FETS laser-wire diagnostics: proposed solution for laser beam delivery

on behalf of
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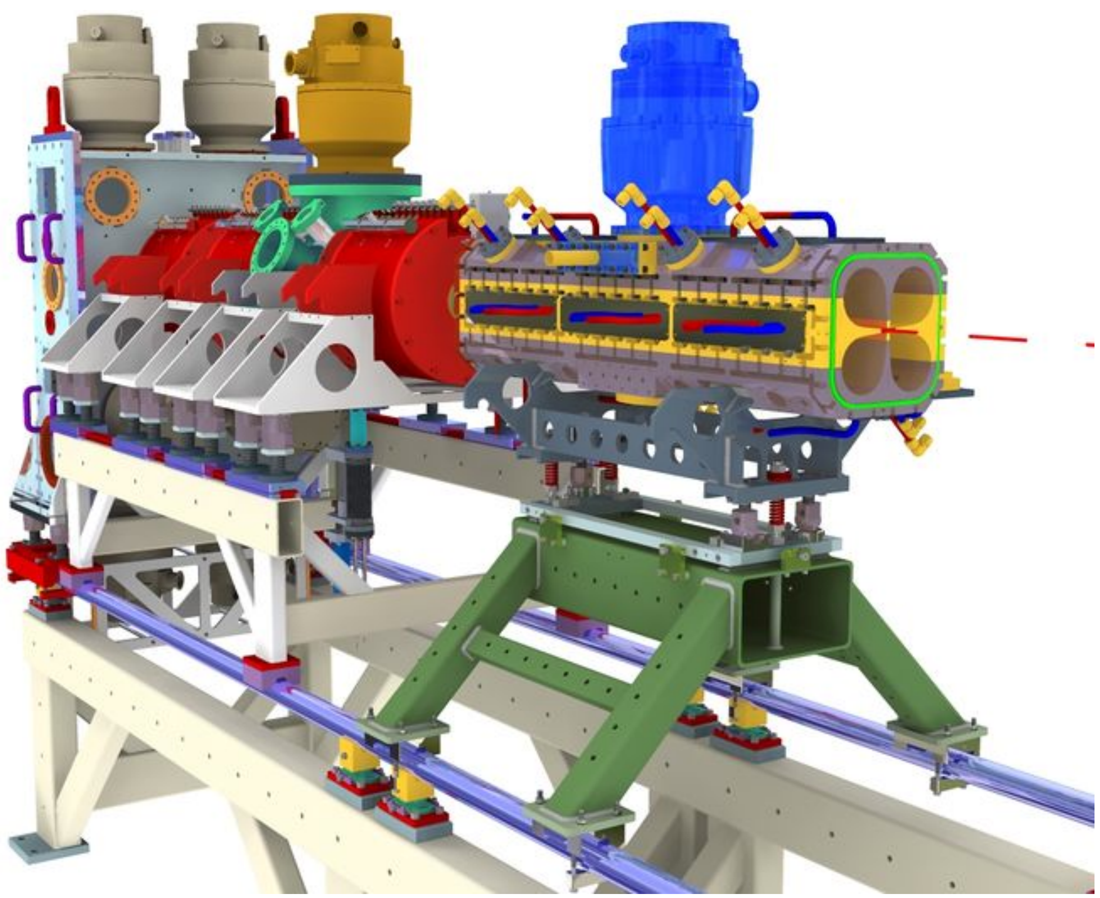
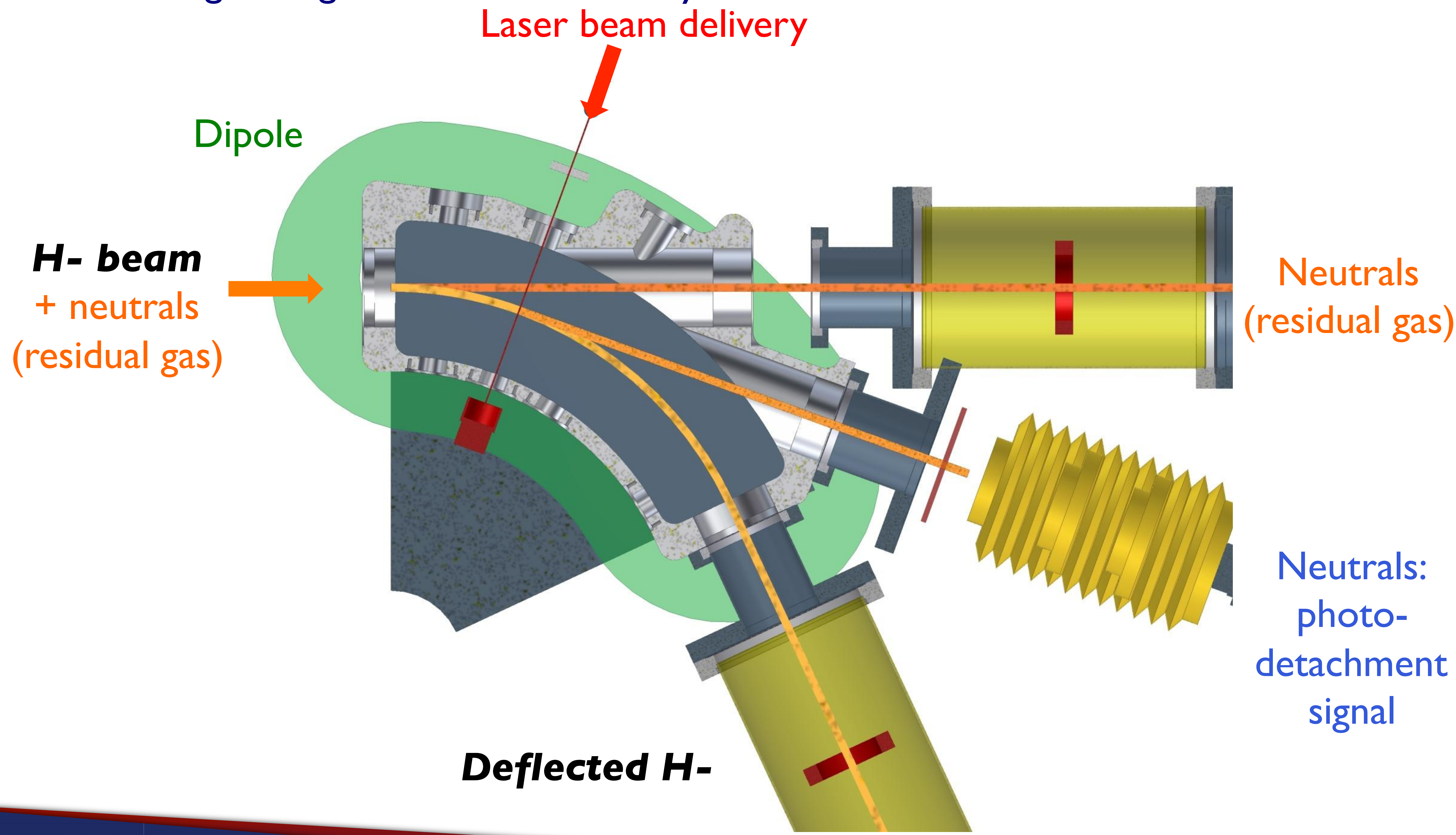
Outline

- Emittance via photo-detachment
- Laser characterization and status
- Laser location and beam delivery.
- Adaptable front end optics
- System integration phases, costing and future.



