Discharge based capillary target development

for PWFA and LWFA at FEBE

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on behalf of S. Boogert, R. D'arcy, D. Graham, G. Xia

- Plasma Wakefield Acceleration at CLARA FEBE will make this facility the first in the UK to achieve energy doubling.
- This project will foster both national and international collaborations.
- Early studies using PIC codes of QV3D an
at energy doubling is feasible at CLARA F
- The focus is on the PWFA experiment, bu
explore alongside this experiment
  - X-ray source based on PWFA
  - Betatron diagnostics
  - Plasma beam dump

Phased approach to high-repetition-rate staging @ CLARA

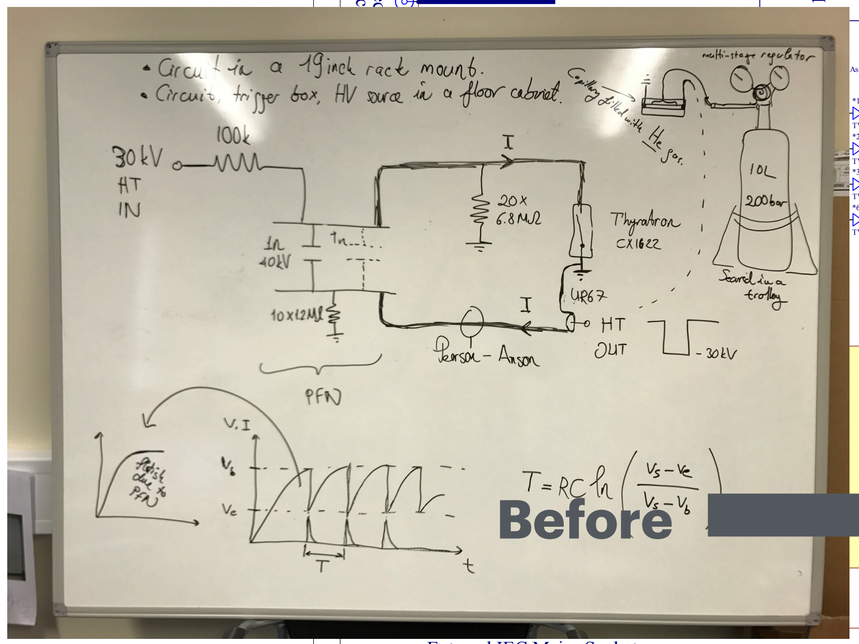
	CLARA 'mode'	Staging	Repetition Rate
Phase 1 (year 1*)	***Single bunch*** ("Day 1") → no acceleration (*deceleration only*)	***Goal***: Beam-quality-preserving inter-stage optics (*no acceleration*)	***Goal***: Plasma and plasma-source temperature mapping *(low repetition rate)*
Phase 2 (year 2-3*)	***Twin bunch*** (optimised) → high-gradient and nonlinear acceleration	***Goal***: Beam-quality-preserving inter-stage optics (*plasma acceleration 250 → 500 MeV*)	***Goal***: Acceleration with novel temperature-stabilised stage *(high repetition rate)*
Phase 3 (year 3-5*)	***Fully leveraged CLARA + FEBE***	***Goal***: Beam-quality-preserving staging @ high repetition rate (*two beam-driven stages**, 250 → 500 → 1000 MeV*)	

*conservative timeline assuming no additional funds secured beyond pre-existing baseline contributions from Oslo, Oxford, and Cockcroft

Discharge source

Heart of the technology

- HV discharge circuit is almost complete
- IAA, commercialisation, **Tritec Development Ltd**



Before

After

External IEC Mains Socket

Could operate the PSU externally by making small remote control box ?

