Upgrades of the Experimental Setup for Electron Beam Self-modulation Studies at PITZ.

M. Gross[1*], R. Brinkmann[2], J. Engel[1], F. Grüner[3,4], G. Koss[1], O. Lishilin[1], G. Loisch[1], J. Osterhoff[2], G. Pathak[1], S. Philipp[1], D. Richter[5], C. Schroeder[6], R. Schütze[1], F. Stephan[1]

[1] DESY, Zeuthen, Germany, [2] DESY, Hamburg, Germany, [3] UHH, Hamburg, Germany, [4] CFEL, Hamburg, Germany, [5] HZB, Berlin, Germany, [6] LBNL, Berkeley, USA

* matthias.gross@desy.de

Abstract

The self-modulation instability is fundamental for the plasma wakefield acceleration experiment of the AWAKE collaboration at CERN where this effect is supposed to be used to generate proton bunches short enough for producing high acceleration fields. For ease of experimentation it was decided to set up a supporting experiment at the electron accelerator PITZ (Photo Injector Test facility at DESY, Zeuthen site), given that the underlying physics is the same. The goals are to demonstrate and investigate in detail the self-modulation of long electron beams.

In 2015 a first set of experiments was conducted utilizing as key elements a novel cross-shaped lithium plasma cell and an ArF excimer laser for plasma generation. No self-modulation was observed yet because of various experimental shortcomings. The properties of the experimental setup were studied in detail and in this contribution we report about the upgrades which are projected to enable the observation of the self-modulation in the upcoming experimental run.

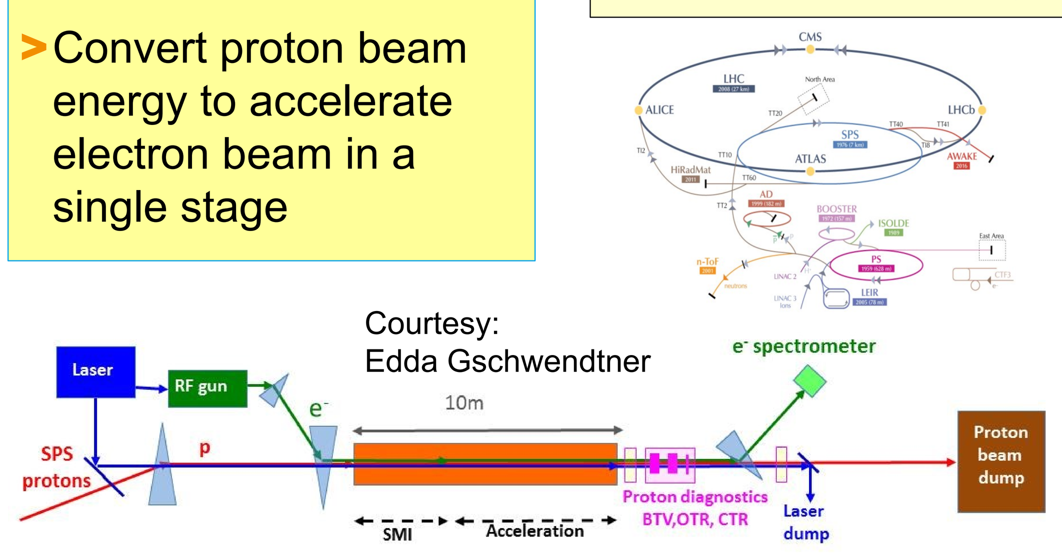
Motivation: A Proton-Driven Plasma Wakefield Experiment at CERN (AWAKE) needs self-modulation

> Use high energy proton beams from SPS to drive plasma wave

> Convert proton beam energy to accelerate electron beam in a single stage

Caldwell et al., Nature Physics (2009):

$$E_{z,max} = 240(MV\,m^{-1})\left(\frac{N}{4x10^{10}}\right)\left(\frac{0.6}{\sigma_z(mm)}\right)^2$$



> High accelerating gradient requires **short** bunches (σ_z less than 100μm)

> Existing proton machines produce **long** bunches (10cm)