Emittance via photo-detachment

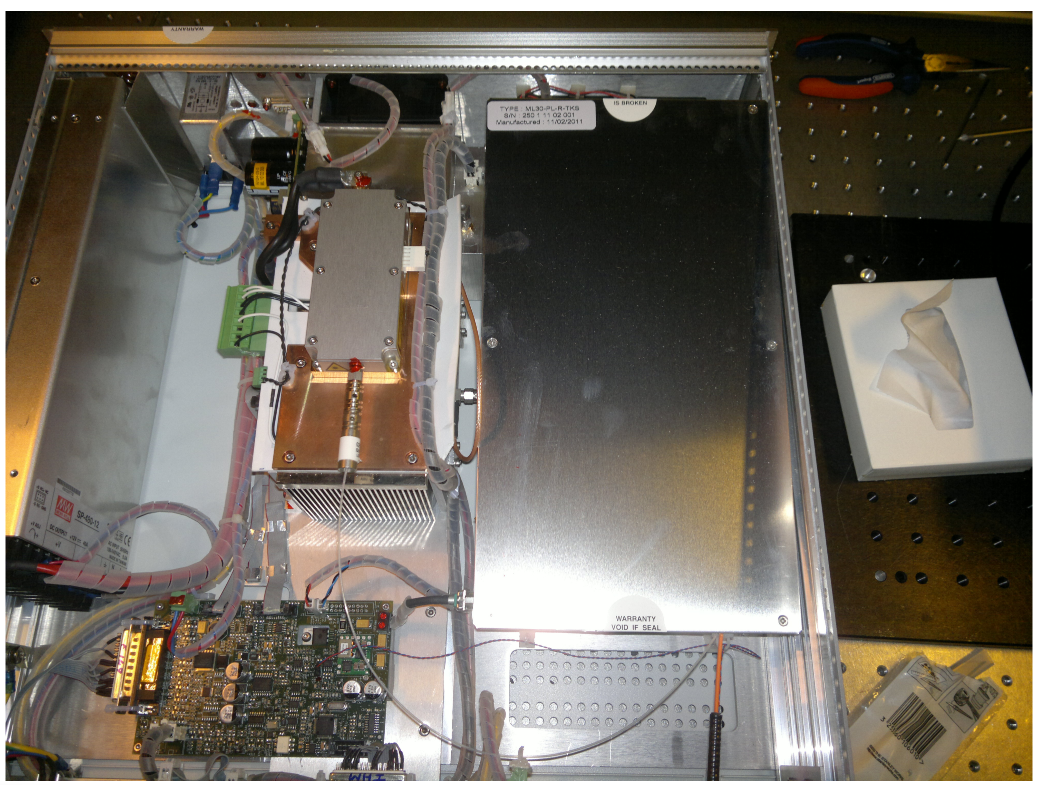
- Basic principle: laser interacts with H- in chamber to photo-detach electrons, leaving H0 signal to be measured by scintillator + camera.



Laser characterization and status

- Light source is a Q-switched, diode pumped, all fibre master oscillator and power amplifier (MOPA) laser.
- ML-30-PL-R-TKS by Manlight S.A.S (Lannion France).

Wavelength	1064 nm
Average power	30 W
Repetition rate	Up to 30 kHz
Energy per pulse	1 mJ @ 30 kHz
Pulse duration (FWHM)	150 ns
Pulse peak power	6.7 kW
Beam quality:	Gaussian profile. M^2 not specified.



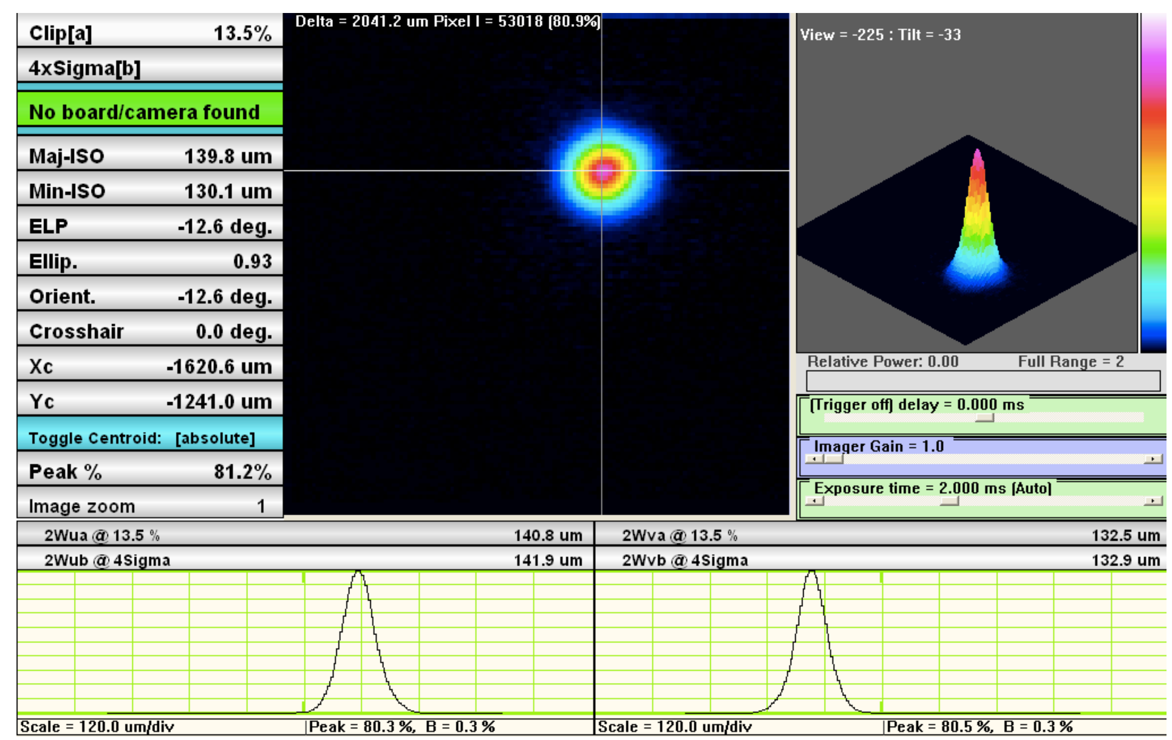


Fig. 6. Laser spot image recorded at the focal plane of the 500 mm plano-convex singlet lens.

Laser characterization and status

- Laser specification tested, M^2 of collimated output measured as ~1.81 H and 1.61 V.
- Output power lower than specified – laser returned and under repair at manufacturer (indication that part has been replaced for minimal cost).
- Laser tests written up in summary document.

