Status of the preparations for a plasma wakefield acceleration experiment at PITZ

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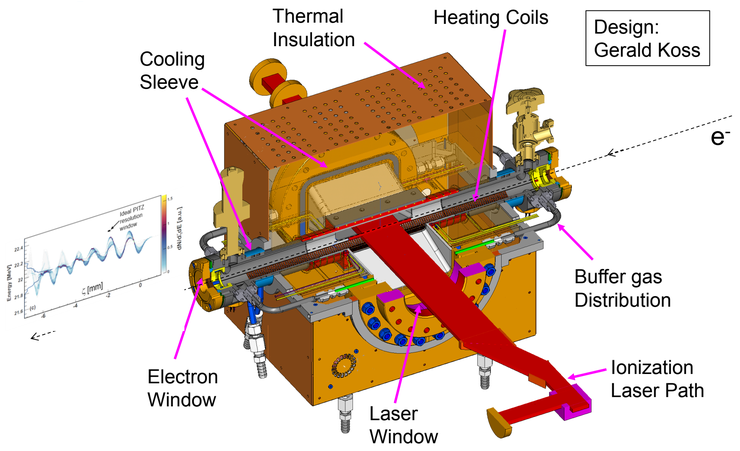
Abstract

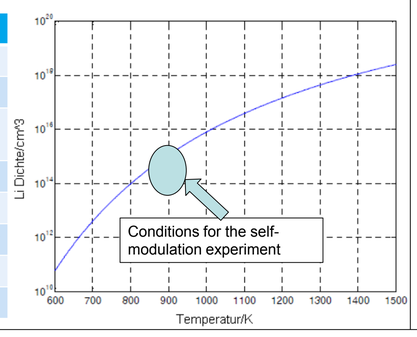
A proof-of-concept experiment for the AWAKE experiment is in preparation at the Photo-Injector Test Facility at DESY, Zeuthen site (PITZ) [1]. The goal of the experiment is to observe and measure the energy and density self-modulation of a long electron beam passing through a laser-generated Lithium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

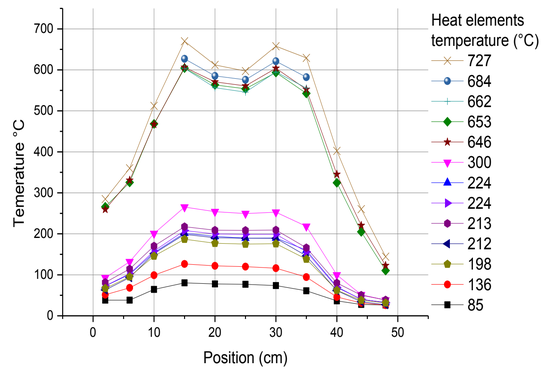


Parameters	
Inner tube diameter	36 mm
Heater length	23 cm
Distance between cooling jackets	35 cm
Heat insulation length	33 cm
Orthogonal structure length	28 cm
Buffer gas	Ar, 0.7 mbar
Heating power	900 W
Max. temperature	700 °C

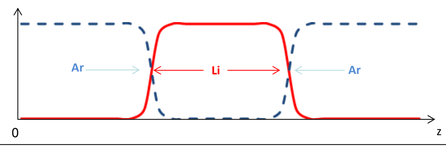


Heat distribution

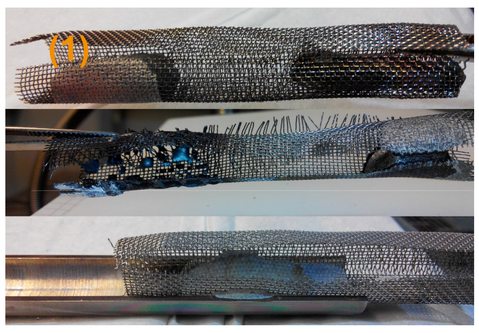
Measured **temperature distribution without Li** along the longitudinal axis of the plasma cell. As heat pipe starts to function, the temperature at the central region equalizes.



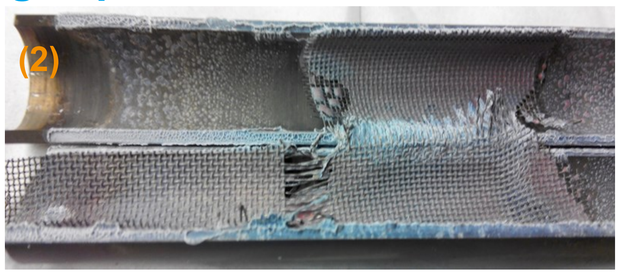
Schematic view of the Li vapor confined by buffer gas zones:



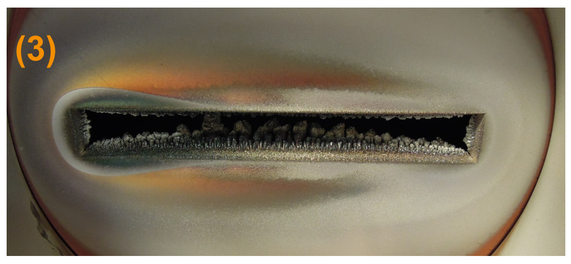
Evolution of Lithium melting experiments



- Goal of the experiments: study the distribution of liquid Li over the mesh parts and especially over connections between them (the side ports design entails a complex design of the wire mesh).
- The experiments were conducted with a specially made small heat pipe oven.
- Lithium reacts quickly with components of air and forms a protective layer that prevents proper melting → all operations with Li were conducted under Argon atmosphere.
- Experimental parameters:
  - Amount of Lithium
  - Wire mesh constructions **(1)**
  - Heating temperature
  - Temperature temporal profiles.



