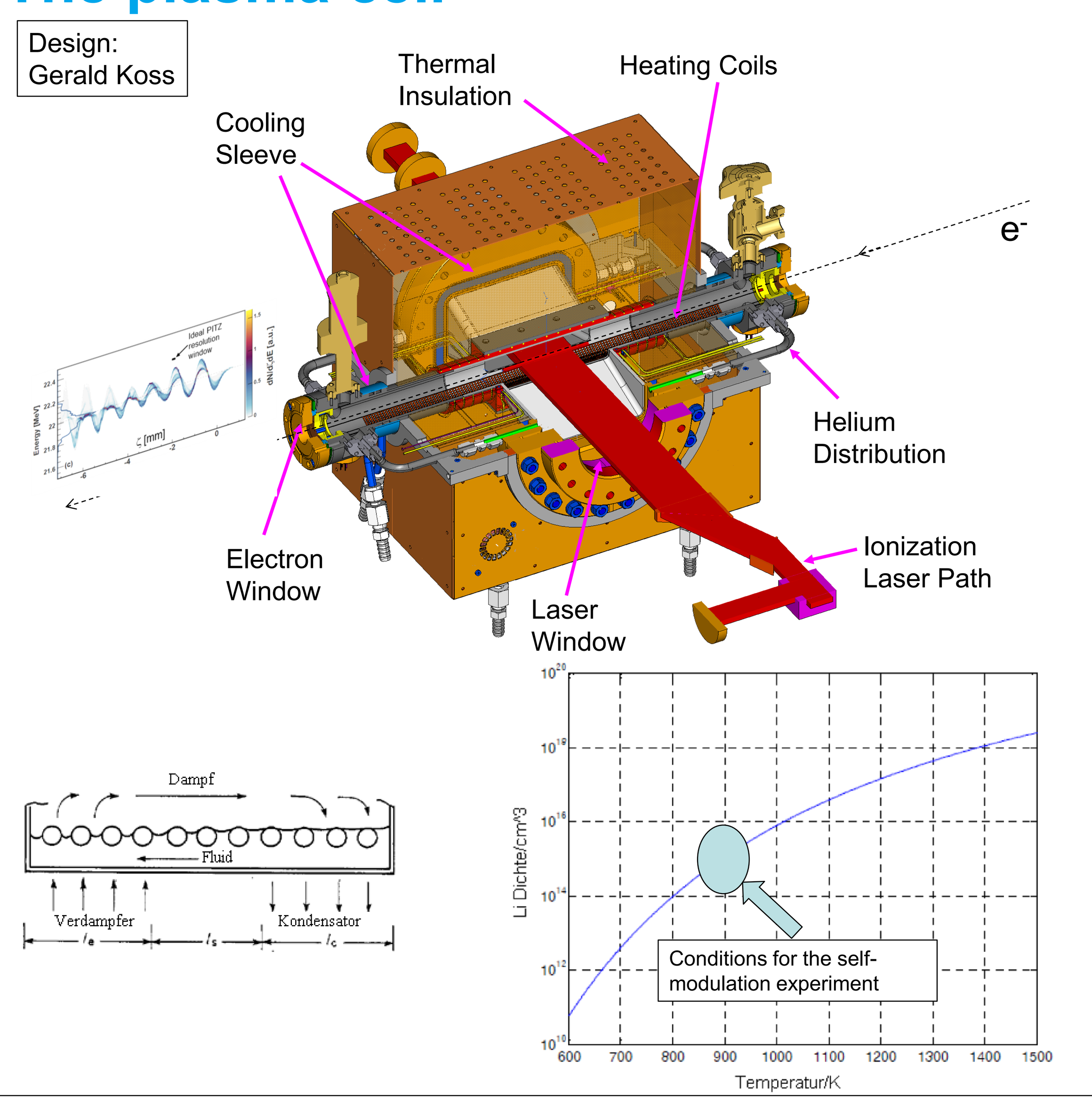
Abstract

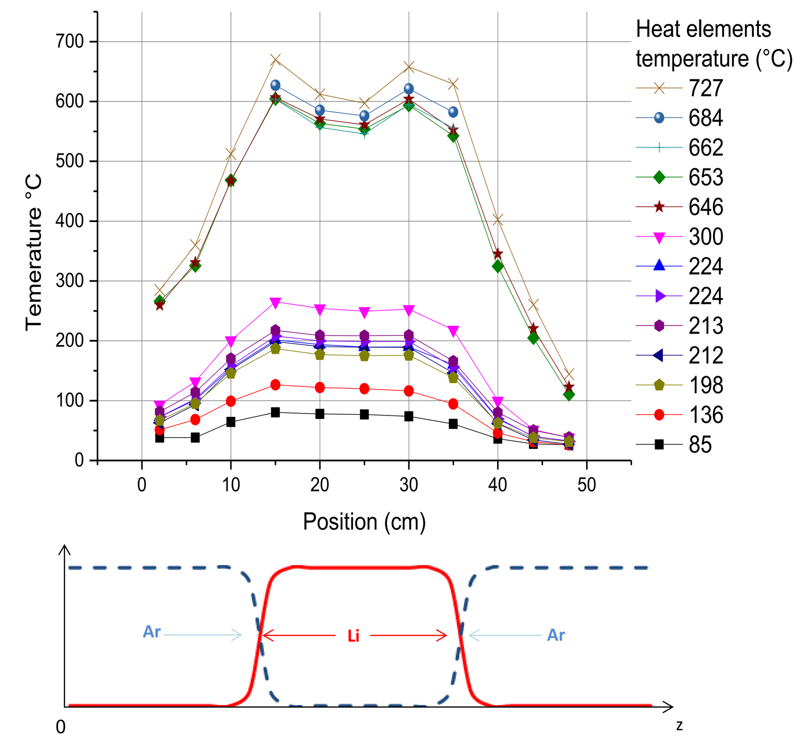
A proof-of-concept experiment for the AWAKE experiment is in preparation at the Photo-Injector Test Facility at DESY, Zeuthen site (PITZ) [1]. The goal of the experiment is to observe and measure the energy and density self-modulation of a long electron beam passing through a laser-generated Lithium plasma.

A new type of plasma cell was designed and manufactured to fulfill feasible constraints of the plasma experiment at PITZ. The plasma cell is a Lithium heat pipe oven with inert gas buffers at all input/output ports. Key aspects of the construction are an ArF ionization laser coupled through side ports for the plasma generation, as well as electron windows which separate the plasma from the vacuum beam line. Although the side ports design is more complicated than a coaxial laser coupling, it also has an advantage: a shadow mask can be used to precisely control the plasma channel parameters, including its length. The electron windows have to be thin enough to minimize electron scattering, but have to be thick enough to maintain low buffer gas diffusion out of the plasma cell. Other aspects of the preparations are the generation of homogenous Lithium vapor inside the cell and adjustments to the beam line to accommodate the experiment.