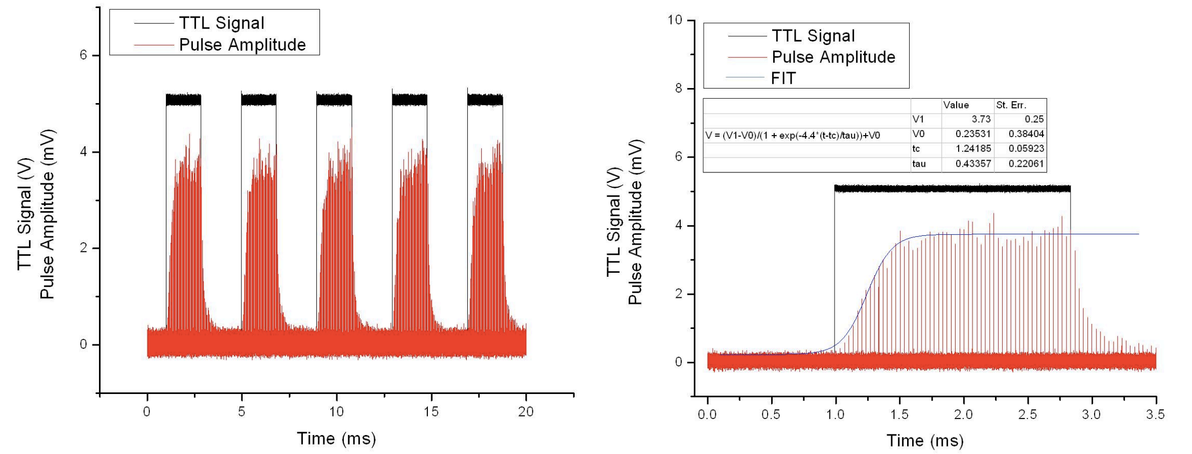
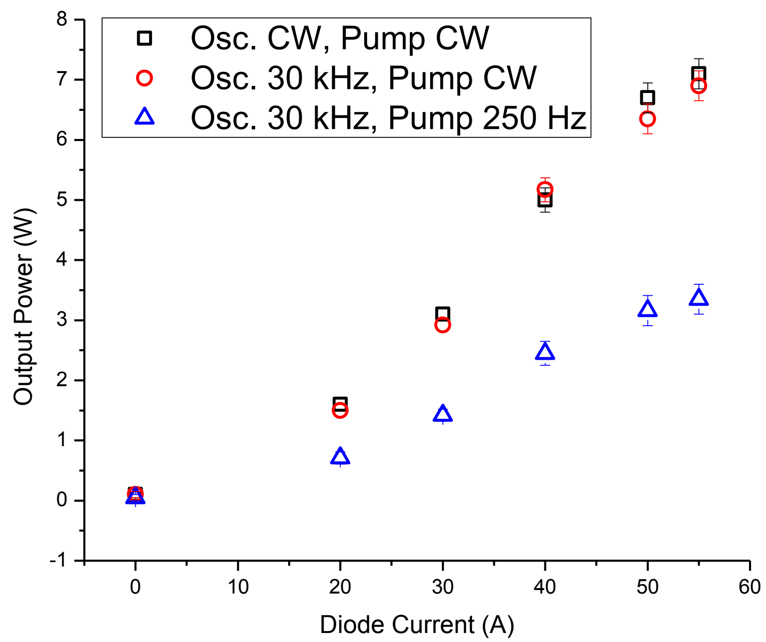
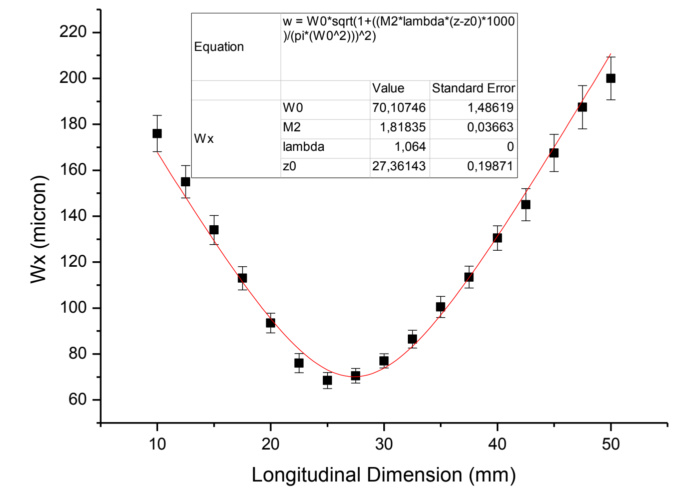
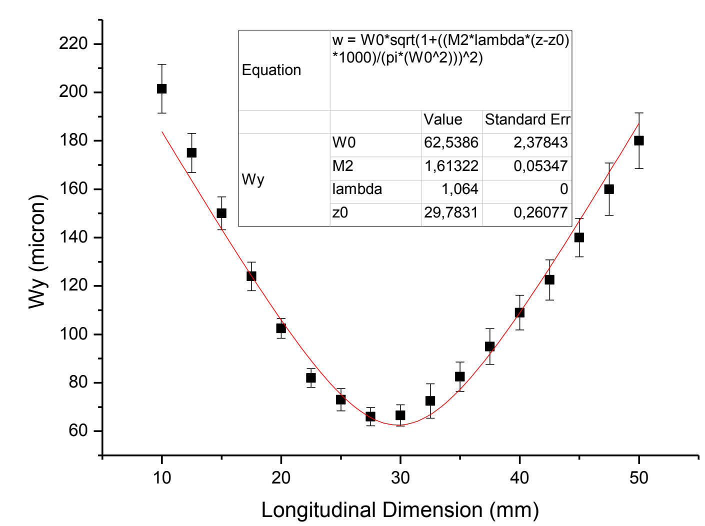


Fig. 3. a) Scope trace of amplified pulses with pump diode driven by a 250 Hz TTL (2 ms pulses). b) Zoom on a single macro-pulse for analysis.



Power measurements Vs diode current for different amplification regimes.

