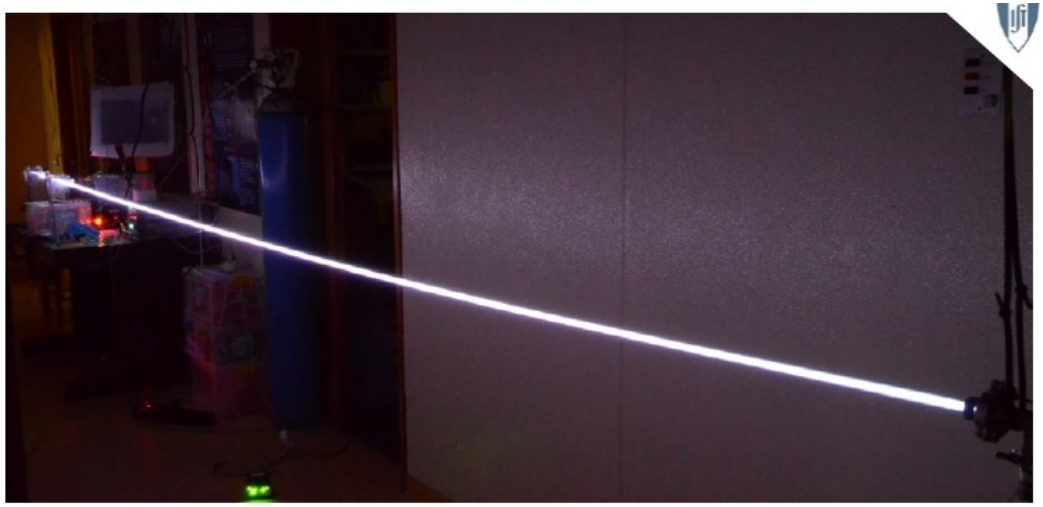
Argon Gas Discharge Plasma for PITZ Wakefield Experiments

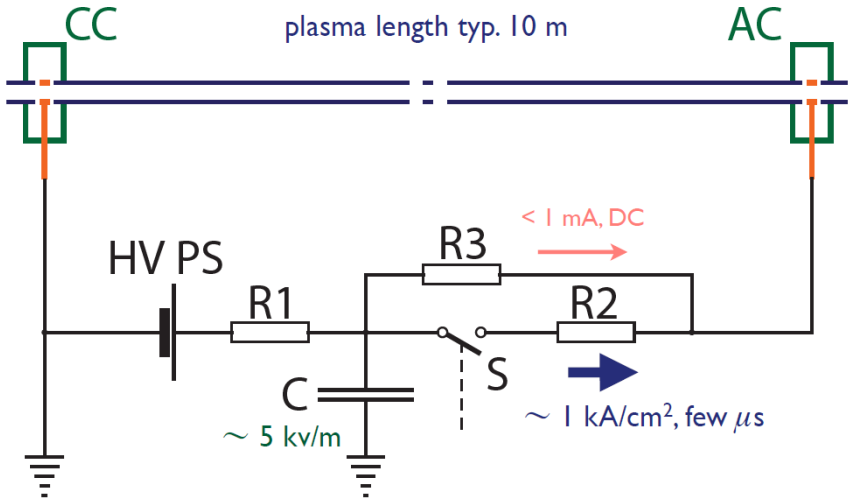
Parameters

Electron density	$1x10^{15}$ cm^{-3}
Plasma length	10cm
Gas Pressure	ca. 0,04 mbar – 0,4 mbar
Discharge duration	ca. 1-10µs
Total length	150 – 200 mm
PRR	10Hz
Voltage	1-2kV
Peak-current	200-400A

