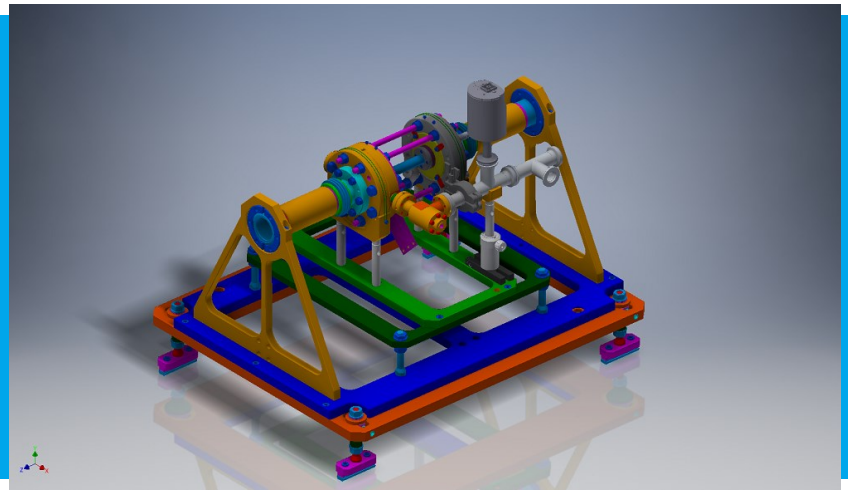
Argon Gas Discharge Plasma for PWFA-Experiments at PITZ .



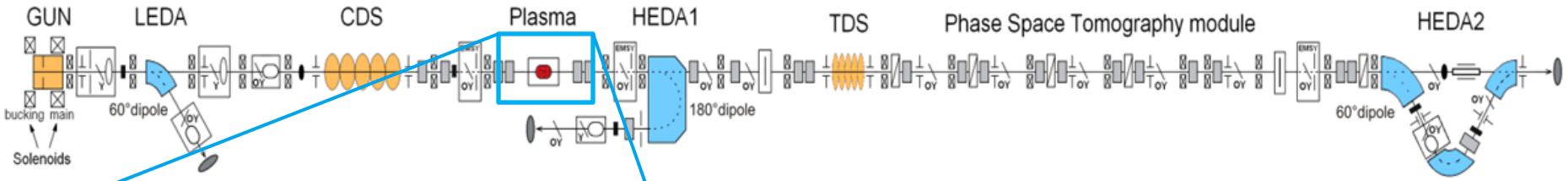
Gregor Loisch

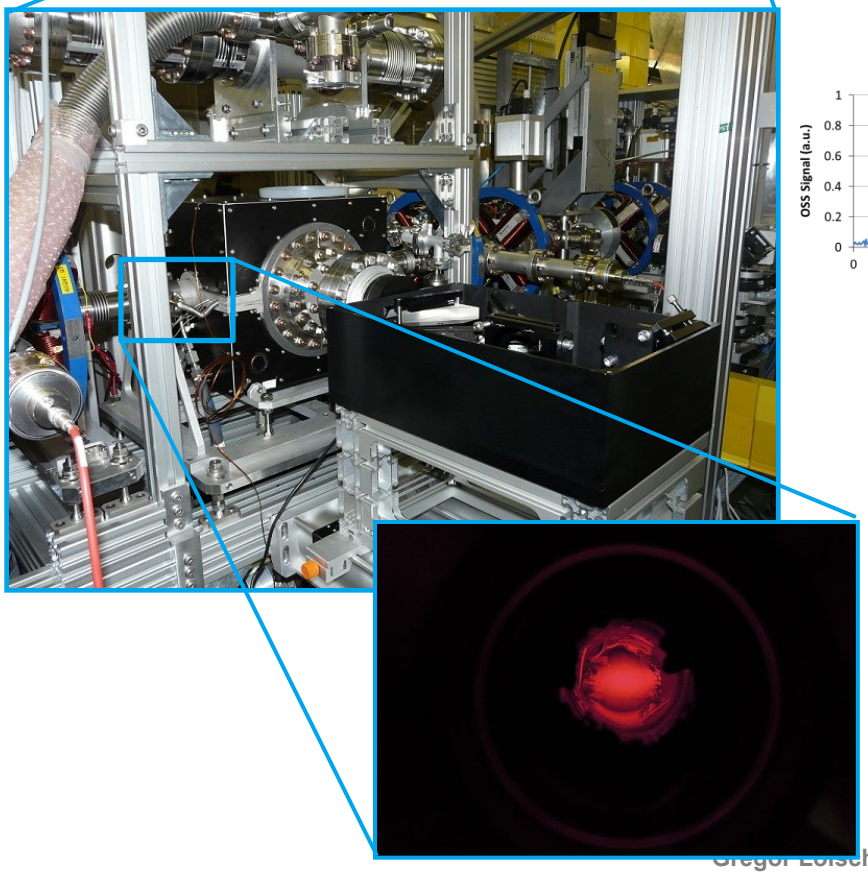
DPG-Frühjahrstagung
Darmstadt, 17.03.2016

