PITZ Laser Beamline Upgrade

Variable Magnification; transport of green light

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Motivation

Flexible beam transport from various Photocathode laser systems to accelerator tunnel

Beam transport Requirements (Laser system / transverse shape on photocathode)

1. MBI / flat top: **UV**; BSA with fixed laser magnification – current implementation
2. MBI / truncated Gaussian: **UV**; BSA with variable laser magnification
3. ELLA: **UV**; variable(?) laser magnification
4. Pharos bypass: **UV**; BSA with fixed(?) laser magnification
5. Pharos 2nd harmonic: **Green**; BSA with fixed(?) laser magnification
6. MBI 2nd harmonic: **Green**; BSA with variable(?) laser magnification

Restriced space, especially in the shaft: combine all beamlines?

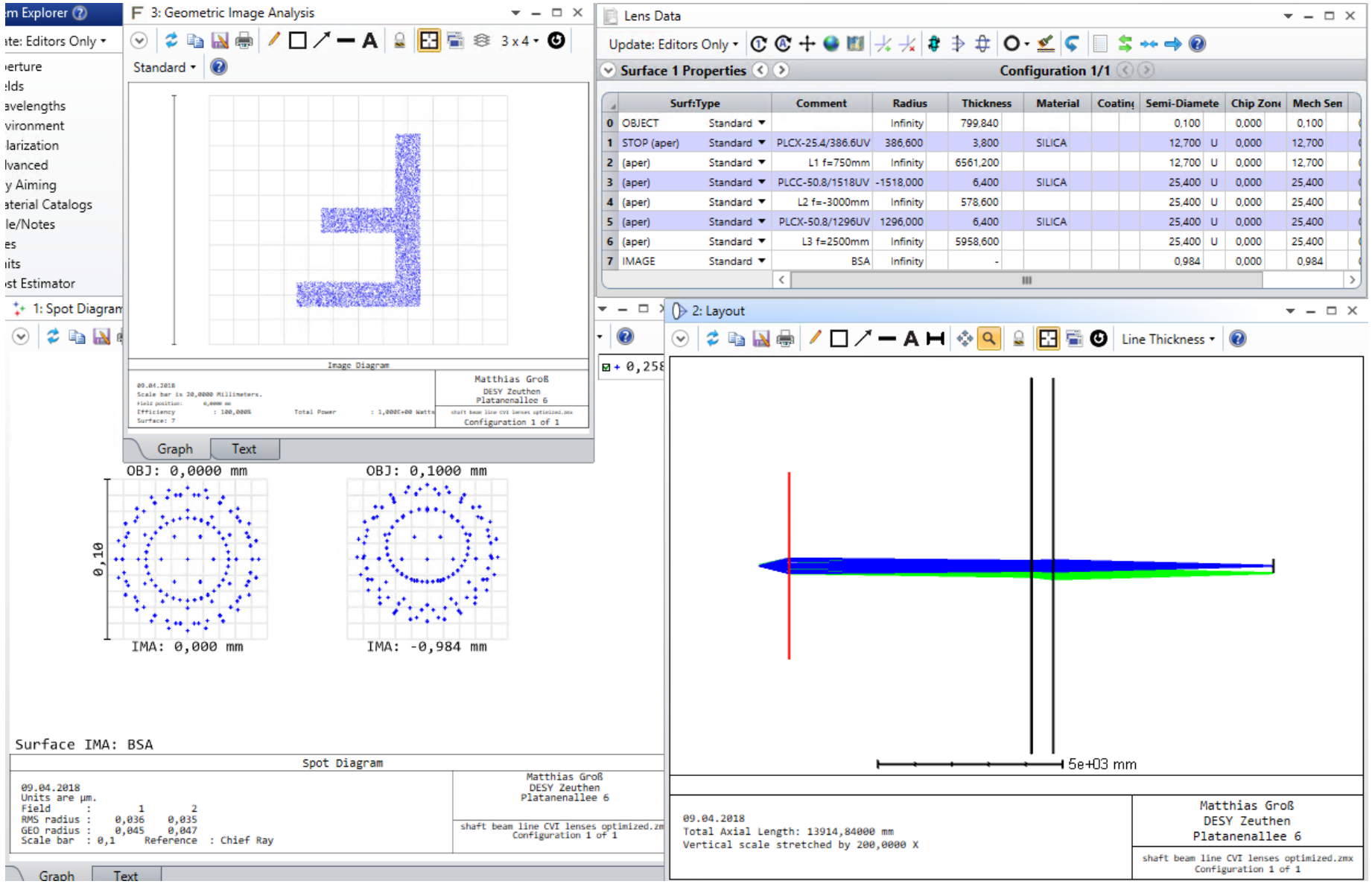
- Turning mirrors and lenses: need special coating to handle both wavelengths (can be done with R>99%)
- Lenses: AR coating R<0.5% → ok; focus length is a function of the wavelength → check
  - Transmission in green for UV AR coated lens ≈90% (pulse energy in green ≈5x higher / ≈3x higher after 5 lenses)