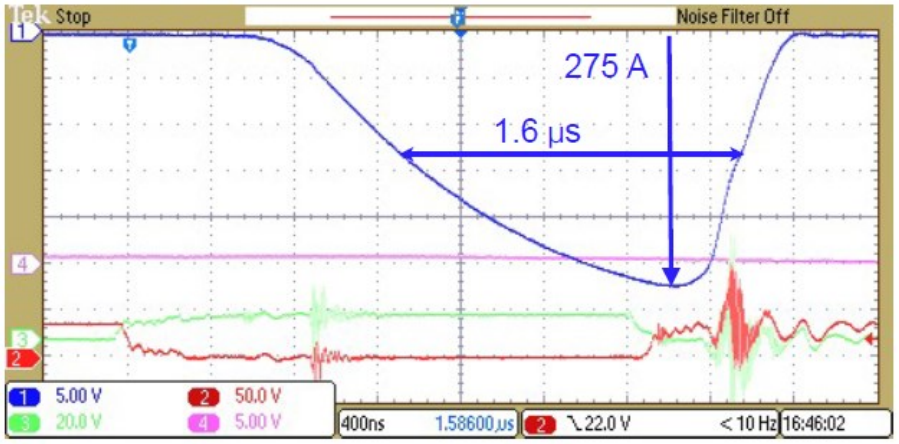
References

AWAKE Ar-GDP Design





Density requirements of 0.2% homogeneity result from witness-bunch σ_z …

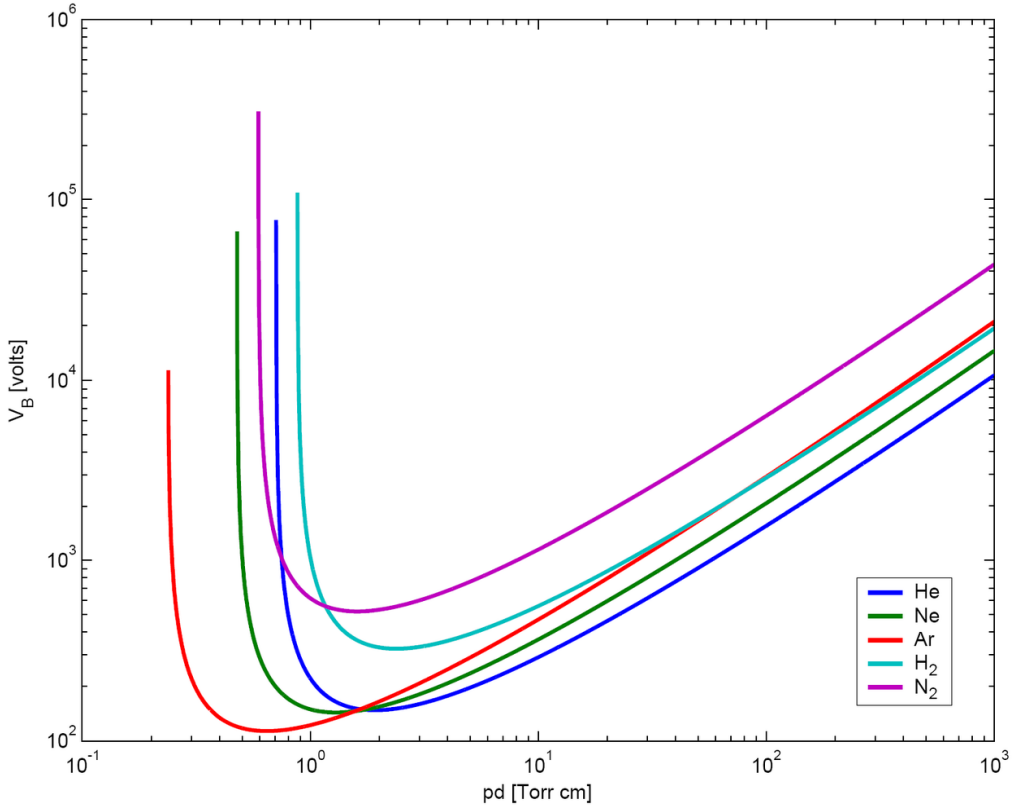


See also:
Rosenzweig et al. 1989
Demonstration of PWFA in gas discharge (hollow cathode arc @ 10^{13}cm^{-3})

And:

- Possible CTF3 test facility considerations…
- Budker Institute proposal…
- CLARA proposal…
- SPARC design…

Why Argon?