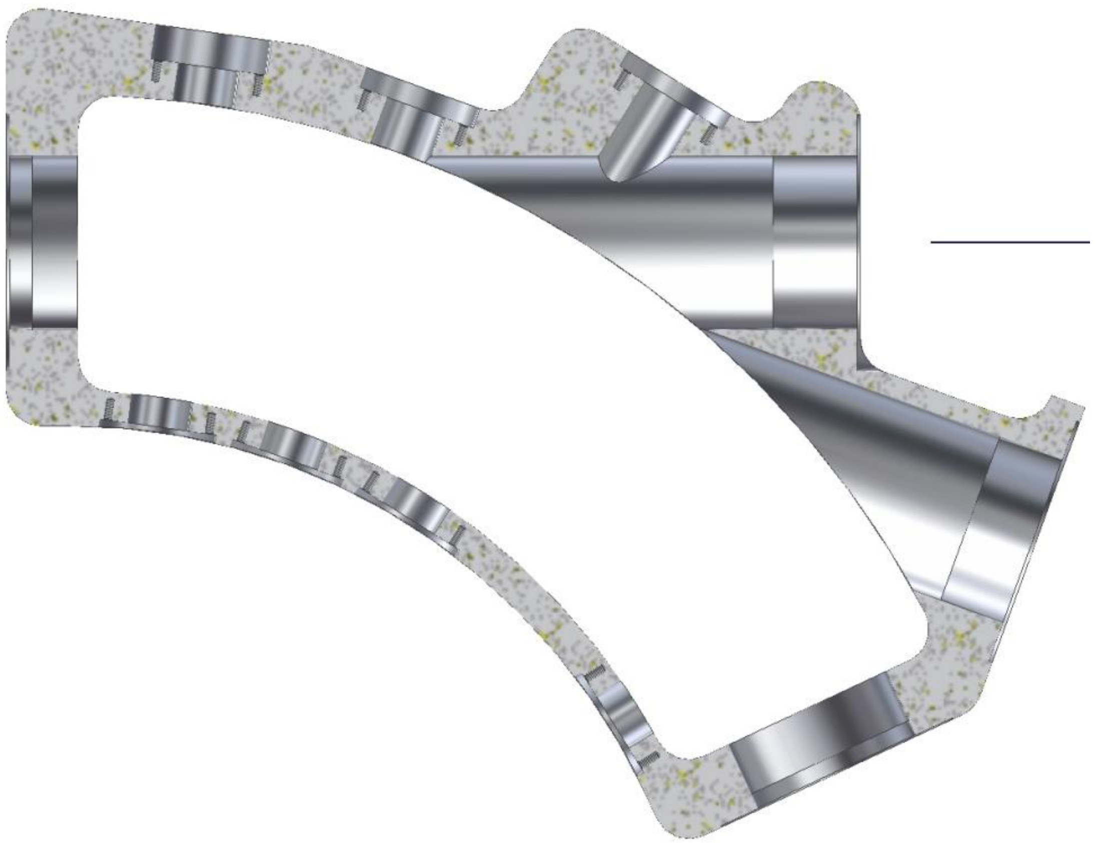




Beam delivery requirements

- Need to deliver pulsed laser light to the interaction chamber in a collimated beam, which can be scanned laterally across H- particle beam to measure the beam profile.
- Variable particle beam size (~5mm to 30mm) – delivery optics must be adaptable.
- Must overcome: radiation environment within shielding, space constraints, magnetic field, heat dissipation and class 4 safety requirements.

3 window ports for laser entry



Vacuum chamber design (v7) by Peter Savage:

Propose fibre delivery solution

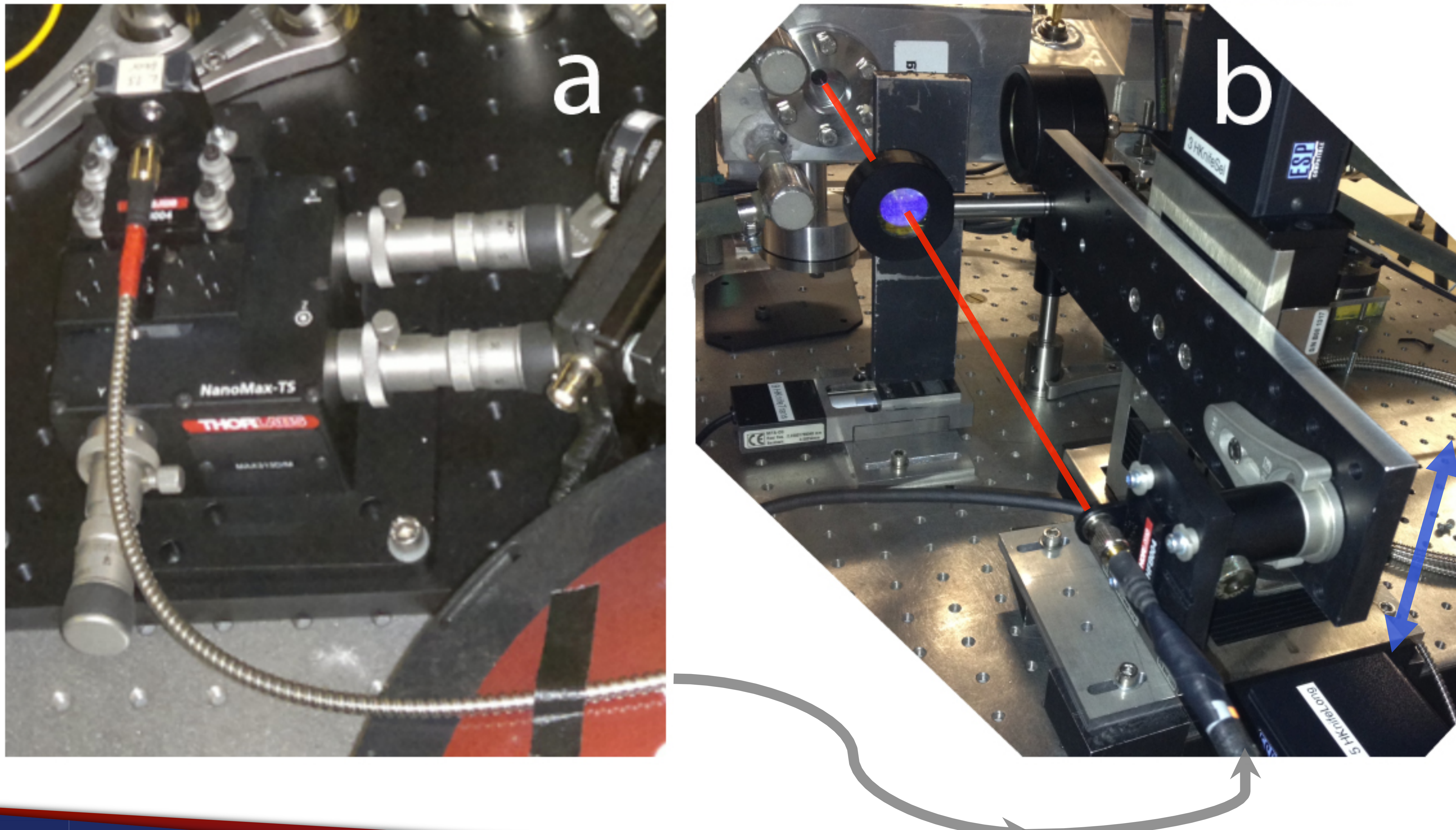
- Propose laser system and diagnostic optics are housed in a remote laser room alleviating several constraints:
  - Air conditioned, thermally stable environment for risk free laser operation.
  - Away from radiation environment.
  - Development time decoupled from FETS activities.
  - Diagnostic optics can be within laser room, reducing space needed within FETS.
  - Class 4 safety interlocks easily installed on laser room door.
  - Additional (gravity fail safe) safety shutter to block light when triggered by an external signal (in case of access to FETS / beam delivery optics).
- Fibre delivers light via simple and adaptable optics within shielding. No need for human access.
- Experience with similar system in operation at PETRA III in DESY.