HELMHOLTZ ASSOCIATION

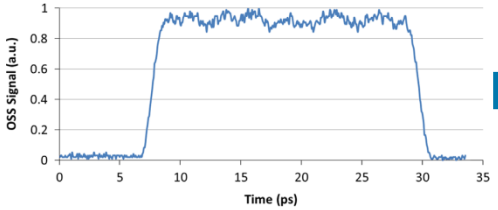
DESY

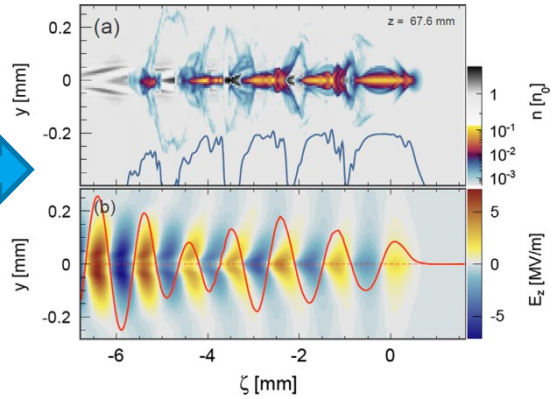
LAOLA @ Photo Injector Testfacility Zeuthen PITZ



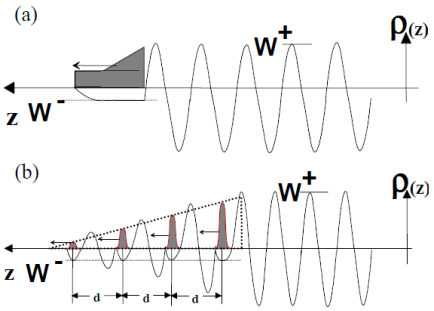


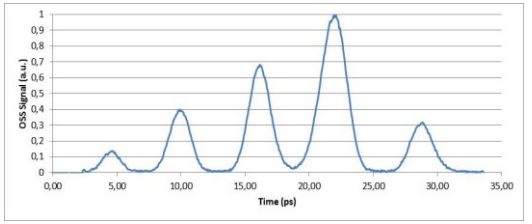
Self-modulation





High transformer ratios





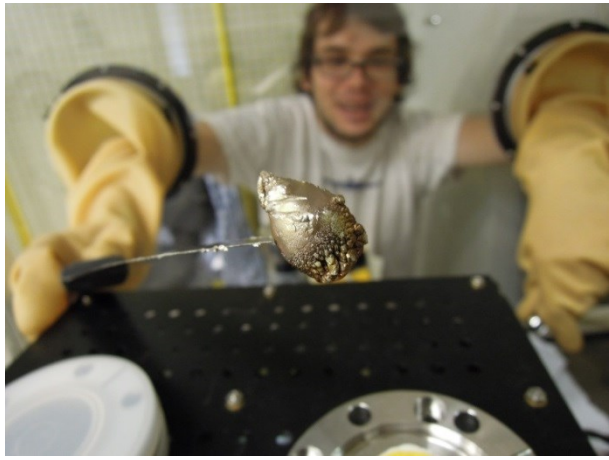
Outline

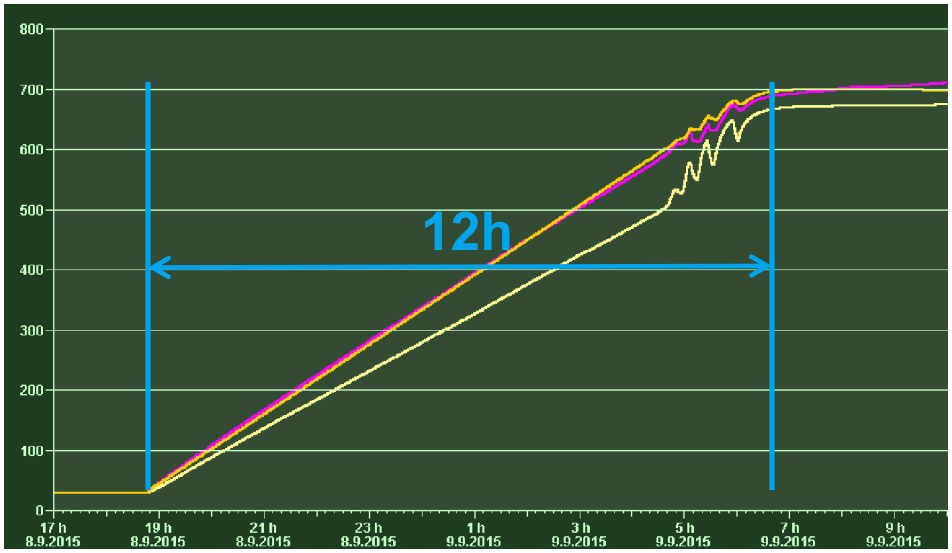
1. Why build a gas discharge plasma?
2. Introduction to GDP