Breakdown voltage at required pd:
~200-500V

Lower mobility than H_2 or He
→ Stabilisation of the discharge

Type of discharge

"Wall-stabilised linear discharge"
→ Skin-depth > plasma diameter

Left branch of Paschen-curve: hollow cathode geometry

Right branch of Paschen-curve: pre-ionisation by low current glow discharge

Influence on beam?
400A, fully space charge compensated…

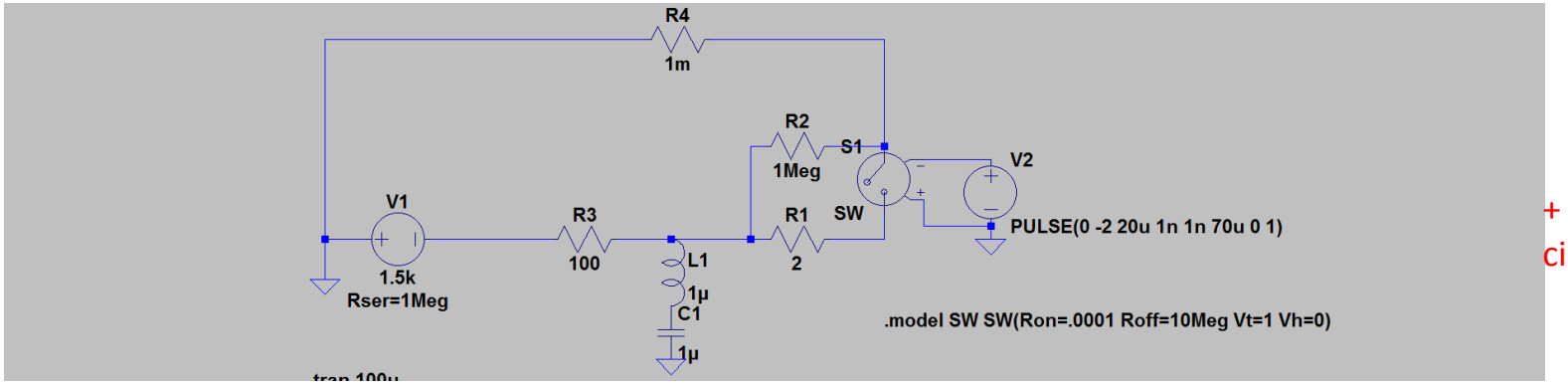
→ Comparison with heavy ion "plasma transfer channel" (*Watrous et al. 1989*):
Li^+ ions 30MeV/u in $10^{17}cm^{-3}$ at 11.1kA

$B\varrho_{Li+}/ B\varrho_{PITZ}=74$ and $I_{Li+}/I_{PITZ}=28$
BUT: charge state change in dense plasma Li+ → Li3+
$B\varrho_{Li3+}/ B\varrho_{PITZ}=25$