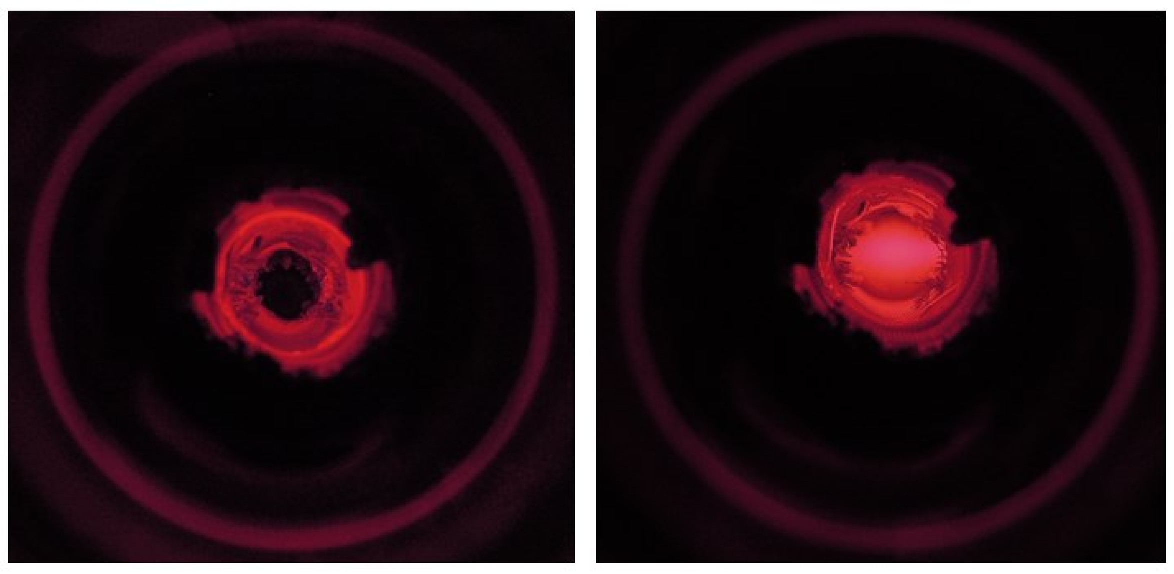
Self-modulation

↳ Detailed study at PITZ

2015 Run: Preliminary Results

First Plasma in a Cross-shaped Plasma Cell

> Laser off (heat glowing) > Laser on (plasma)