HV PSU interlock requires door closed and 5 minute timer to have passed

- J2 Interlock (Open = Off) Cabinet Door and Thyratron Heater interlock
- J3 V Monitor 0-10V
- J4 HV Status Low = HV Off, High = HV On
- J5 HV Enable 2.5-15V ON, 0-1.5V OFF
- J6 Fault Status Low = OK, High (5V) = Fault (HV off)
- J8 Mode Status Low = Voltage mode, High = Current mode
- J9 Remote HV ONStatus (Use Digital Common)
- J10 Remote HV ONStatus (Use Signal Common)
- J11 I-Monitor (Use Signal Common) 0-10V

Switch between J3-15/16 allows HV ON to be done remotely

NB Some Analog in/outputs require setting to REMOTE on PSU

Check if this model has Arc status fitted ?

- IEC C14 socket
- External IEC Mains Socket
- External IEC Mains Socket
- J12 BNC Socket
- Optical FSMA Socket

Cabinet

All Bulkhead BNCs to be have signal and ground isolated from mechanical fixing e.g. 031-10-RFXG1

Case Earthed but from where ? One of IEC Leads ?

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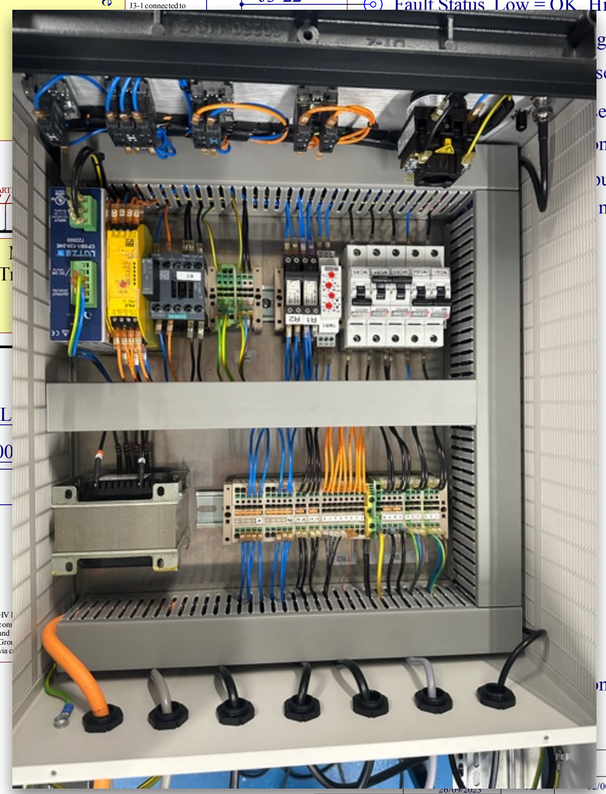
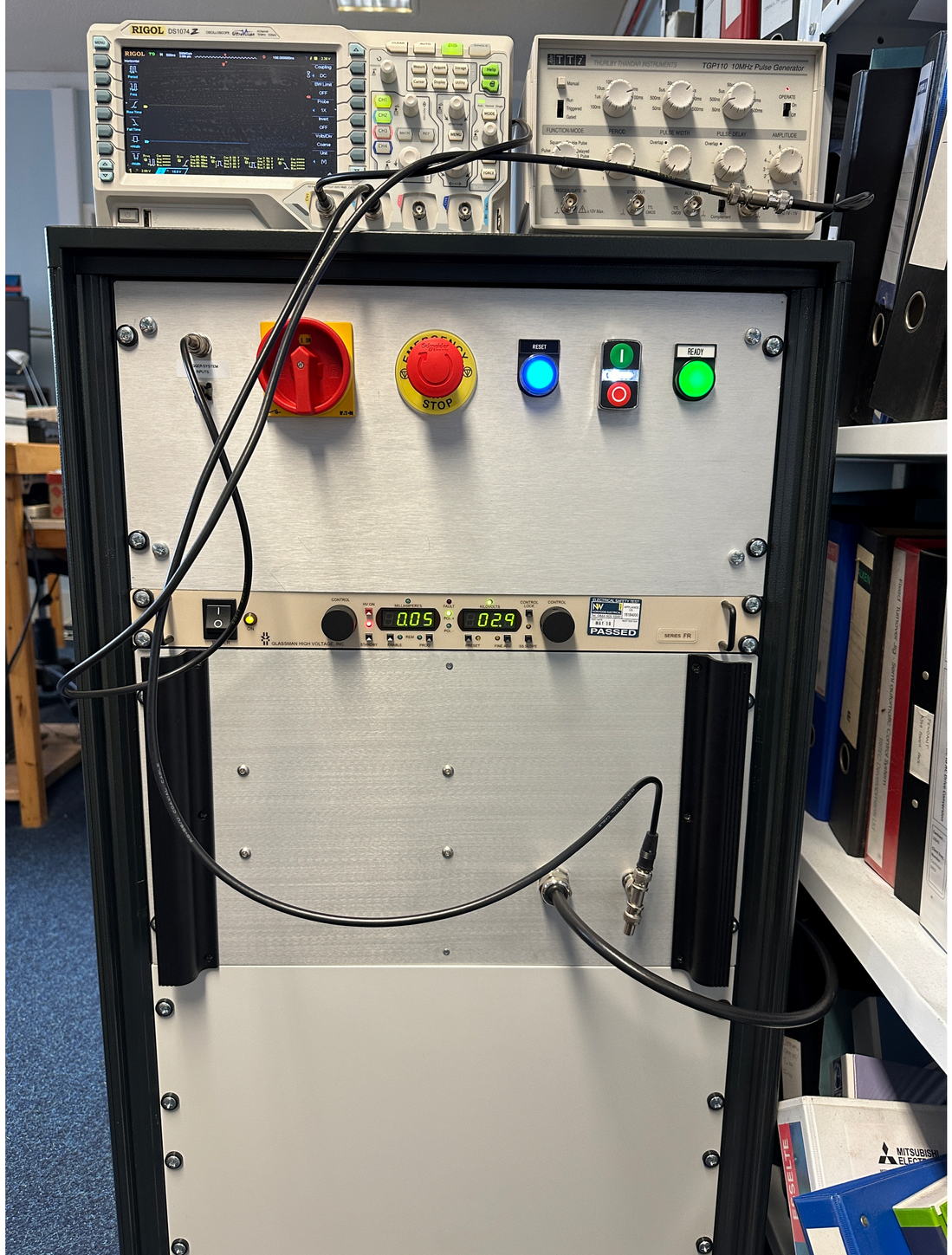