3. Layout of PITZ discharge cell
4. Diagnostics
5. First Lab-Data
6. Discussion & Summary

Why another plasma cell?

Intrinsical disadvantages to overcome:

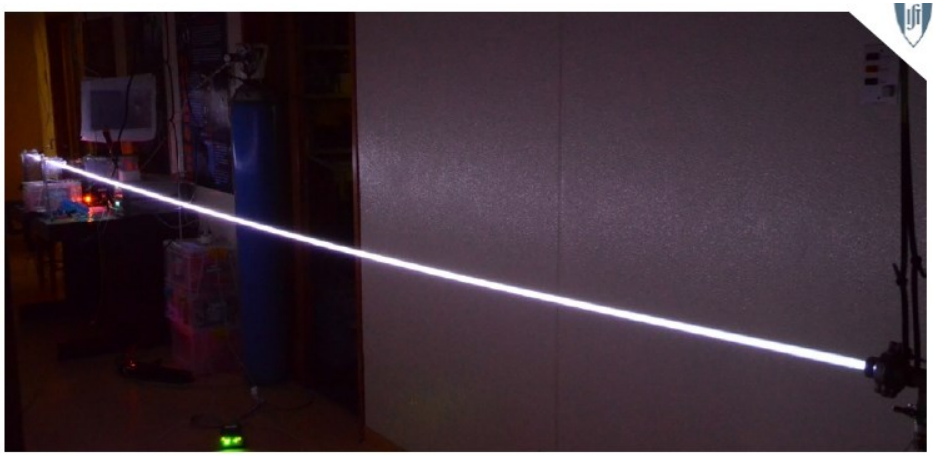
- **Complicated handling (Lithium)**
- Complicated density measurements
- **Scalability to longer lengths?**
- Costs (materials, gas, etc.)
- **Danger of accelerator damage (Lithium)**
- Long procedures (Heating up, cooling down)