1) MBI / flat top (current setup)

Baseline

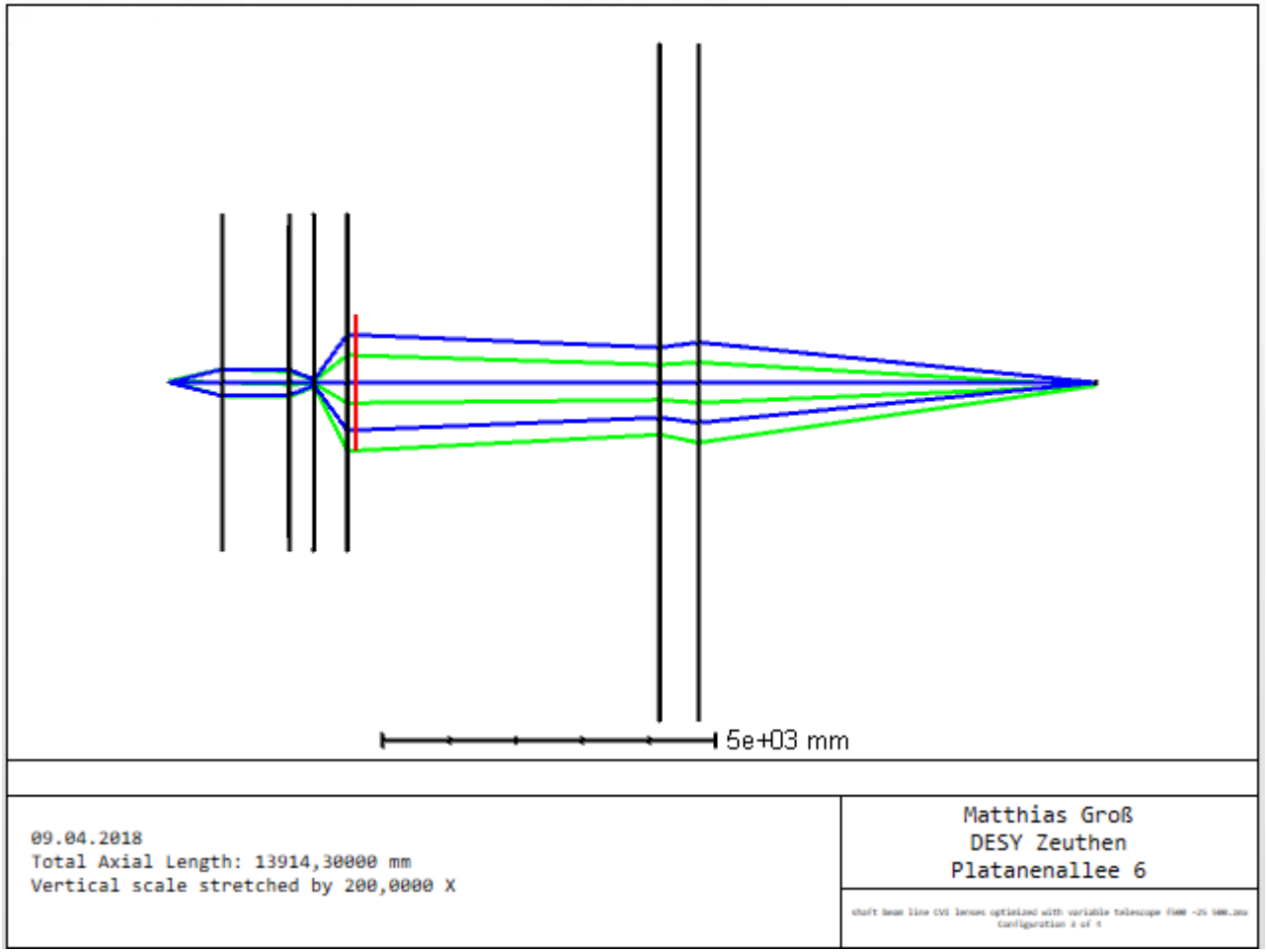
- No mirrors in simulation: Phase front errors etc. negligible