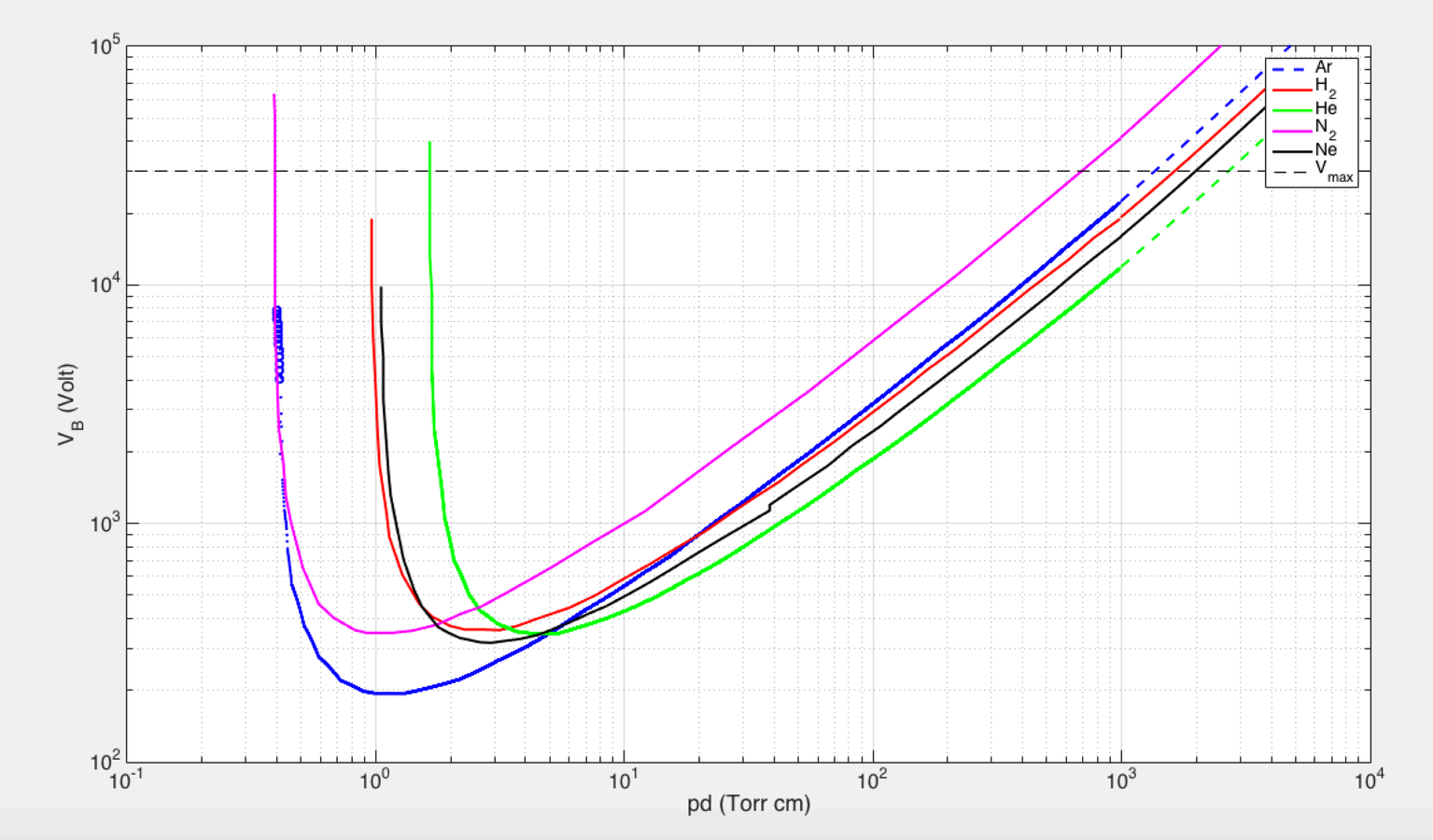

RIGOL DS1074
THURLBY THANDAR INSTRUMENTS TGP110 10MHz Pulse Generator
STOP
RESET
READY
0.05
029
PASSED


GND
INPUT
Stangenes Industries, Inc.

Discharge source

Example working range for He

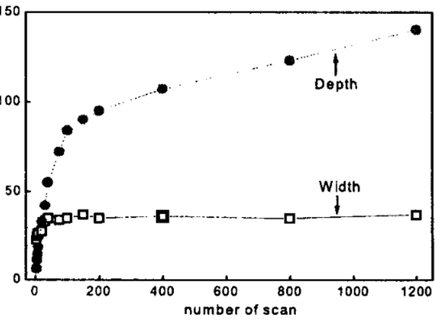
n(cm^{-3})	Pressure (mbar)	Pd (10cm) (Torr cm)	V (V)
4.12E+13	0.22	1.6480	INF (pressure too low)
5E+13	0.3000	2.0000	828
1E+14	0.5	4.0003	349
5E+14	3	20.002	619
1E+15	6	40.003	967
5E+15	27	200.02	3172
1E+16	**54**	**400.03**	**5543**
5E+16	**267**	**2000.20**	**22620**
6.75E+16	360	2700	power limit