Fibre-coupled laserwire at DESY

Petra III fibre-coupled laserwire

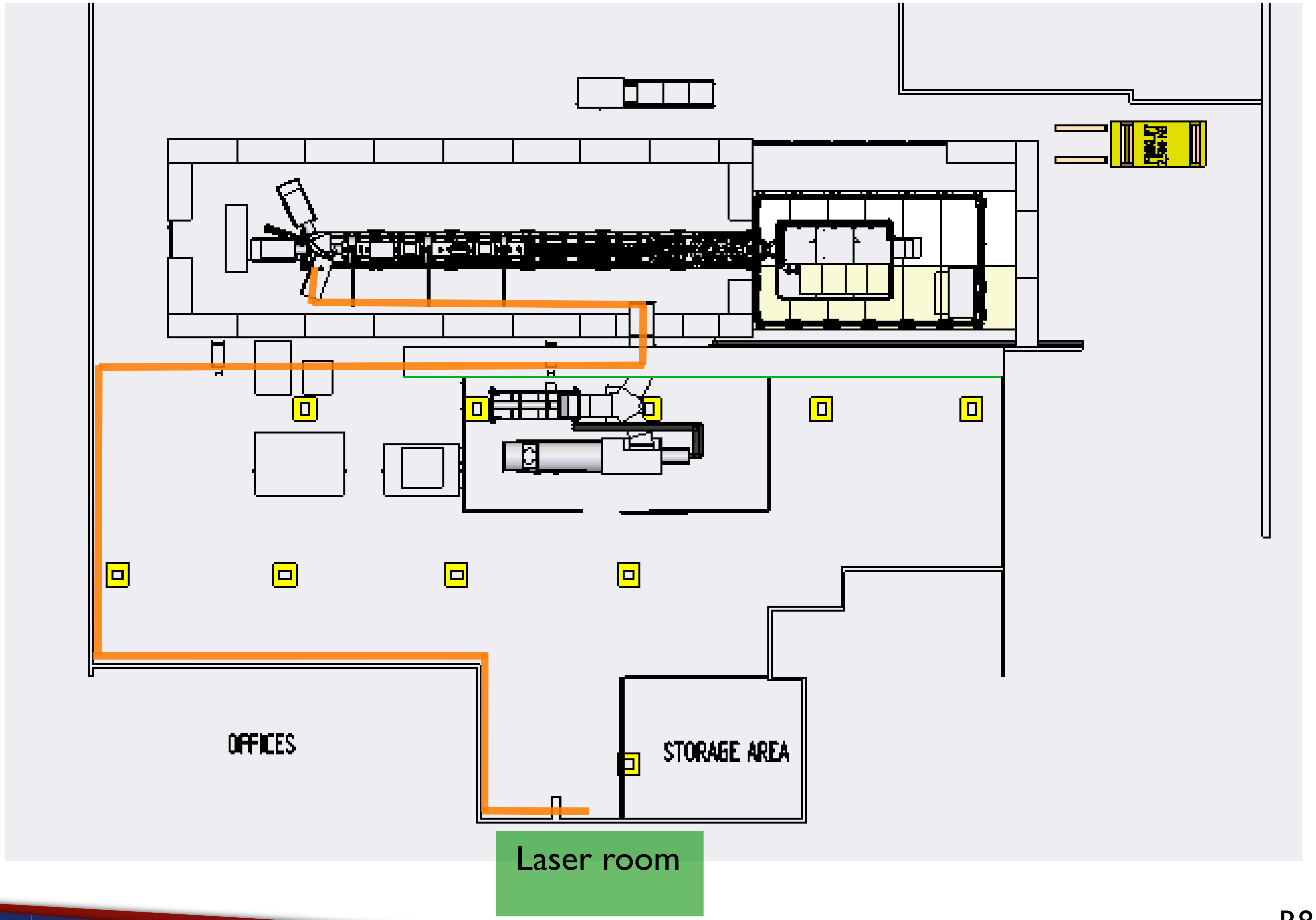
- Free space laser beam coupled into fibre using standard lens and Thorlabs stage

- Simple beam delivery optics on base plate, which is mounted to pair of stages.
- Fibre-coupled collimated output directed via lens to vacuum window.



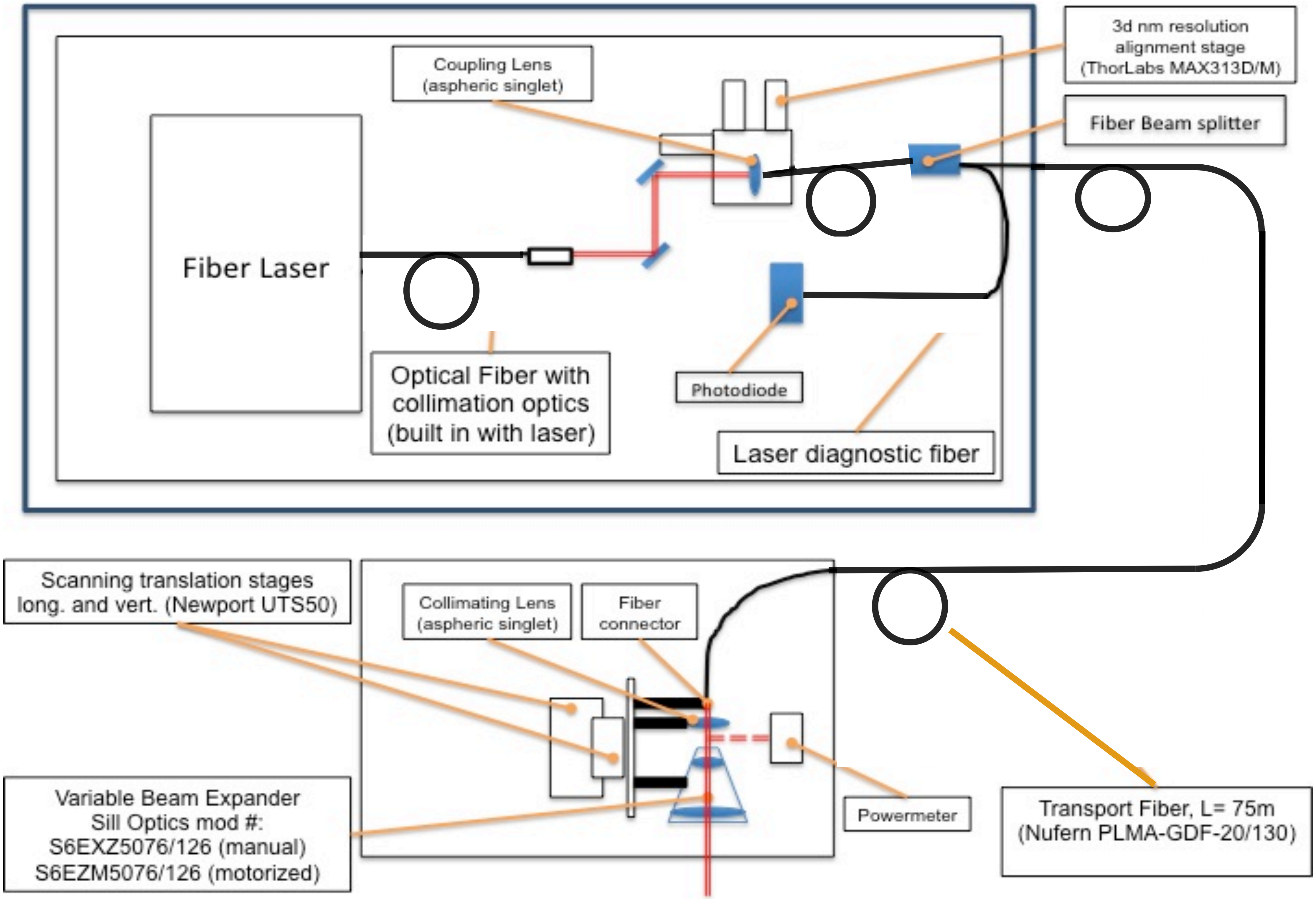
Proposed laser location in R8

- Safety interlocked laser room, with fibre to convey light to FETS.
- Route of existing cable tray shown (~75m)