- Results:
  - Image quality: RMS spot radius of on-axis and off-axis beams
  - Magnification (ratio of image size to object size |IMA/OBJ| for off-axis beam)
  - From VC2 images: FWHM of laser beam at BSA: ≈3 mm with M≈10



2) MBI / truncated Gaussian

Add Galileian zoom telescope with 3 lenses (f: 500 mm -25 mm 500 mm)

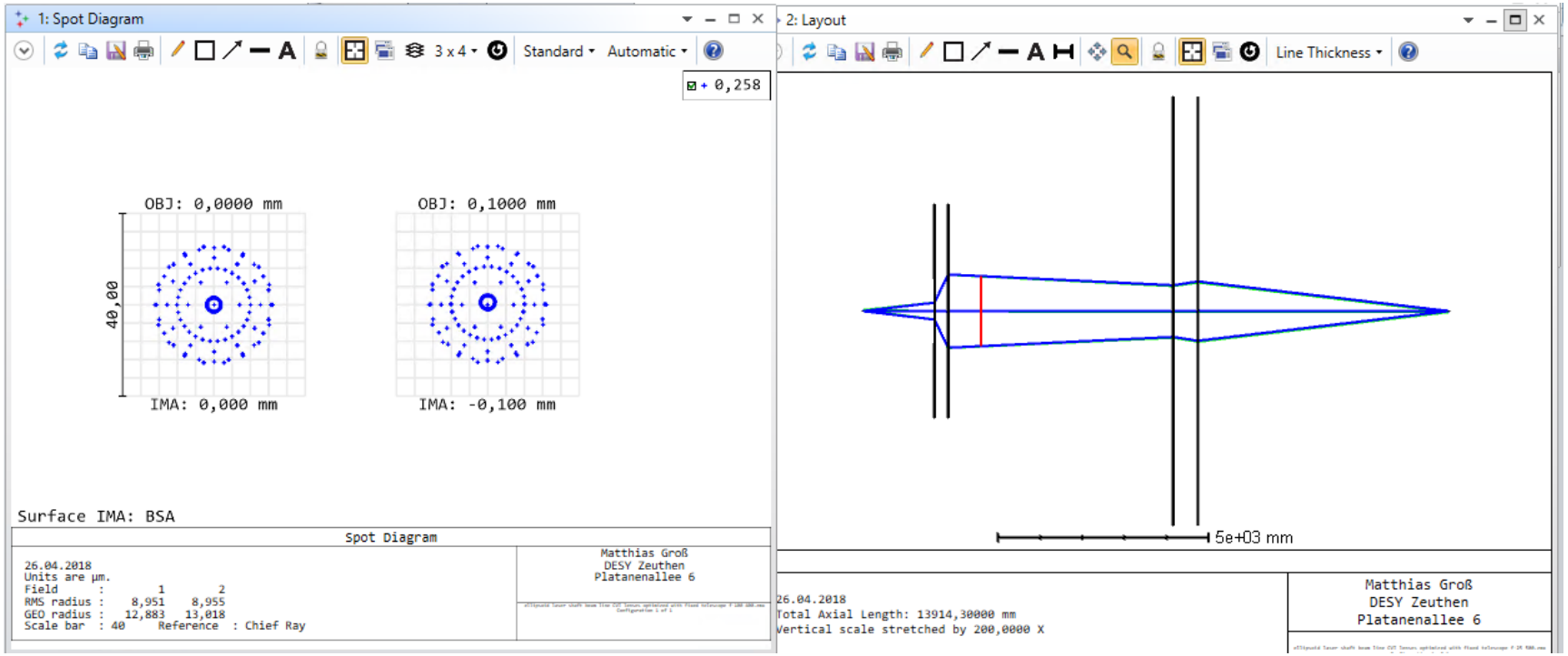


	Magnification	RMS radius 1	RMS radius 2
Current setup	9.8	<1 μm	<1 μm
Telescope config 1	10.0	<1 μm	<1 μm
Telescope config 2	5.0	<1 μm	2.0 μm
Telescope config 3	2.5	2.0 μm	7.5 μm
Telescope config 4	1.25	31 μm	60 μm