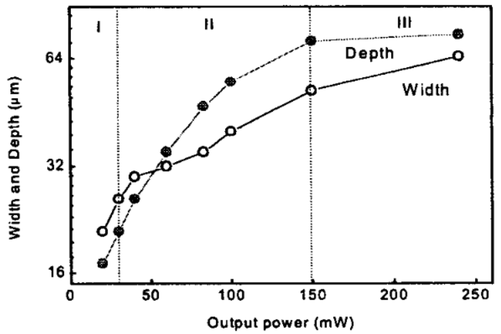


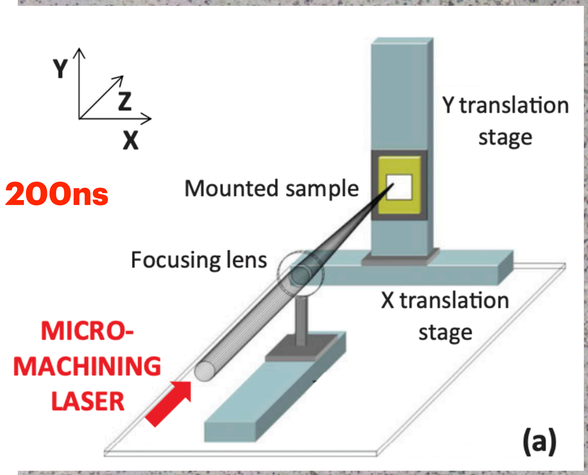
Sapphire target

Laser machining

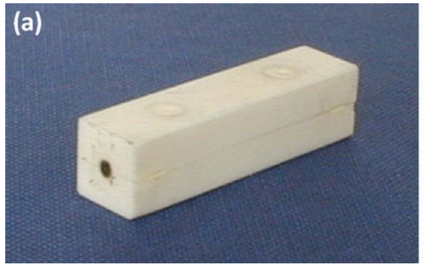
Microscopic image courtesy of Andy Wootten (STFC)