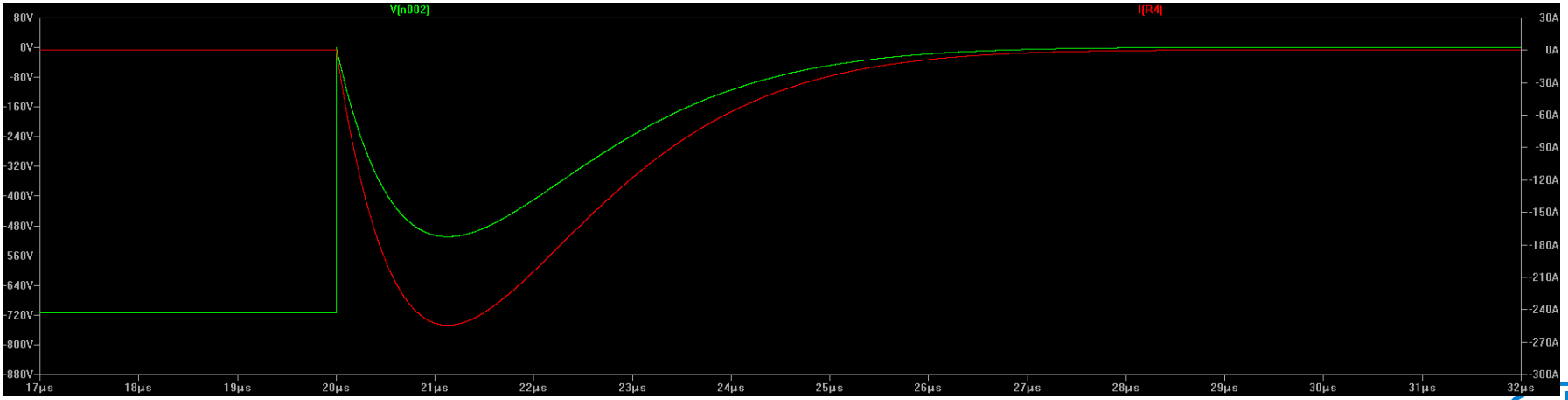
→ No intense focussing expected from this comparison…