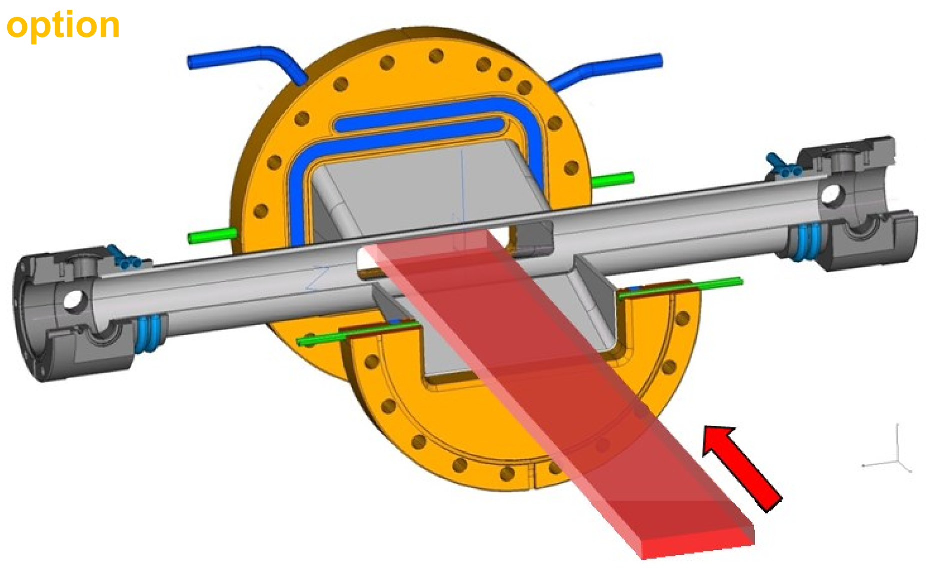


But: No Self-modulation seen

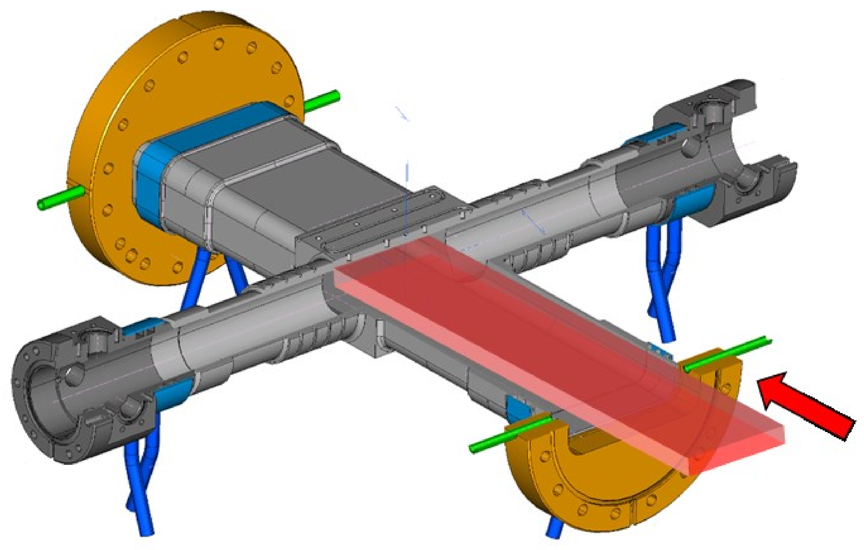
Problems	Solutions
Heating wires overpowered	Stronger heater / better heat insulation
Lithium accumulation in cooling zones	• Grooves → better lithium transport • Longer side arms
Only 10% laser pulse energy delivered to plasma cell	• Better optics (e.g. cylinder lenses; antireflection coating) • Increase efficiency of laser transport (less atmospheric absorption)
Electron windows increase achievable focus size	Thinner electron window foils (old: 8μm; new: 0.9μm)

Update #1: New Plasma Cell

Old: Funnel shaped side arms for Ti:Sapphire option



New: Straight side arms – ArF Ionization Laser



Liquid Lithium Transport: Replace Mesh with Grooves (better for Complicated Geometry) → Works in Test Pipe!