R8 layout thanks to Mike

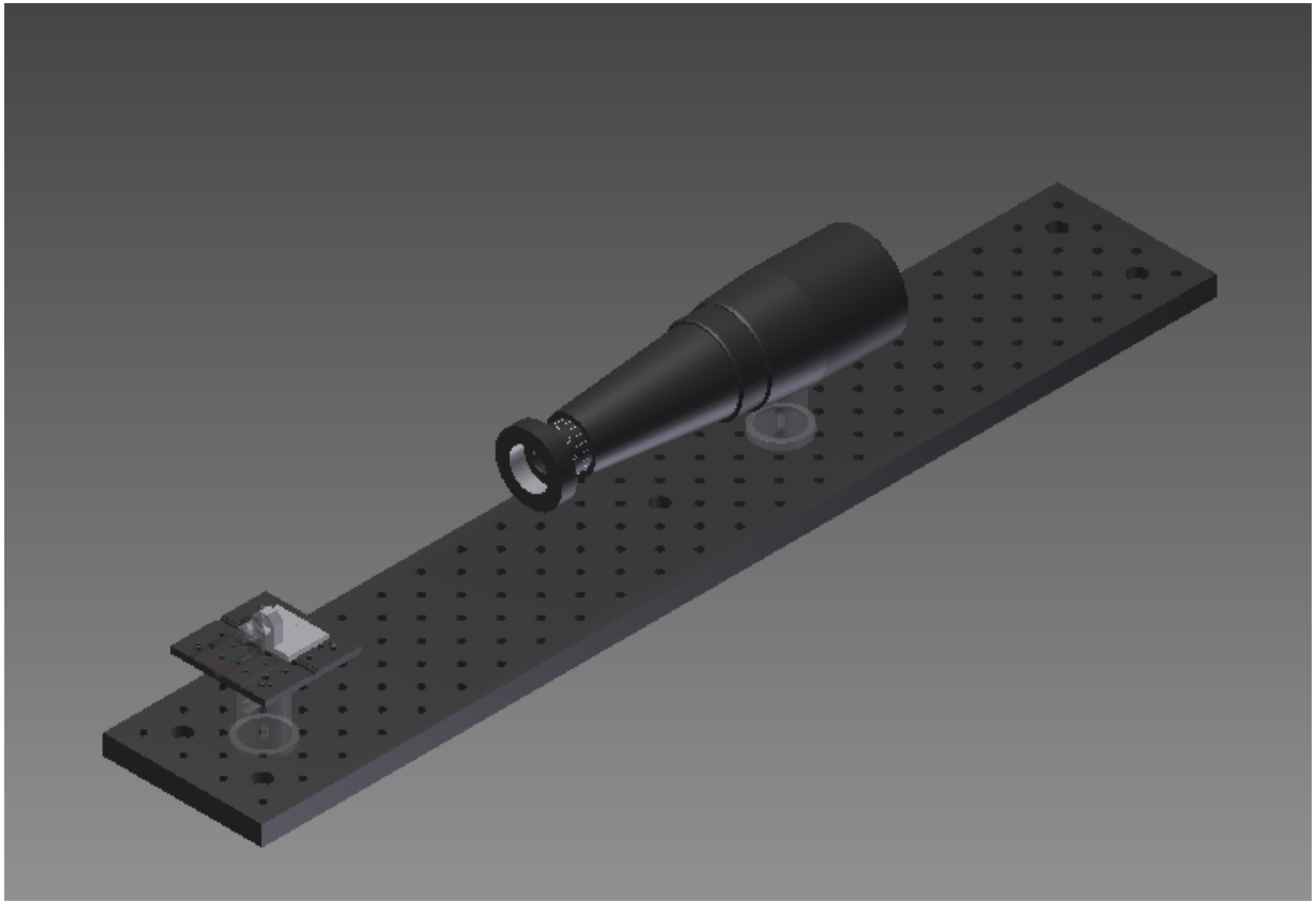
Overview



3d nm resolution alignment stage (ThorLabs MAX313D/M)
Coupling Lens (aspheric singlet)
Fiber Beam splitter
Fiber Laser
Optical Fiber with collimation optics (built in with laser)
Photodiode
Laser diagnostic fiber
Scanning translation stages long. and vert. (Newport UTS50)
Collimating Lens (aspheric singlet)
Fiber connector
Variable Beam Expander Sill Optics mod #: S6EXZ5076/126 (manual) S6EZM5076/126 (motorized)
Powermeter
Transport Fiber, L= 75m (Nufern PLMA-GDF-20/130)

Beam delivery optics

- Simple optics for final beam delivery: fibre, lens and beam expander



Base plate mounted to crossed pair of vertical and horizontal translation stages
(existing stages have 50mm travel and 1um resolution – more than adequate)

Beam delivery optics

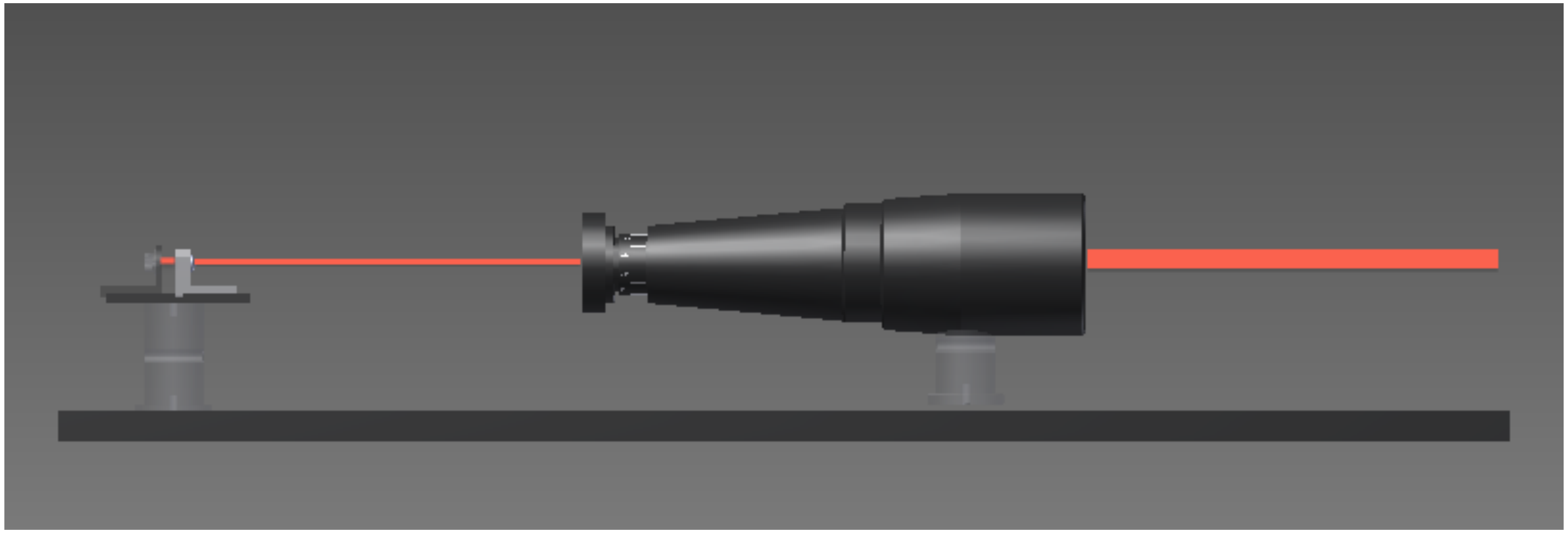
- Simple optics for final beam delivery: fibre, lens and beam expander