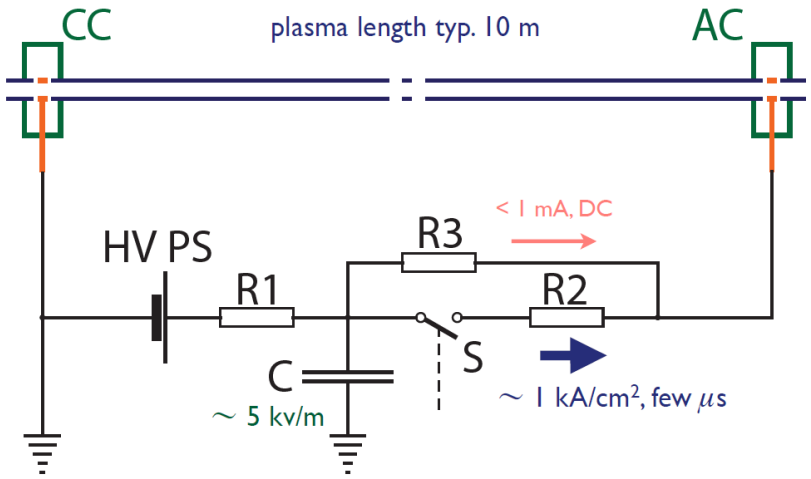


Other Solutions - GDP in PWFA

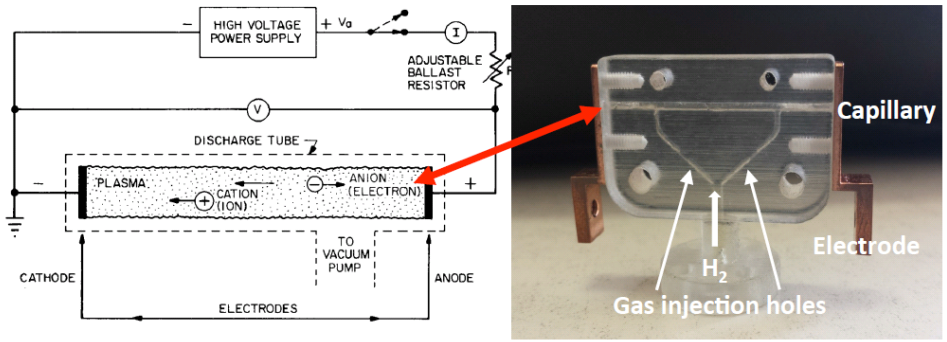
AWAKE Ar-GDP Design



0.2% homogeneity requirement due to witness-bunch σ_z (phase slippage)



SPARC Lab capillary discharge



See also:
Rosenzweig et al. 1989
Demonstration of PWFA in gas discharge
(hollow cathode arc @ 10^{13}cm^{-3})

And:

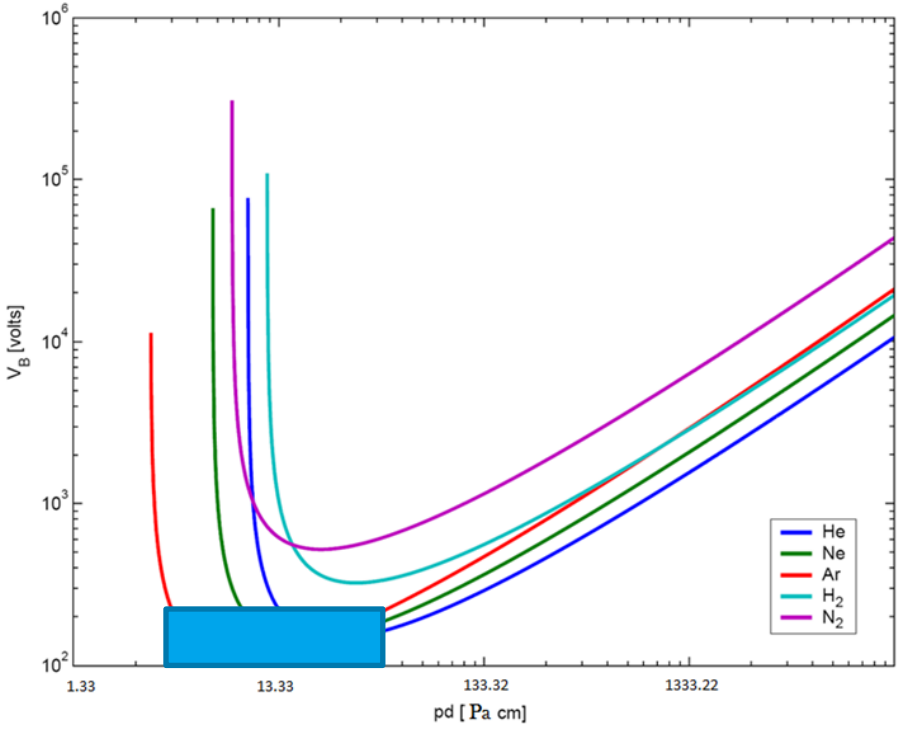
- Possible CTF3 test facility considerations
- Budker Institute proposal
- FLASHForward
- CLARA proposal…