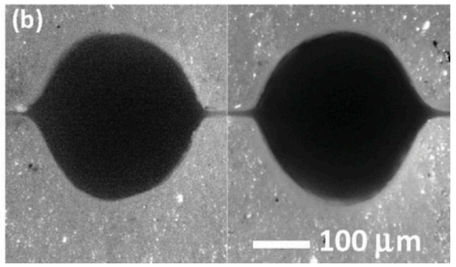


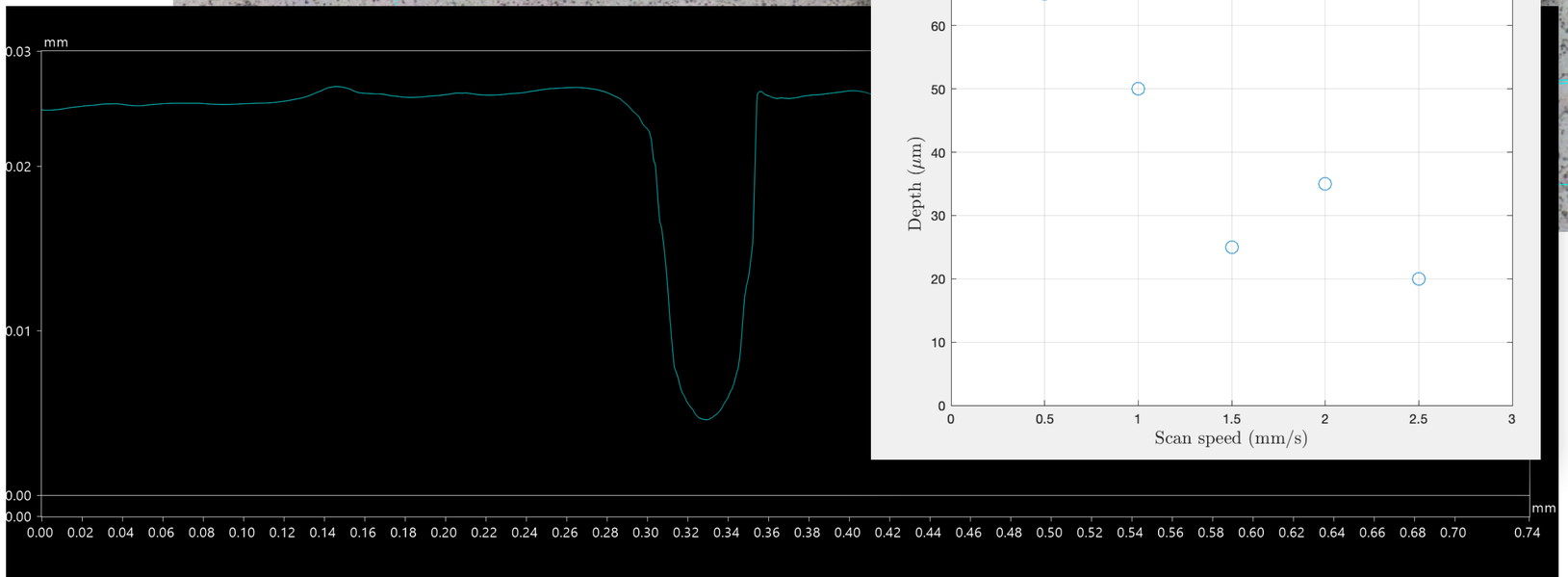




1kHz, 1mJ, 200ns





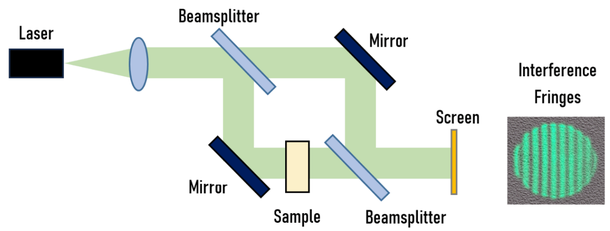


S. M. Wiggins et al., Journal of Plasma Physics,78, pp 