Setup

PITZ-design: electrical circuit



+ earthing/emergency circuit



Setup

PITZ-design: discharge vessel

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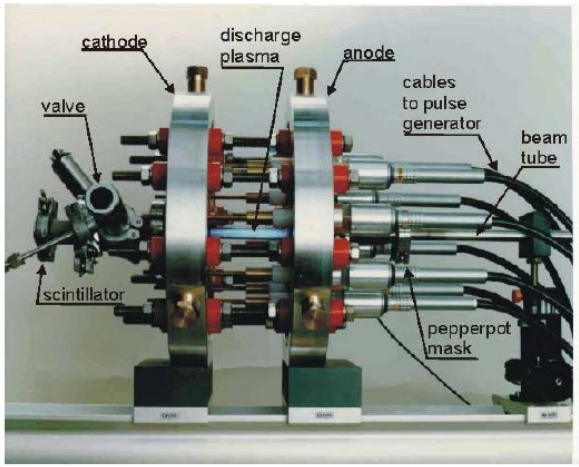
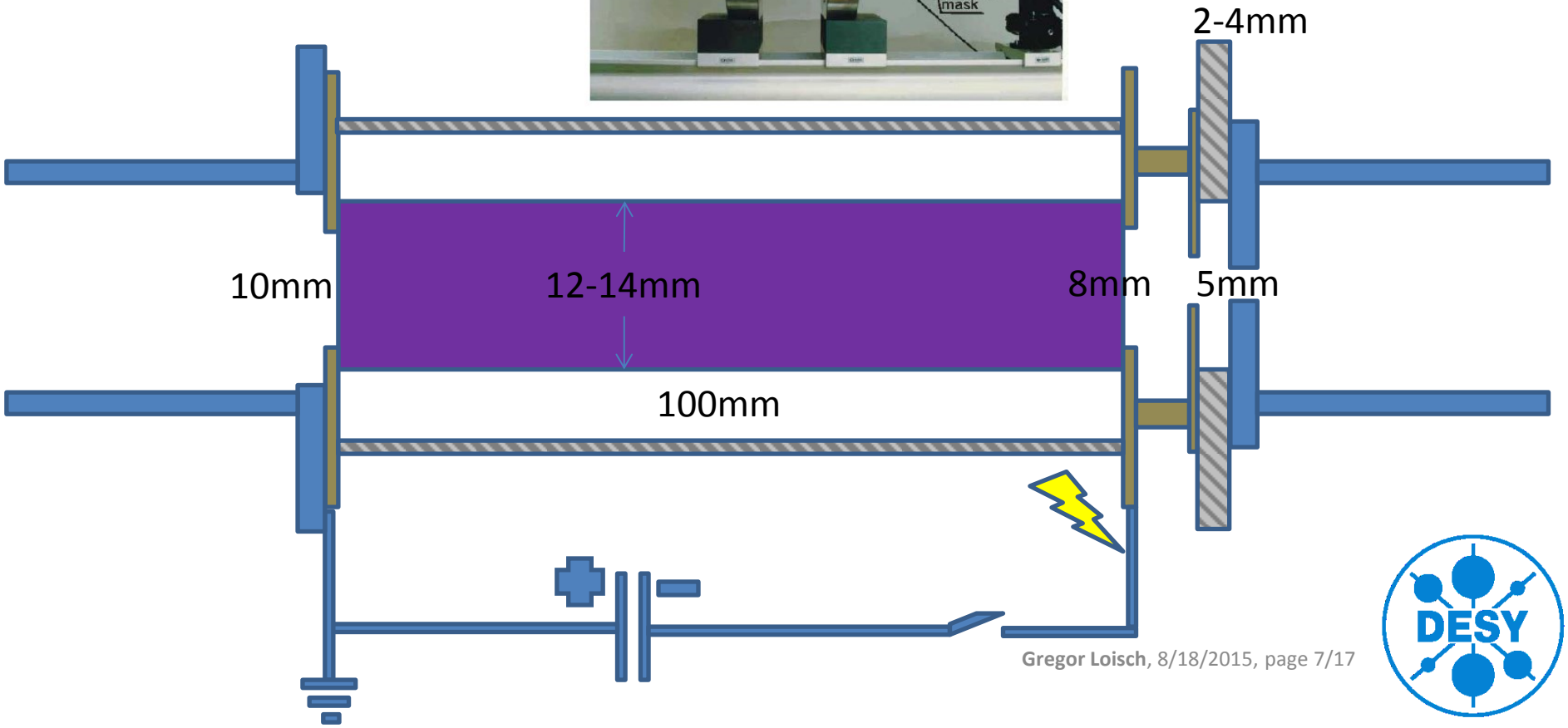
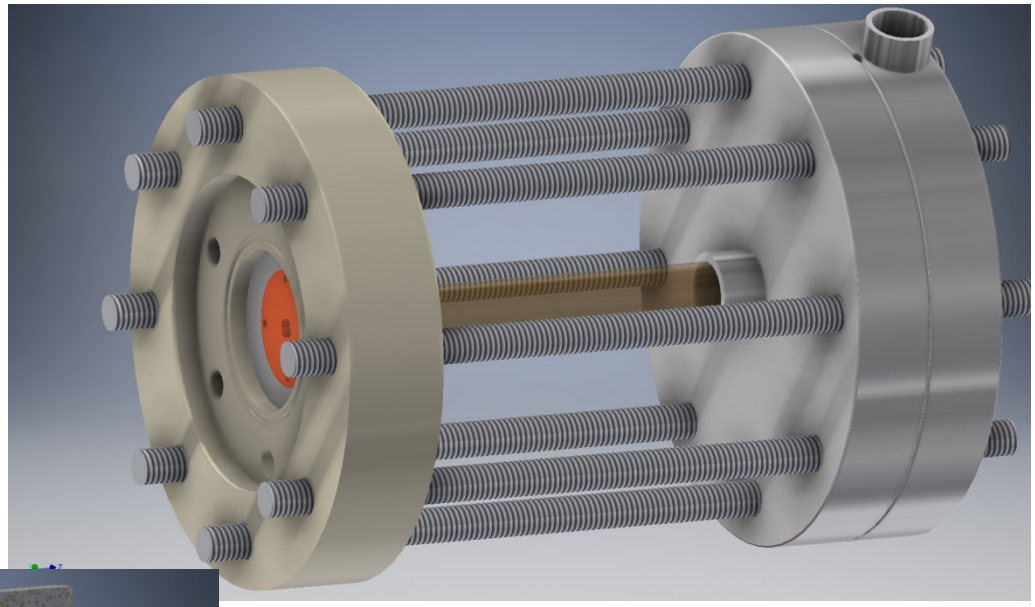