Physics of gas discharges

Paschen curve

- Shows breakdown voltage
- Suggests Argon (also preferable for stabilisation due to high mass)

$$V_B = \frac{apd}{\ln(pd) + b}$$



Breakdown mechanism

- Capacitive
- Statistical
  - ➢ Pre-ionisation
  - ➢ Special electrode design

Discharge current

- Collisional heating of gas
- Spitzer formula of plasma resistivity

$$\eta = \frac{\pi Z e^2 m^{1/2} \ln \Lambda}{(4\pi\varepsilon_0)^2 (k_B T)^{3/2}}$$

- Confinement of plasma (→ **wall stabilisation**)
- Could influence beam (**simulation confirmed negligible influence at PITZ parameters**)

Saha….

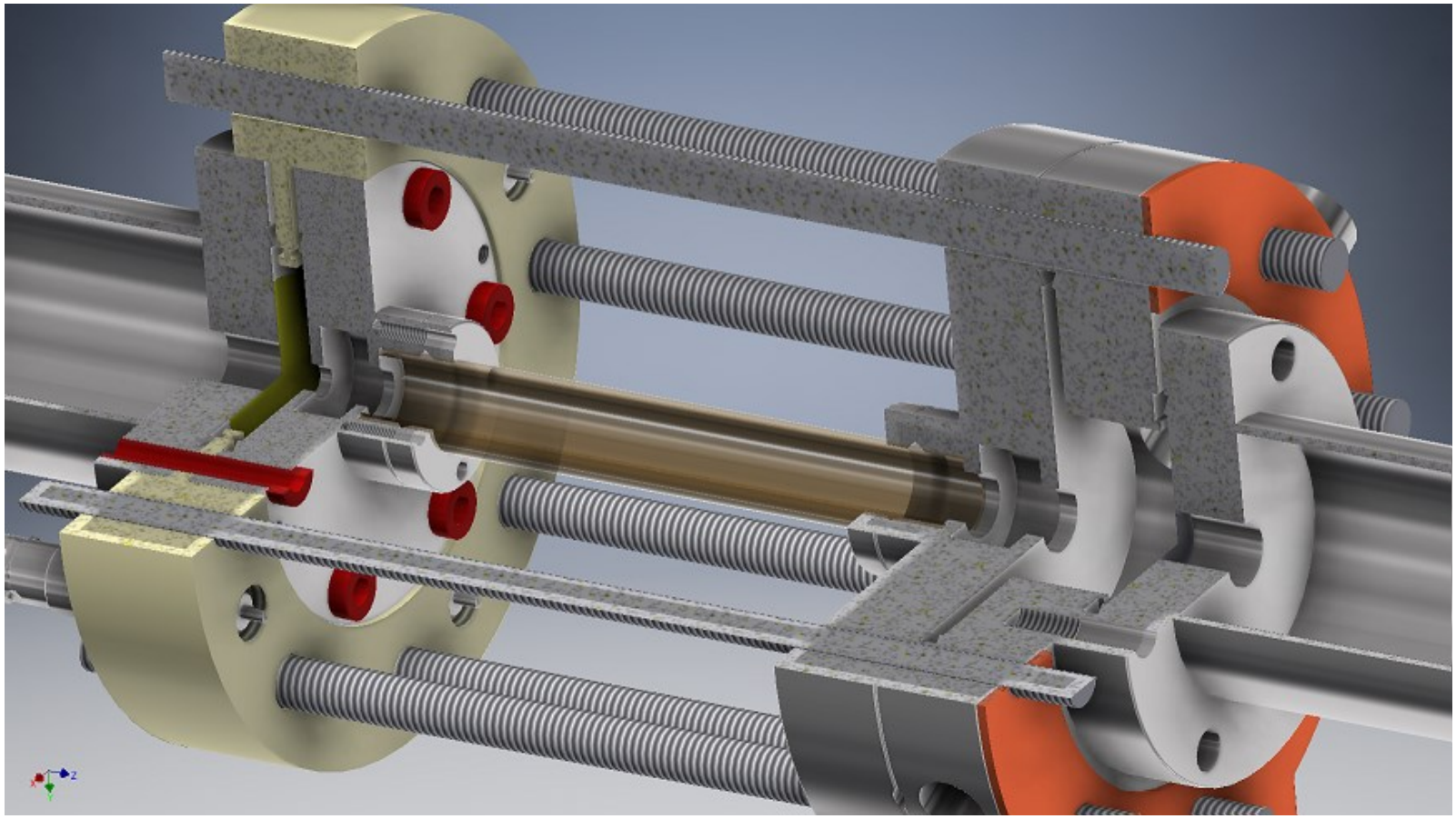
Parameters

Electron density	10^{15} cm^{-3}	Defined by PITZ beam
Plasma length	10cm	Defined by simulation