3/4) ELLA / Pharos Bypass

Same shaft beamline: last two lenses are identical

- Fixed telescope with optimized Magnification e.g. M = 1
  - → Add one or two lenses on ELLA laser table

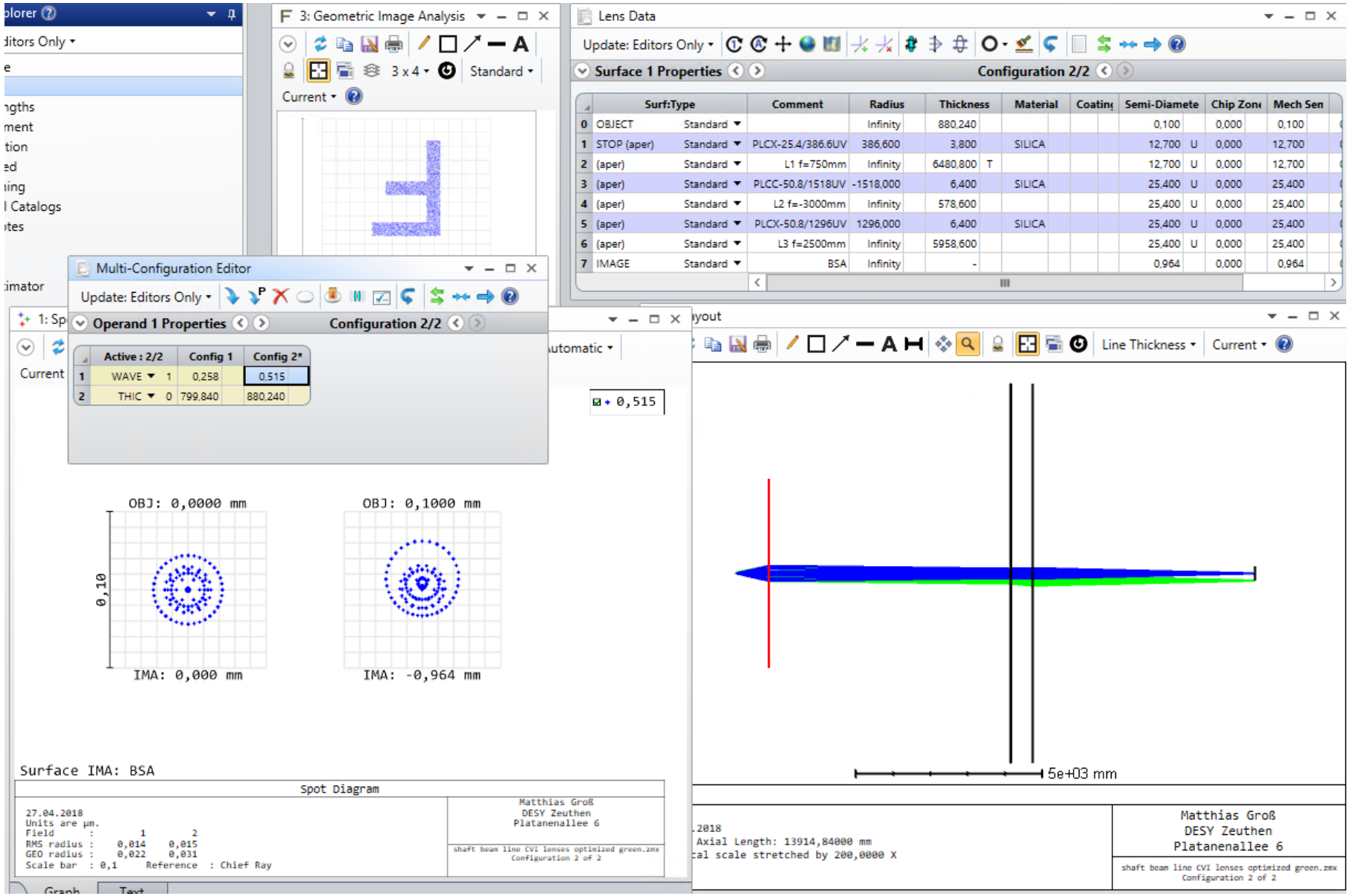


- OR
- Variable telescope with similar setup as on the MBI laser table (could get rid of first lens)