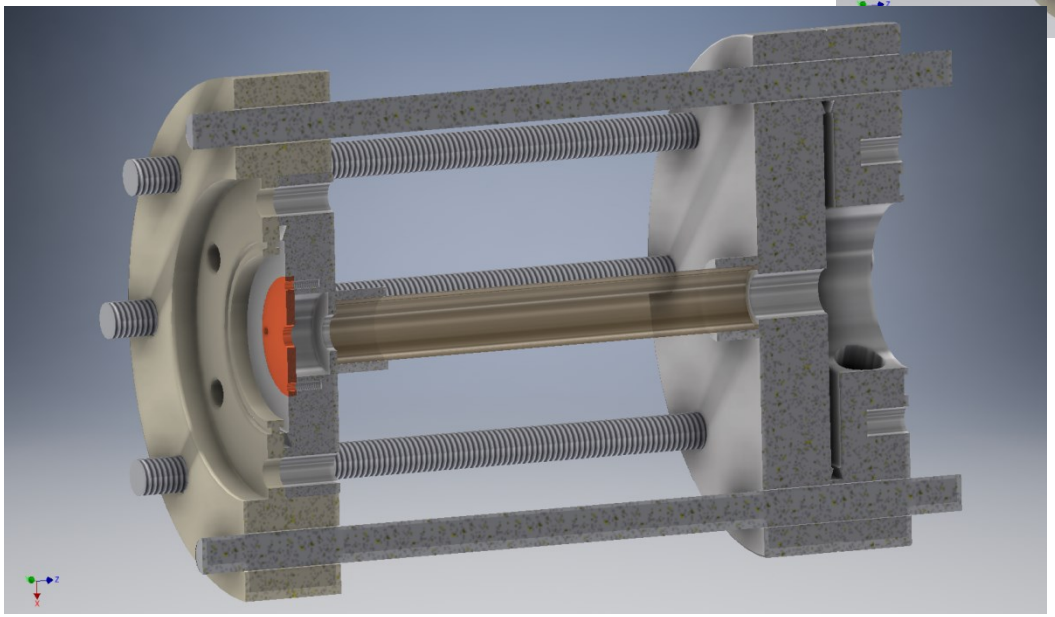


Setup

Additional Considerations:

- External current return to avoid amplification of pinch behaviour
- No 50 Ohm matching needed due to short length of 10cm





Open constructional tasks:

- HV-connections
- (Sealing between metal and glas)
- (Sealing between insulator & metal flanges)
- Exact positioning of gas-inlet/pump port
- Electrode material

Technical requirements

Commercial:

- HV-Source (~2.5kV, 60mA) (preliminary parameters available)
- Rogowski coil
- Voltage probe (available)
- Pulse capacitor (4x 1µF)
- Pulse resistors
- MegOhm HV-resistor
- Power switch
- Ar-Gas (available)
- [Remote controlled valves for pressure adjustment from CR (?)]

In-house production:

- Discharge vessel
- Electrical circuit housing
- EM-housing

Diagnostics

- ArH2-Gas
- Fast camera, ~.1µs, ~DiCam (Hamburg?)
- Monochromator (Dortmund?)
- Callibration lamp
- Oscilloscope
- High accuracy pressure gauge

Discussion: Why a GDP-cell?