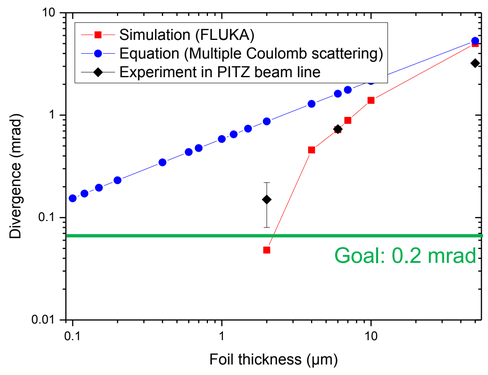
- Result: **Li distributes well** over the mesh and the mesh connections in the small oven **(2)**.
- Experiments with plasma cell: after several days of operation period Li tends to form depositions on the border between the vapor and the buffer gas zone near cooling jackets **(4)**.



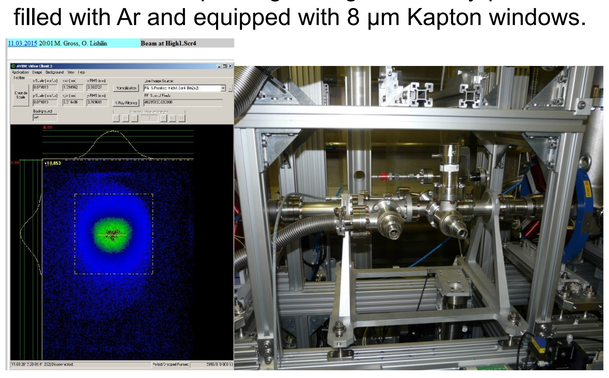
- After 4 days of continuous run a big ball of Li was grown, blocking the beam path completely **(5)**.
- Possible reason for depositions: mesh does not provide enough **capillary force** to transport condensed Li back to the heater zone.
- Mesh number N (wires per inch) for alkali metal heat pipes should be 40 to 300 [2] - in our case: N = 26.
- Another problem: length of orthogonal pipe is too low; copper shadow masks were installed in the side ports as temporal fix. **(3)**: shadow mask covered with Li crystals.

Electron windows

Calculated and measured **scattering** values for Kapton foils of different thicknesses.



Beam seen after passing through a dummy plasma cell filled with Ar and equipped with 8 μm Kapton windows.



Foil	Permeability, K, m^2s^{-1}	Gas	Gas load into PITZ, Q, *mbar l/s*
Mylar, 2 *μm*	$9.88 \cdot 10^{-9}$	He	$3 \cdot 10^{-6}$
Mylar, 2 *μm*, gold coated	$5.77 \cdot 10^{-9}$	He	$5 \cdot 10^{-6}$
Kapton, 25 *μm*	$1.97 \cdot 10^{-13}$	He	$4 \cdot 10^{-11}$
Kapton, 8 *μm*	$9.85 \cdot 10^{-15}$	Ar	$4 \cdot 10^{-12}$
PET, 0.9 *μm*, aluminium coated 2x37.5 *nm*	$2.58 \cdot 10^{-14}$	Ar	$1 \cdot 10^{-10}$
Kapton, 12.7 *μm* [3]	$3.04 \cdot 10^{-13}$	He	$1.2 \cdot 10^{-11}$
Kapton, 7.9 *μm* [4]	$1.52 \cdot 10^{-12}$	He	$9.7 \cdot 10^{-11}$
Mylar, 45.7 *μm* [5]	$1.69 \cdot 10^{-12}$	He	$1.9 \cdot 10^{-11}$

Table above shows measured **gas permeability** values for foils of different materials and thicknesses tested at PITZ (courtesy Dieter Richter) and literature data. An allowed gas load coming from the windows is $1 \cdot 10^{-6}$ *mbar l/s*, therefore, almost all tested foils could be used without compromising the machine run. Another major property of the electron windows is **mechanical strength**. The windows have to withstand a pressure difference of 1 bar. 8 μm Kapton windows were tested in PITZ beam line with a dummy plasma cell and they are being used in current self-modulation experiments. Experiments are ongoing to find the most suitable window material.

Outlook

- Self-modulation experiments are in preparation
- Lithium melting expertise gained
  - Li distribution over the connections between mesh parts was studied
  - Proper mesh parameters to be found
- 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
- New plasma cell design to be created to solve the problems with the Li deposition

References

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