Collimation lens:
(4.55, 6.20, 8.07mm)

Silloptics beam expander
manual zoom 1x to 8x
(or motorized option available)

Space reserved to add
short focal length lens
for 2D confocal scans

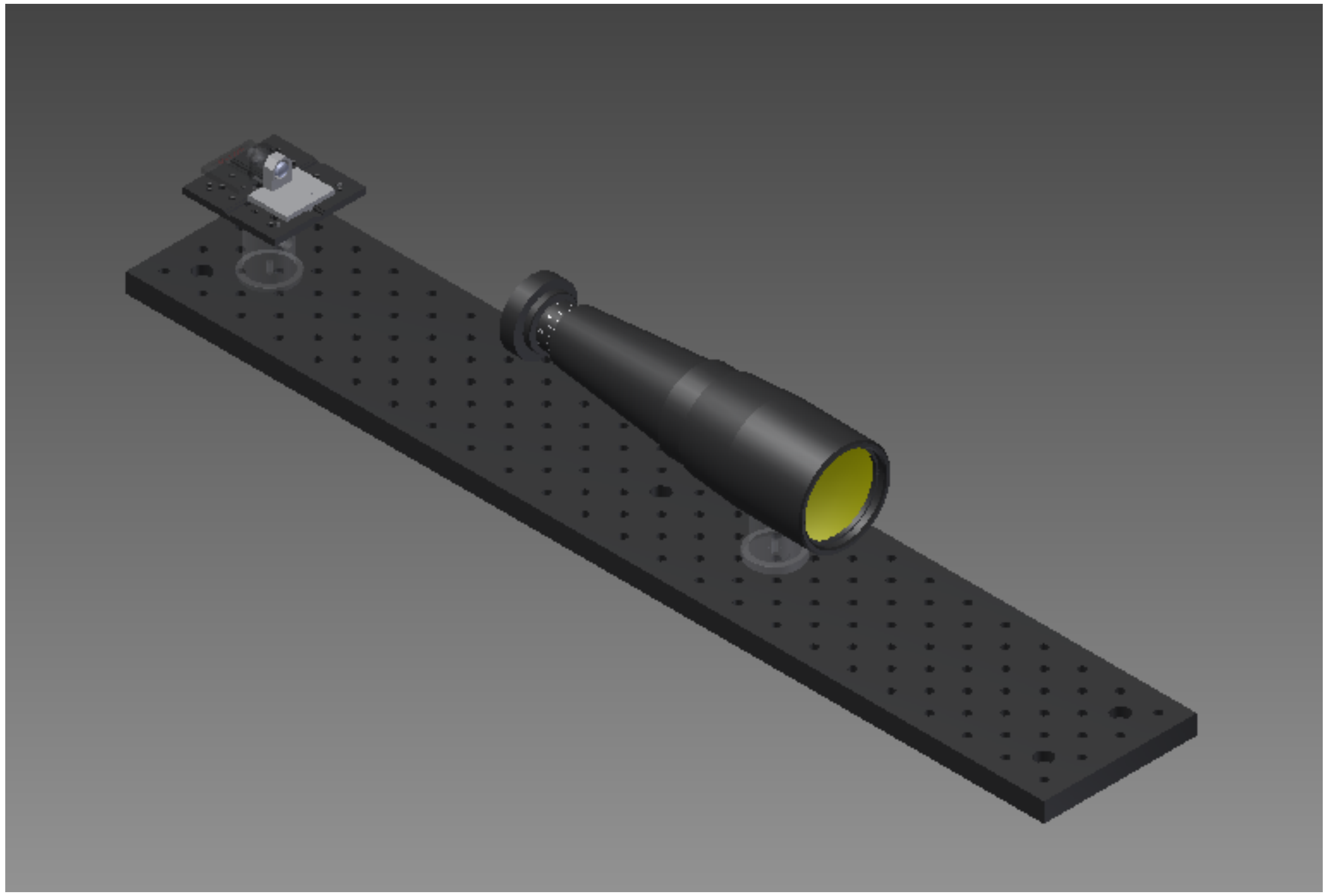
Light conveyed
by fibre to input
FC connector

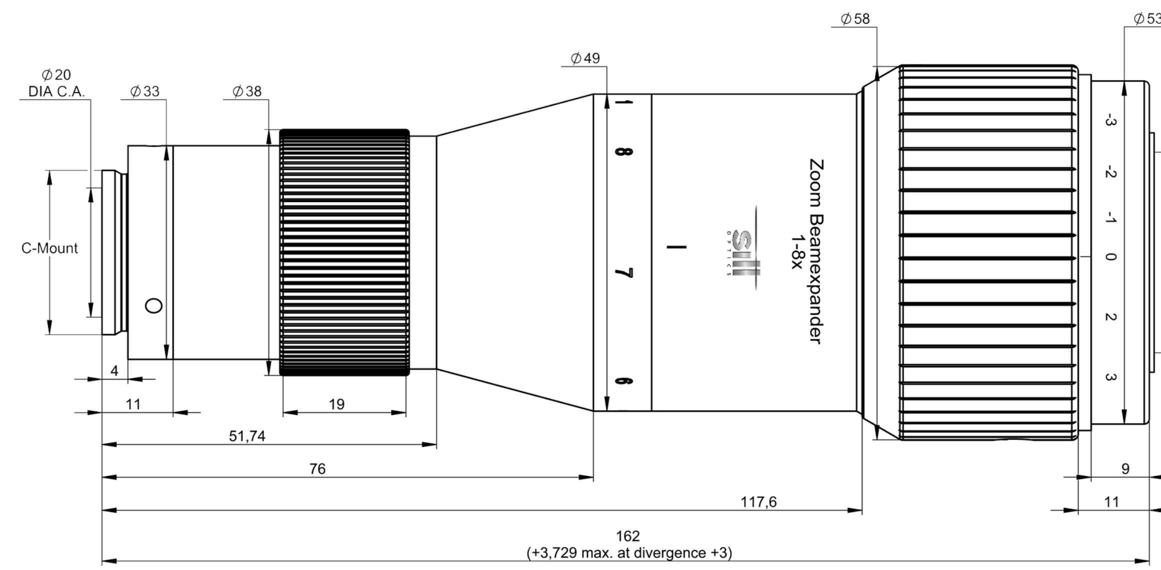


To window in
vacuum chamber

Base plate mounted to crossed pair of vertical and horizontal translation stages
(existing stages have 50mm travel and 1um resolution – more than adequate)

Zoom beam expander





Beam expander (Thorlabs above)
Silloptics S6EXZ2075/126
manual zoom 1x to 8x
(or motorised option available)

part number standard	*part number* motorized	*magnification*	*max. exit-Ø* [mm]	*length* [mm]	*max. outside-Ø* [mm]	*thread*	*adjustable divergence*
S6EXZ2075/126	S6EZM2075/126	1.0x - 8.0x	30.0	157.0	58.0	C-Mount	✓

Spatial collimation specification

- The distribution measured is a convolution of the particle beam size and laser beam profile, such that the particle beam size is obtained via:

$$\sigma_B = \sqrt{\sigma_T^2 - \sigma_L^2}$$

where σ_L is the radius of the laser beam at $1/\sqrt{e}$ position (corresponding to $w_0/2$, w_0 the radius at $1/e^2$).