Gas Pressure	ca. 0,04 mbar – 0,4 mbar	Set by e-density and Spitzer formula
Discharge duration	ca. 1-10µs	Set by wall stabilisation and Spitzer formula
PRR	10Hz	PITZ nominal
Voltage	1-3kV	Def. by Paschen curve
Peak-current	200-600A	Def. by Spitzer formula

PITZ-beam: 21ps flat top, 20MeV, 100pC (Self Modulation-studies)

→ **Max. allowed δn=5%** (***Schroeder et al.,* Physics of Plasmas 19, *2012***)

PITZ GDP design



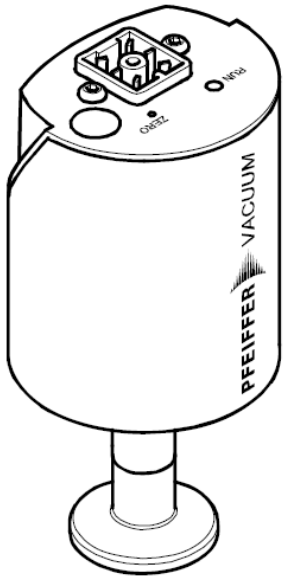
Wall-stabilised, linear discharge

- Initial skin-depth > plasma diameter
- 12 mm plasma diameter
- Hollow electrodes for enhanced ignition
- LxD = 150x114 mm

Diagnostics

- Verify discharge stability
- Define operation parameters
- Calibrate electronics

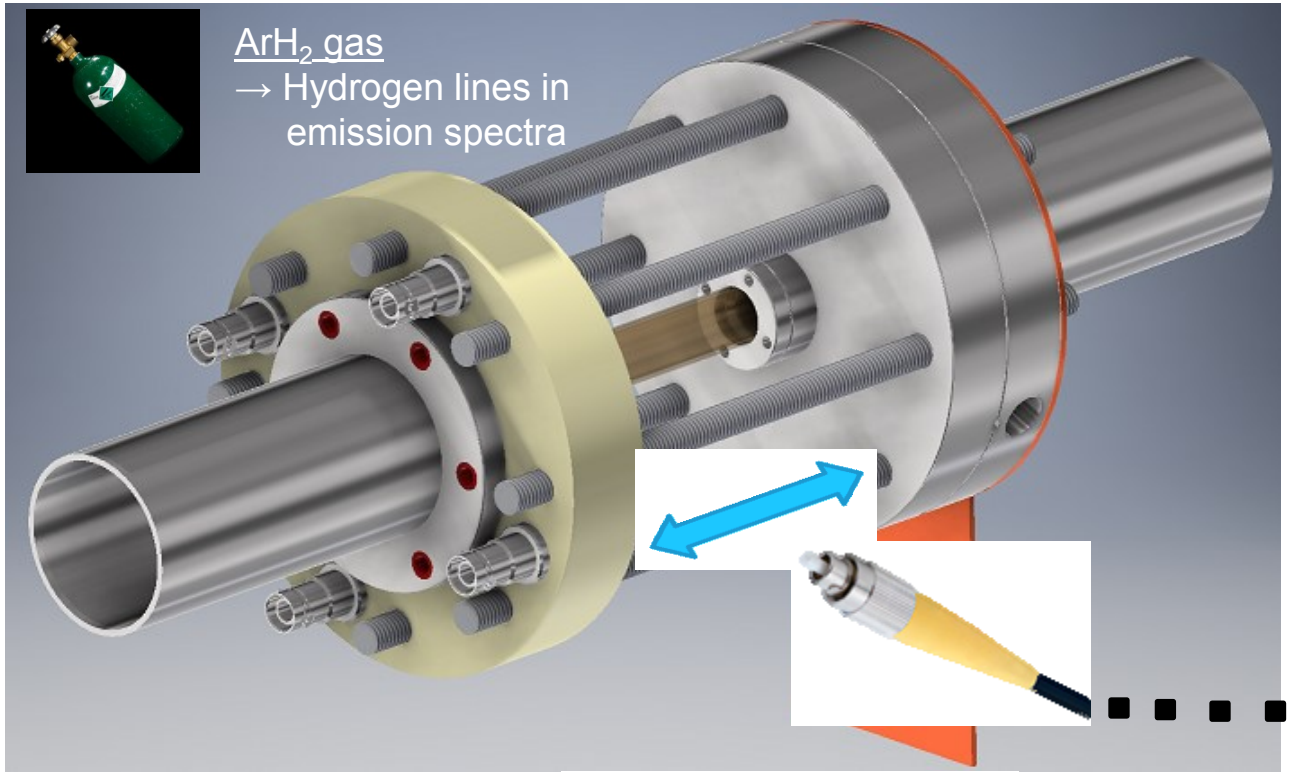
Rogowski coil
- 0.01V/A
- >20ns rise time
- 15Mhz