+	-
No Lithium	EM-Noise
No laser	Type of discharge new for PWFA
Easy remote control	Not as sharp boundaries as Li
Easily scalable to other lengths	
Easy setup and handling	
Easy diagnostics (tr.v. & longit.)	
Thinner Kapton-windows	
(Formation of hollow channels?)	

Discussion: Risks/Unknowns

- Too much EM-Noise for beam line?
- Unstable performance at low pressures/densities?
- Homogeneity not proven yet
- Discharge current disturbs beam/wakefield formation?

Components

Switch

TPI1-0.2k/12
Cold cathode thyratron
Pulsed Technology (Ru)

- 1-15kV
- 0.1-1kA
- kHz
- 1.8k€ (+1k€ Triggerbox)

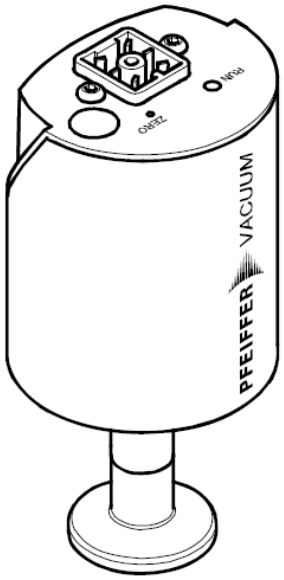
Karlsruher Institut für Technologie

Stacked Semiconductors/Marx generator

- Ca. 100€/stage
- 1 stage ~1kV
- 500A max.
- ~50Hz
- 4kV/400A incl. low noise capacitor charger: ca. 700€

Components

Pressure Gauge



Pfeiffer capacitive gauge CMR363

- 0.2% absolute accuracy
- Not suitable for tunnel
- 2k € (incl. controller)

Pfeiffer Pirani gauge TPR018

- 10% absolute accuracy
- Suitable for tunnel
- available

Components

Other electronics

WIMA GTO MKP Capacitors

- 2kV max.
- 1-10µF
- ~10nH
- Ca. 30€/cap
- Alternatively *Muecap*

SHV cables

- ≤ 5kV
- ~100nH/ft

→ 4 parallel, < 1m

Rogowski coil

- 0.01V/A
- >20ns rise time
- 15Mhz
- 470€

Components

Other electronics

Washer Disc Resistors

- +-10%
- 5kV
- 27,6kJ
- 214€/pc

Thick Film Resistors

- +-10%
- 5kV
- ≥30W
- ~40nH/pc
- ≤95€/pc

HV-film resistor

- 200k-5MOhm (+-1%)
- 4.5kV
- 10W @ 25°C
- 42€/pc

Time & cost estimation

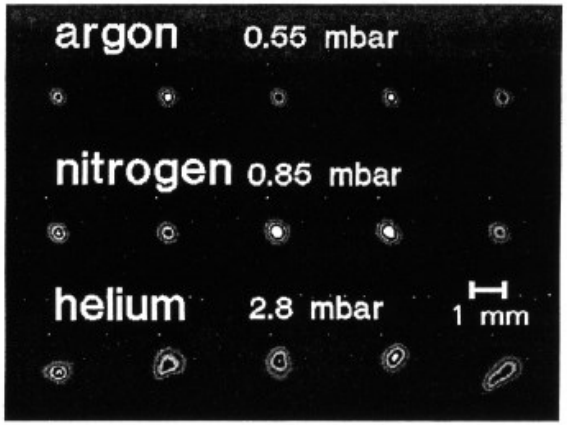
Component	Price
Switch	~700€
Capacitors	~150-250€
Rogowski coil	470€
HV-resistor	90€
Pulse resistors	300€ (max.)
Mechanical parts	~500€
Overall	**2300€**
(accurate pressure gauge)	(+2000€)

Delivery of electronics ~12 weeks
Construction & Workshop 8-12weeks
Assembly (2pers.) 1 week
Comissioning & Diagnostics (2pers.) 3-4 weeks

Thank you for your attention!