The plasma cell

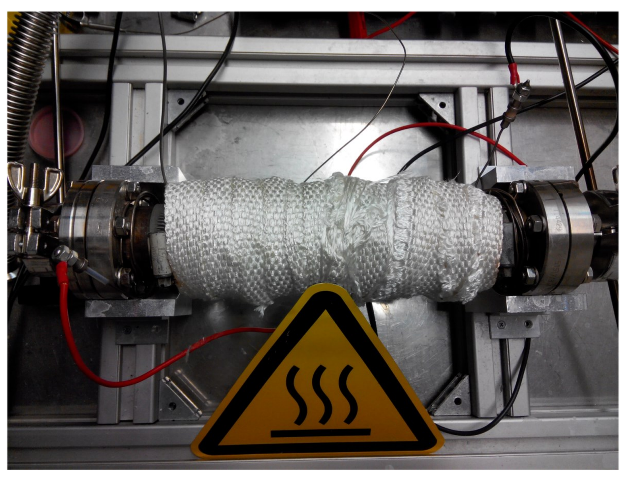
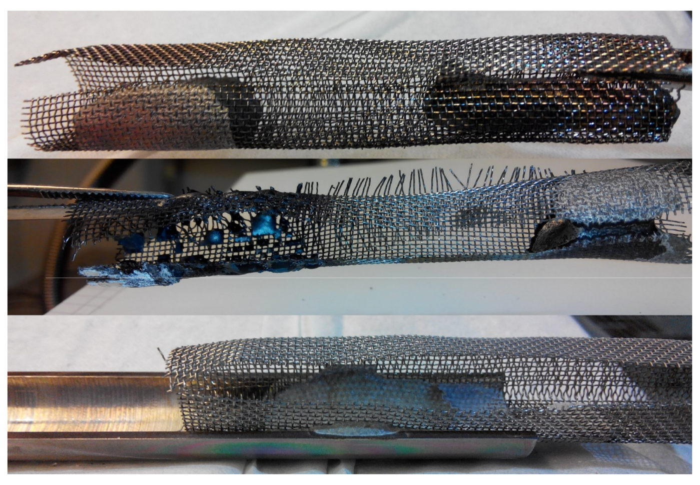
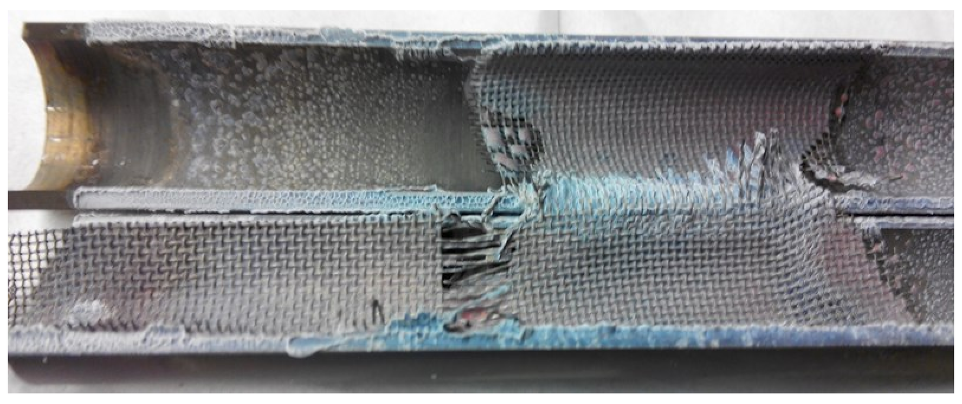
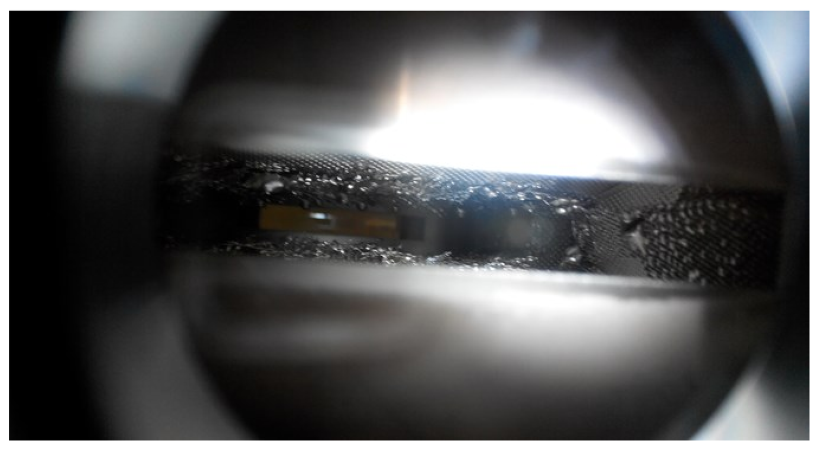


Heat distribution



The upper figure shows the measured temperature distribution along the longitudinal axis of the plasma cell without Li. Experiments with Li inside the plasma cell demonstrated that, as heat pipe starts to function, the temperature at the central region equalizes. Below: schematic view of the Li vapor confined by buffer gas zones.