> 560°C
- Lithium bar starts to melt

> 605°C
- Lithium starts to flow up the walls

> 700°C
- Steady circulation of lithium

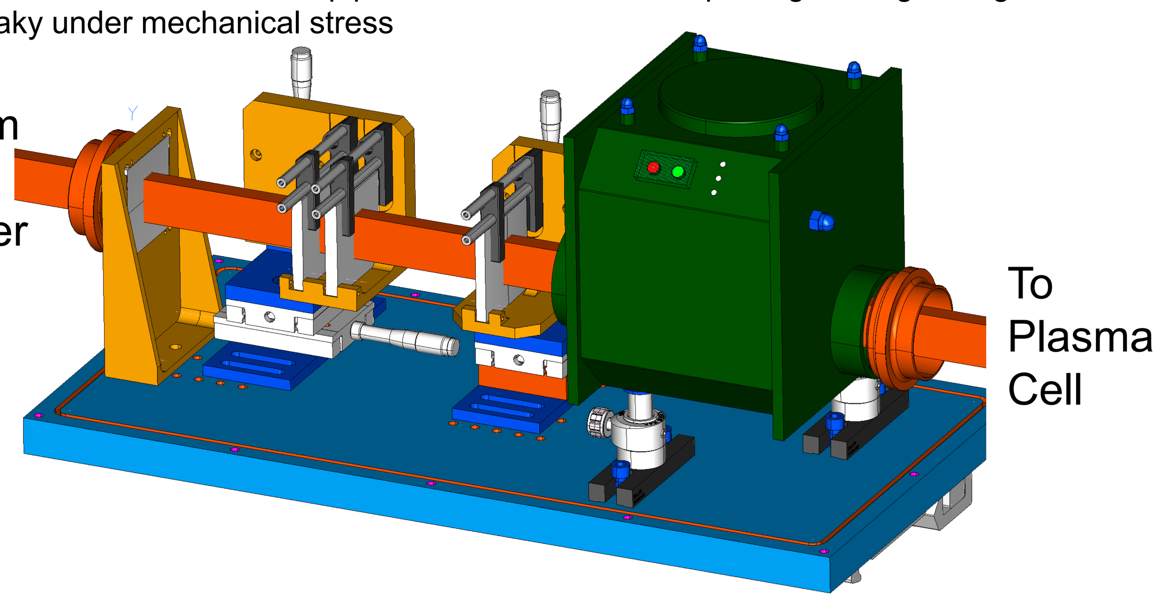
Update #2: Ionization Laser Beam Line

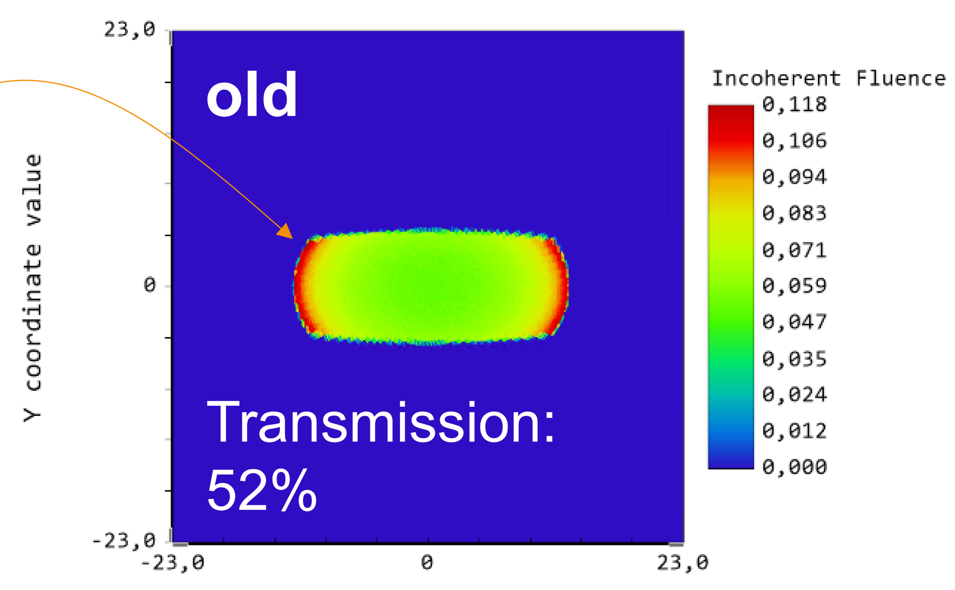
> Laser output: 24mm x 10mm with 3mrad x 1mrad divergence
- Beam transport over ≈12m from laser aperture to plasma cell
- Compensation of divergence done so far with spherical lenses
- Now: 4 cylinder lenses (2 per axis) with AR coating for individual compensation

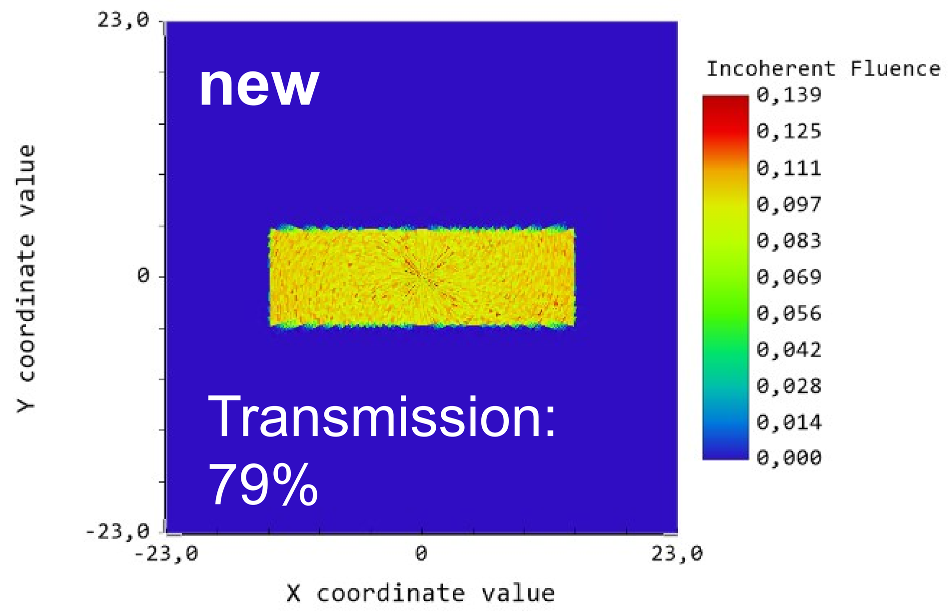
> Absorption origin #1: Cutting at apertures along beam line

> Absorption origin #2: Absorption in air (ArF laser → strong absorption of 193nm light by oxygen)

> Improvements
- Redrilled hole from laser lab: better alignment to following hole / less cutting
- Gas tight sealing for mirrors in holder
- Bellows for connection of pipes to mirror holders – replacing sealing O-rings which can be leaky under mechanical stress







Summary

> Experiments this summer are in preparation

> Several significant upgrades have been done compared to last year:
- New plasma cell design (better heating, no loss of lithium)
- Grooves replacing wire mesh (better lithium transport) → in test cell we already measured much higher gas density
- Better ionization laser beam transport: less clipping, less absorption
- Window foil candidate with very low scattering was found (has to pass stress test)

> We are optimistic to be able to see self-modulation this year!

IPAC16 WEPMY005