Some historical pictures

A. Tauschwitz et al.



Size and reproducibility of the focal spot for different discharge gases

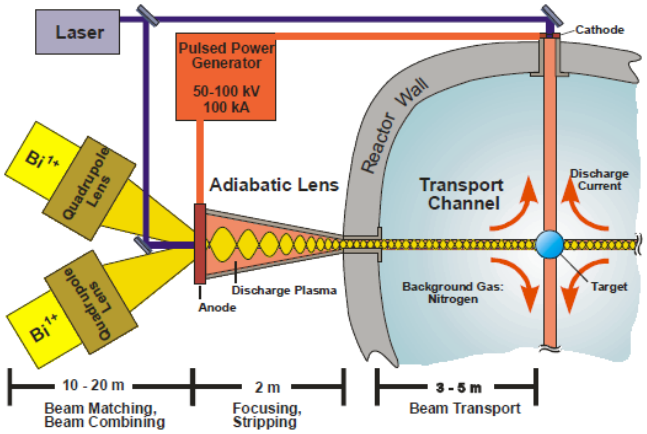


Figure 7.1: Principle layout of a heavy ion driven IFE Reactor with Plasma lens focusing and discharge channel final transport

A. Tauschwitz et al.

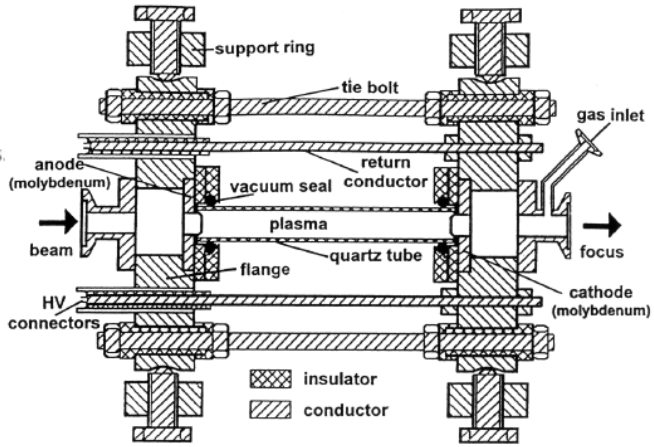


FIGURE 4. Mechanical design of a plasma lens for currents up to 30 kA.

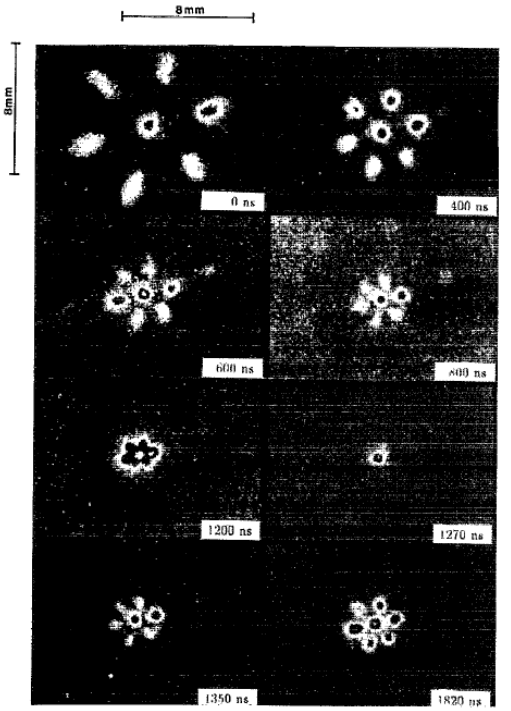


FIG. 3. Continuous series of framing snapshots taken end-on of the seven gold beamlets which were masked out by a pepper pot plate. Exposure time was 200 ns each, the scintillator was positioned at 200 mm distance behind the plasma lens. The maximum focusing corresponds to the merging of the beamlets at $t = 1270$ ns (exposure time here only 30 ns).