355-361 (2012) doi:10.1017/S002237781200006

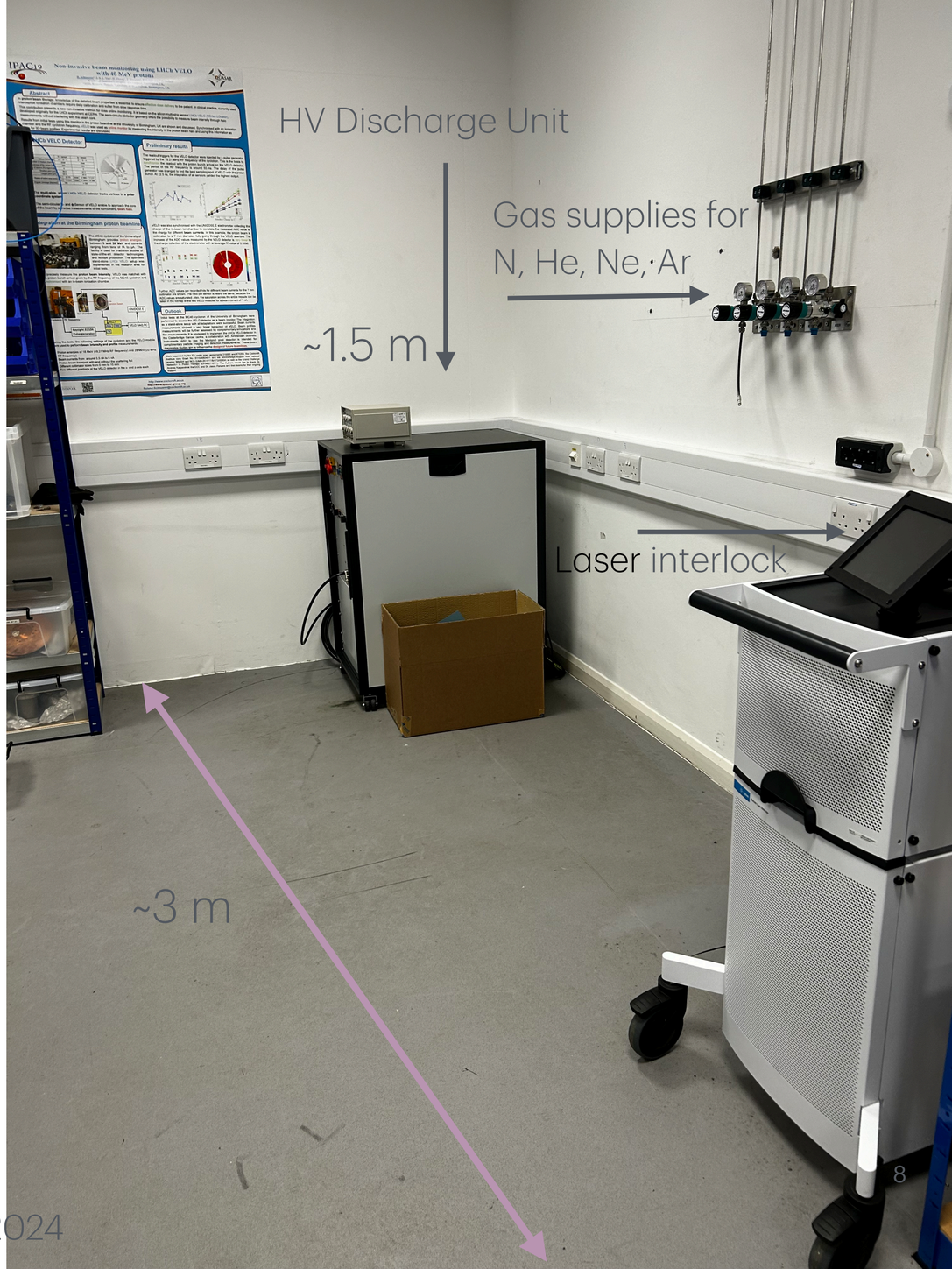
K. S. Kim, et al., 14th Annual Meeting of the IEEE Lasers and Electro-Optics Society, doi: 10.1109/LEOS.2001.969038.