Lithium melting experiments

Figures above show an experimental oven used for Li melting tests and an evolution of the melting experiments. Goal of the experiments was to study a distribution of the liquid Li over the mesh parts and especially over connections between them (the side ports design entails a complex design of the wire mesh). Lithium reacts quickly with components of air and forms a protective layer that prevents proper melting, so all operations with Li were conducted under Argon atmosphere. A series of tests was conducted under a variety of conditions: parameters were different amounts of Lithium, wire mesh constructions, heating temperature and temperature temporal profiles.

The studies show that the following conditions have to be fulfilled to ensure good distribution of the melted Lithium over the mesh and the mesh connections:

- Exclude any contact of the lithium samples with air;
- The sample should be inserted into a pre-heated oven to start the melting process immediately;
- The mesh should lie very close to the walls of the oven to provide capillary force for a distribution of liquid Lithium.

Last picture shows interior of the plasma cell after melting Lithium inside and cooling it down. The picture is taken through the side port window. One can observe the shadow mask and a complex mesh construction inside: it consists of central cylindrical part and four side parts, two for each side. Lithium drops condensed on loose wires used to connect the mesh parts. The mesh is covered with a layer of Li in the central region.

Electron windows

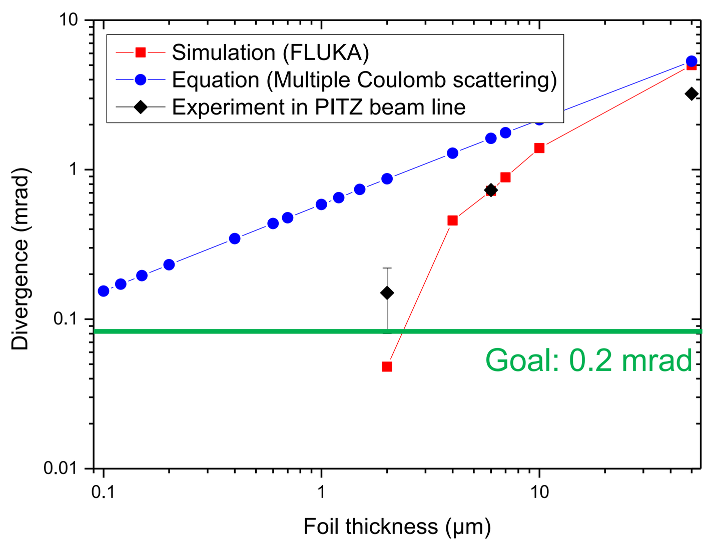
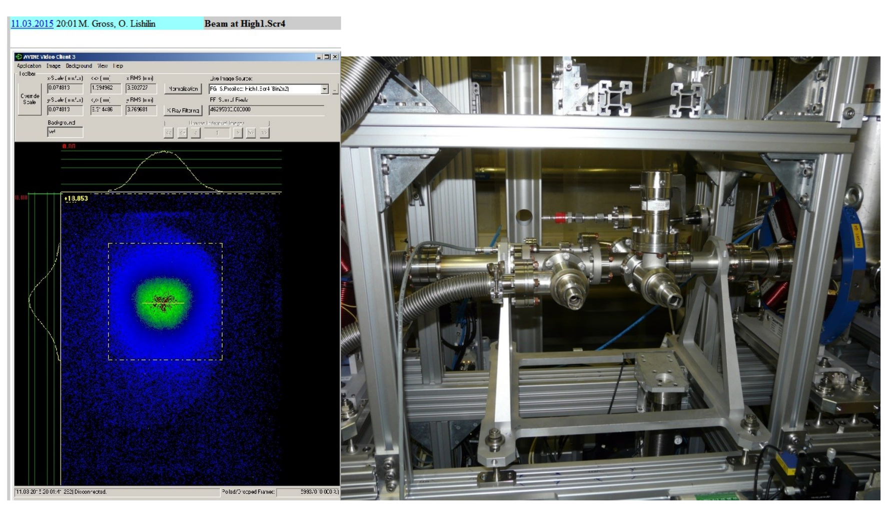
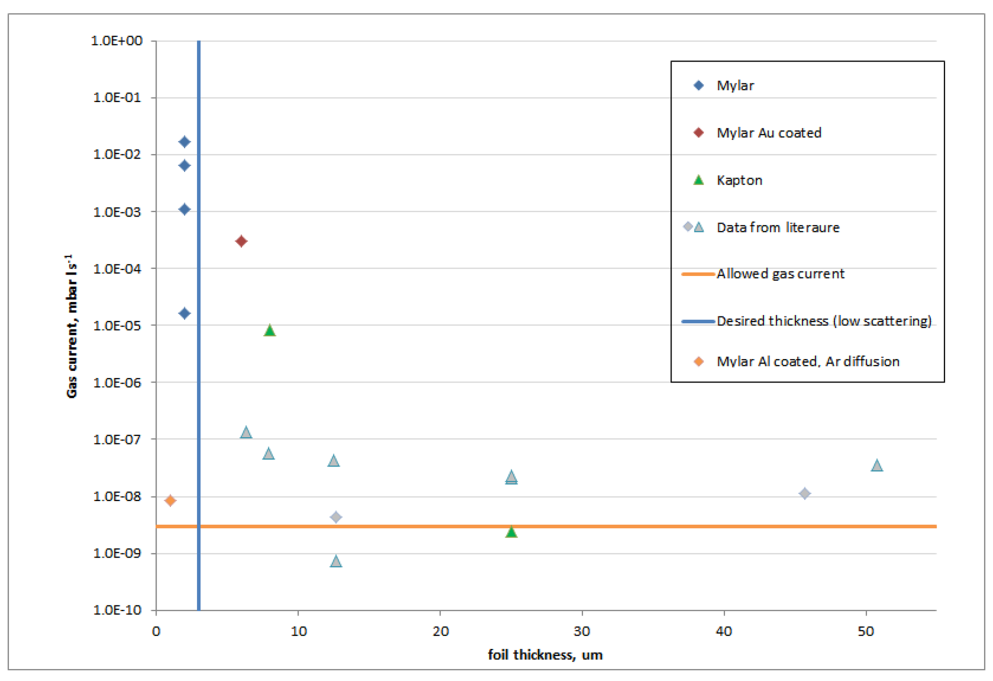


Figure above shows the calculated and measured scattering values for Kapton foils of different thicknesses. Below: beam seen after passing through a dummy plasma cell filled with Ar and equipped with 8 μm Kapton windows.





Plot above shows calculated gas currents of Helium for Kapton and Mylar foils of various thicknesses, experimental (courtesy Dieter Richter) and literature [2-4] data. The blue line represents desired foil thickness for low electron scattering, the orange line – maximum allowed gas current to the PITZ beam line. For the last point, Al coated Mylar foil, Ar permeation was measured. Argon is more suitable buffer gas than Helium, thanks to its higher mass and size of an atom, it absorbs Li particles more effective and diffuses slower through the windows. 8 μm Kapton windows and Ar buffer gas will be used for the first self-modulation experiment at PITZ.

Outlook

- Self-modulation experiment is in preparation
- Lithium melting expertise gained
  - Li distribution over the connections between mesh parts was studied
- Electron windows test:
  - 8 μm Kapton foil could be used for first experiments
  - Tests are ongoing to determine the best material and thickness
- A measurement of the Li vapor density is in preparation
- First self-modulation experiment is planned to July
- New plasma cell design to be created

References

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