- The particle beam size $2\sigma_B$ varies from 4 - 32mm.
- Require difference $\varepsilon = (\sigma_T - \sigma_B)/\sigma_B$ to be < $0.01*\sigma_B$ to limit experimental resolution to less than 1%. Results in minimum laser w_0 of 0.56mm.
- Results are based on Nufern fibre with a core size of 20μm, numerical aperture of 0.08 for which the M^2 equivalent is 2.35.
- Use a 6.25mm focal length lens to collimate beam to waist of 0.5mm.

Spatial collimation specification

- Variable beam expander with magnification of x1 to x8 enables laser beam sizes as follows, with corresponding Rayleigh range, $Z_R = (\pi w_0^2)/(\lambda M^2)$:

Beam Size σ_B [mm]	Laser Size w_0 [mm]	Rayleigh Range [m]
2	0.56	0.394
4	1.12	1.576
6	1.68	3.546
8	2.24	6.304
10	2.80	9.850
12	3.36	14.184
14	3.92	19.306
16	4.48	25.217

- Summary of spatial characteristics for beam delivery system:

Translation stage range (scan range)	50 mm
Translation stage resolution	1 μm
Fiber core	20 μm
Fiber NA	0.08
Equivalent M^2	2.35
Collimated beam waist w_0	0.5 mm
Variable Beam Size	0.5 – 4 mm

Parts and costing: fibre launch

Launch stage:

3d stage:	MAX313D/M	£ 1110.24
Mounting Clamps	AMA010/M	£ 25.63
Right Angle Bracket	AMA009/M	£ 51.34

2 options for fiber holder

Fiber FC Holder	HFB004	£ 32.40
Fiber V-grove Holder	HFF003	£ 79.20

2 options for lens holder

1)Lens Holder M9	HCS109	£ 35.97
2) Lens Holder SM1	HCS031	£ 26.64
Adapter SM1 to M9	S1TM09	£ 15.84
Riser 5.5 mm	AMA093	£ 10.08

5 options for input lenses (we'll have to see which is better). All mounted with M9 thread

Lens 4.55 mm	C230TME-1064	£ 59.76
Lens 6.20 mm	C110TME-1064	£ 59.76
Lens 8.07 mm	C240TME-1064	£ 59.76
Lens 11.21 mm	C220TME-1064	£ 60.48
Lens 18.57 mm	C280TME-1064	£ 59.76

Fiber splitter assembly:

99% - 1% splitter	Sifam		£ quote in progress
2 off Mating Sleeve FC/PC	ADAFCPM1 or	ADAFCPM2	£ 34.56

Parts and costing: fibre output

Interlocked box (dimensions reduced to 450X450 mm2 breadboard:

Breadboard	Thorlabs MB4545/M	£ 226.80
Aluminum panels	?	£ ?
Interlock switches, etc	?	£ ?

Translation stages stack:

2 off Translation stages	Newport UTS50CC	£ 0 (Already avail.)
Right angle bracket	Newport EQ100-S	£ 294.00
Base plate	Newport M-PBN12	£ 0 (Already avail.)
Plate for holding optics	Thorlabs MB1060/M	£ 115.62

Fiber holder + Lens assembly (optical height 70.5 mm)

Fiber FC Holder	Thorlabs HFB004	£ 32.40
Lens Holder M9	Thorlabs HCS109	£ 35.97
3 Options for collimating lens (mechanically they look the same):		
1) 4.55 mm	Thorlabs C230TME-1064	£ 59.76
2) 6.20 mm	Thorlabs C110TME-1064	£ 59.76
3) 8.07 mm	Thorlabs C240TME-1064	£ 59.76
Plate for Fiber holder and lens	Thorlabs MMP1/M	£ 48.96
Pedestal pillar post	Thorlabs RS2P4M	£ 16.92
Spacer 4 mm	Thorlabs RS4M	£ 5.15
Clamping fork	Thorlabs CF125	£ 6.30

2 options for beam expander (mechanically similar, weight ~0.7kg) (optical height 70.32 mm)

Manual	Silloptics S6EXZ2075/126	£ 890
Motorized	Silloptics S6EZM2075/126	£ 1800
C-mount threaded holder	Thorlabs CMR/M	£ 19.87
Pedestal pillar post	Thorlabs RS2P4M	£ 16.38
Clamping fork	Thorlabs CF125	£ 6.30

Parts and costing: totals

Fibre launch:	£ 1721.42
Fibre output:	£ 1893.95 (manual BE)
	or £ 2803.95 (motorized BE)
Transport fibre:	£ 3000 bare fibre (depending on route)
Diagnostics for laser room:	
Fibre splitter to calibrate/monitor power	£ awaiting Sifam quote, expect ~ 1000
Optional beam delivery for laser room:	£ 932.55 (manual BE)
Other optics / camera / power monitor.	< ~£1000

Envisaged experimental phases

- Phase 0: Pre-run tests of laser and beam delivery setup at RHUL.
  - Validation of laser set up, delivery optics, focus and translation control
- Installation of laser and calibration within laser room at RAL.
  - Decoupled from FETS area activity. Timely integration possible.

- Phase 1: Detection of photo-detachment signal
  - Simple, adjustable beam delivery for rapid enhancement of signal.
- Phase 2: Profile measurement: translation of laser-wire across H- beam
  - Operation of one translation axis. Trial of various laser beam sizes.
  - Motorized beam expander would enable change without human access within shielding.
- Phase 3: Addition of final focus lens for 2D measurements.
  - Combine with second translation axis.
  - Duplicate beam delivery system in laser room would aid understanding of delivered light.

Next steps

- Pending decision to proceed with fibre solution:
  - Ready to order almost all parts (Thorlabs give rapid delivery)
  - Awaiting quote for fibre splitter.
  - Confirm options: manual / motorised beam expander / laser room diagnostic.
- Development at RHUL
  - Commissioning of system in laser room at RHUL.
  - Would be useful for repair laser to be shipped to RHUl if possible.
- Integration with FETS
  - Follow up design of beam delivery and interface to vacuum chamber with Pete.
  - Safety interlock system and safety shutter.
  - Trigger / DAQ signal and cable routing to be defined.