Prototyping

Lab space in A Block



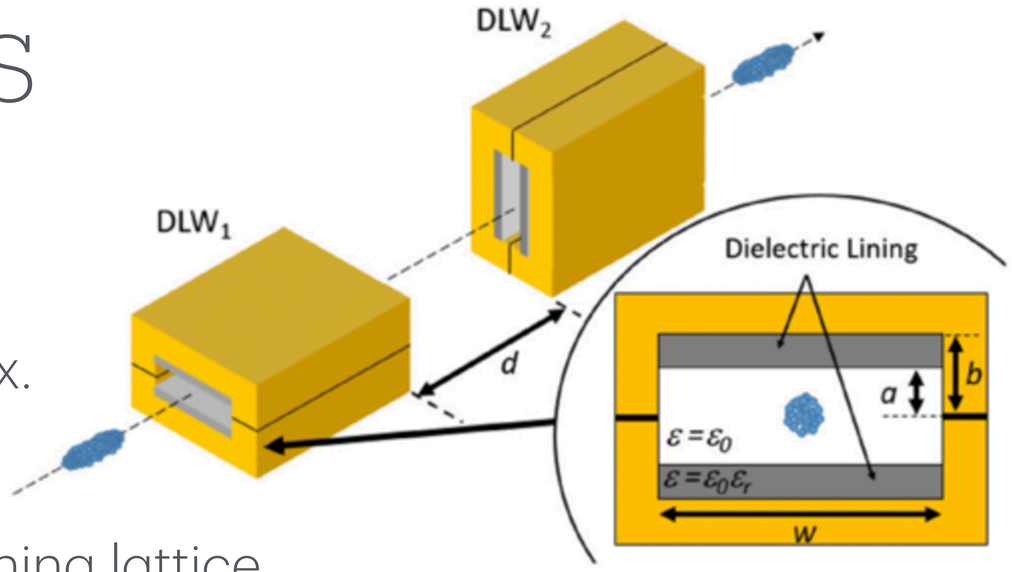
- Mach Zehnder interferometry for density measurements, optical table installed on 20th Dec.
- Procurement ongoing,
  - Manchester strategic, IAA and internal funds + CI funding
  - In process of a new IAA with also industrial contribution.
- Delivery timeframe is compatible with to FEBE timeline.
- Manpower
  - Initially, 0.5FTE PDRA on interferometry
  - MPhys and PhD student on laser machining
  - Dedicated PhD student on implementation into FEBE advertised.