Pfeiffer capacitive gauge CMR363
- 0.2% absolute accuracy
- Not suitable for radiation environment

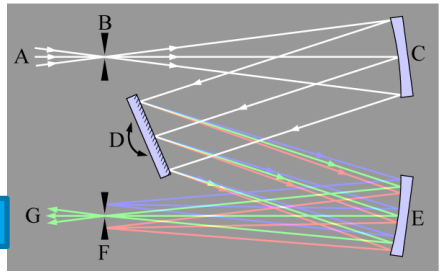
PCO DiCam
- >2ns exposure time (500ns needed)
- Intensified for low emission (lines)

Diagnostics

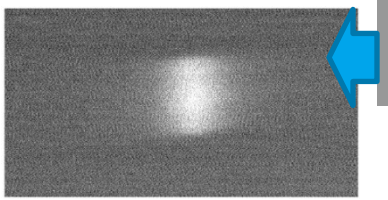


Spatially resolved Stark-broadening diagnostics

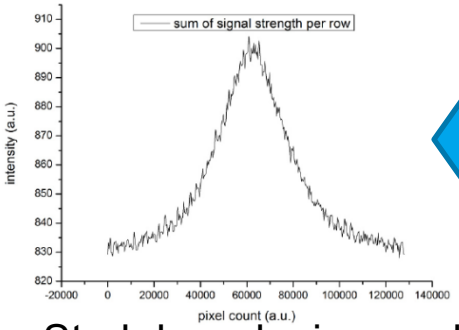
Monochromator



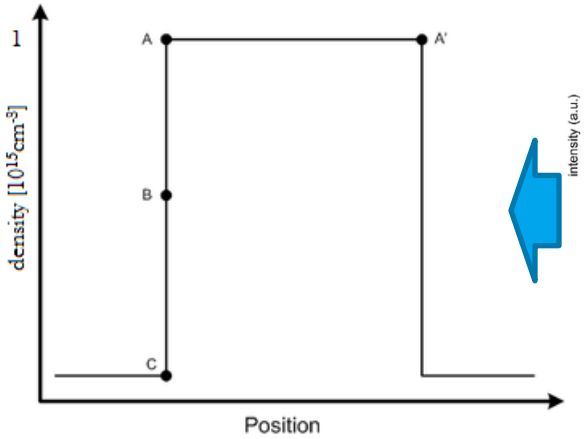
Resolve H_β 486nm line



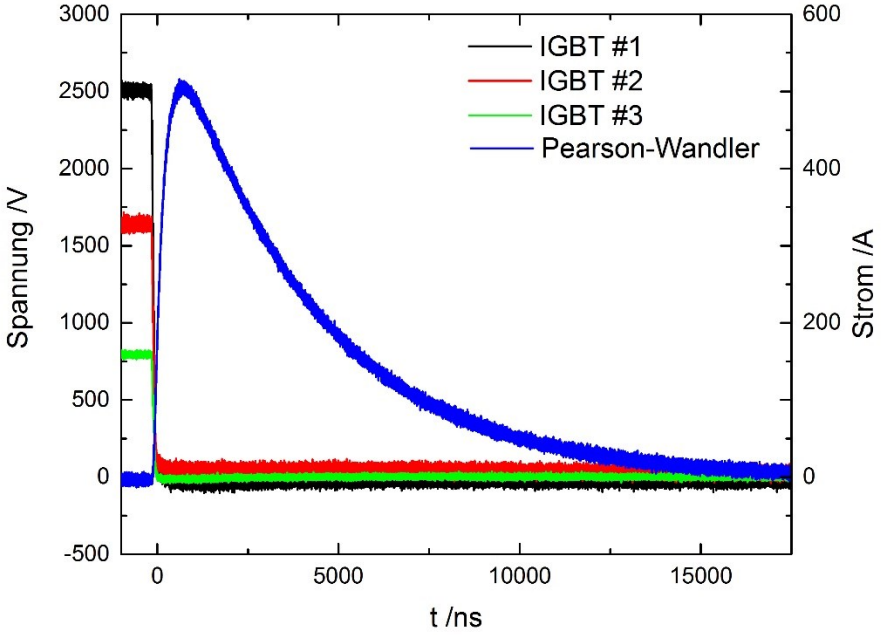
ICCD-camera image



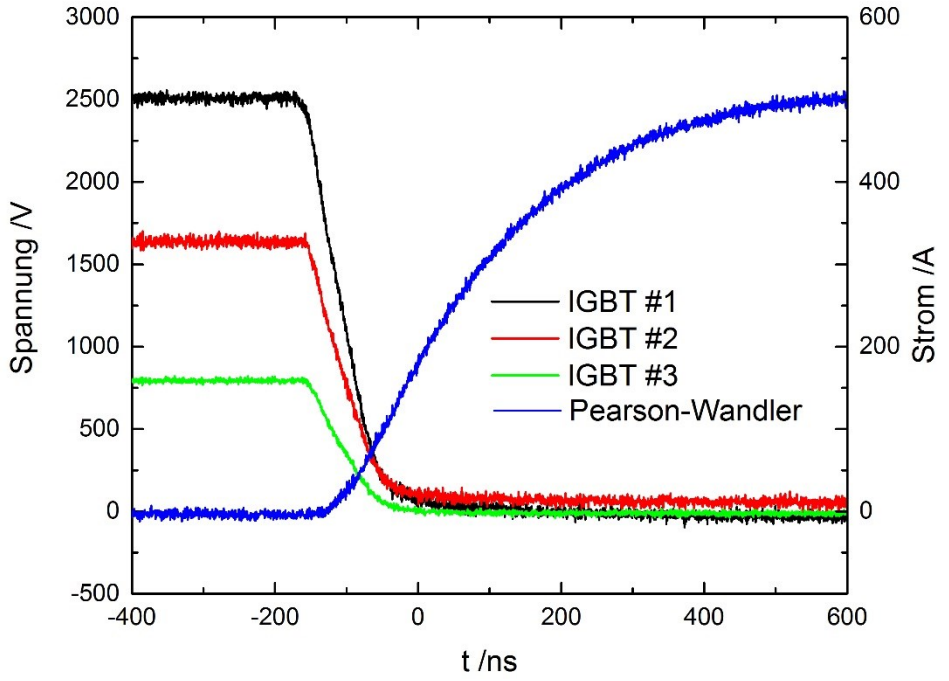
Stark-broadening analysis



First “results“...



Performance of the high voltage pulse network



Summary

1. **Parallel plasma cell approach**

2. **Benefits from Lithium cell infrastructure and technology**
   (beamline slot, vacuum windows, beam transport, IL system)

3. Chance to **overcome intrinsical problems** of Lithium vapour oven

4. Development essential for **high transformer ratio experiments**

5. **Extension of density range** 10^{12} – 10^{16} cm^{-3} with different plasma cell technologies (→ PWFA & Lab-Astro experiments)

6. Next: assembly and density measurements

Thank you for your attention!

G. Loisch

for LAOLA@PITZ
M. Gross, M. Krasilnikov, O. Lishilin, A. Oppelt, G. Pathak, F. Stephan

Special thanks to D. Richter, G. Koss, M. Sack, M. Hochberg, S. Philipp, J. Jacoby and J. Engel

HELMHOLTZ ASSOCIATION

DESY