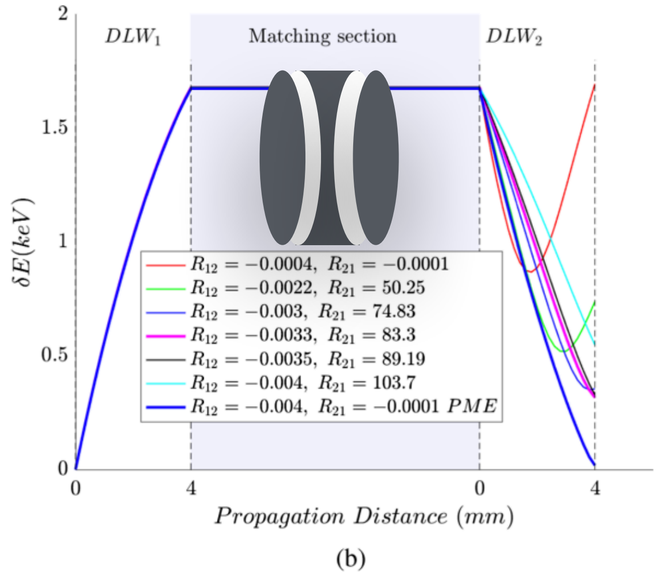


Multi-staging scenarios

Matrix based matching

- Pseudo-inverse matching to extract a transfer matrix.
- Validation using non-periodic transfer matrix.
- Multi-objective optimisation for determining a matching lattice.





(b)

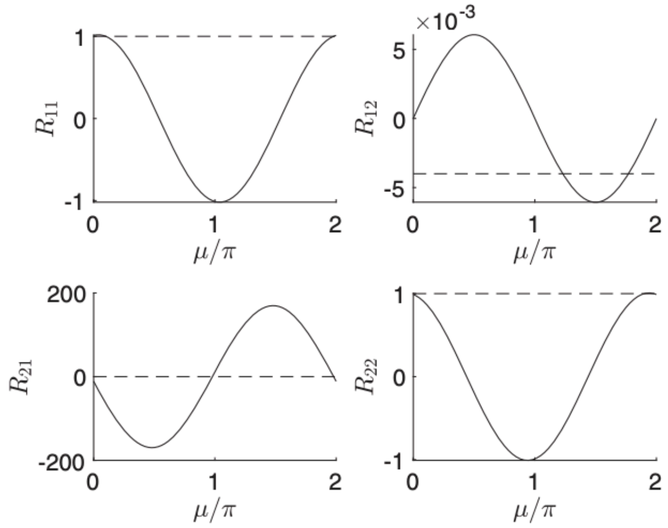


TABLE III. The elements of the transfer matrices corresponding to different triplet designs.

Design	R_{11}	R_{12}	R_{21}	R_{22}
No drift	0.6897	−0.0033	13.1928	0.9039
Q100$D_3$10	0.7845	−0.0033	51.5138	0.9738
Q50$D_3$10	0.7629	−0.0033	97.2900	0.9003
Q100$D_1$150$D_2$150	0.8118	−0.0035	129.0208	0.9870
Q100$D_1$200$D_2$200	0.9157	−0.0037	139.9490	1.1135
Q100$D_1$200$D_2$200$D_3$200	0.7461	−0.0033	46.8733	0.9202

TABLE II. The specifications of quadrupole triplet arrangements with different lattice lengths and resulting energy spread of the multistage.

Design	Matching section length (cm)	g (T/m)	r (mm)	ΔE (keV)
No drift	30	20.4/111.5/7.3	50/9/138	0.92
Q100$D_3$10	31	75.3/0.5/66.2	13.3/201/15.1	0.54
Q50$D_3$10	16	310.2/−0.18/219.2	3.2/567/4.6	0.46
Q100$D_1$150$D_2$150	40	48.8/−1.8/50.2	20/55.8/20	0.49
Q100$D_1$200$D_2$200	50	46.5/−3.7/47.9	21.5/268/21	0.86
Q100$D_1$200$D_2$200$D_3$200	65	61/1.2/10.5	16.4/807/95.4	0.5

O. Apsimon et al., Phys. Rev. Accel. Beams **24**, 121303