5) Pharos 2nd harmonic

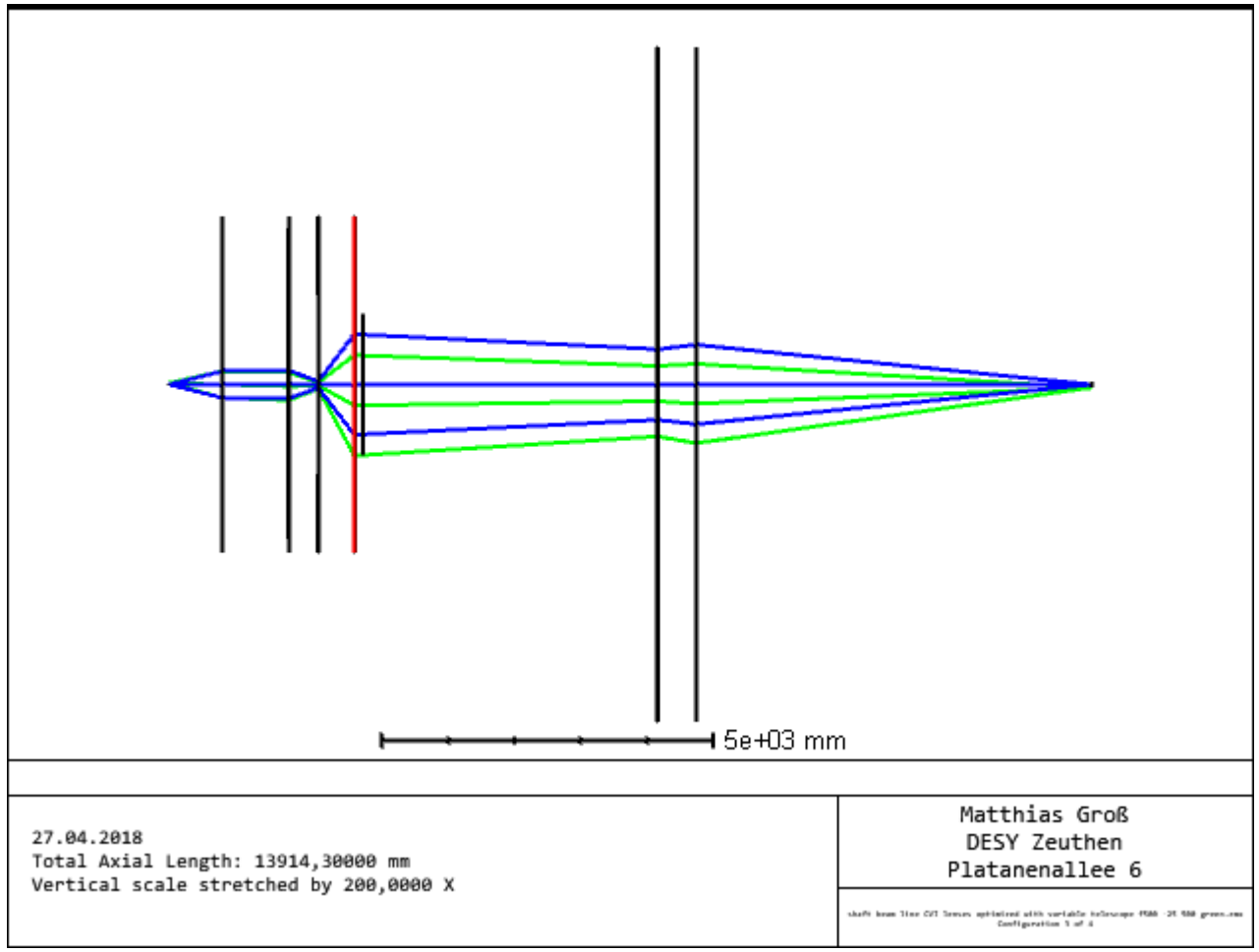
Wavelength: 515 nm

- Comparison to baseline (258 nm) – only difference: first lens is moved by 8 cm
- Results:
  - Magnification is almost unchanged (9.84 to 9.64)
  - Image quality: RMS spot radius of on-axis and off-axis beams are the same, both <1μm
  - With two UV AR coated lenses in shaft the transmission to the BSA would be reduced by ≈20%



6) MBI 2nd harmonic

Optimize Galileian zoom telescope with 3 lenses (slight adjustment of positions)



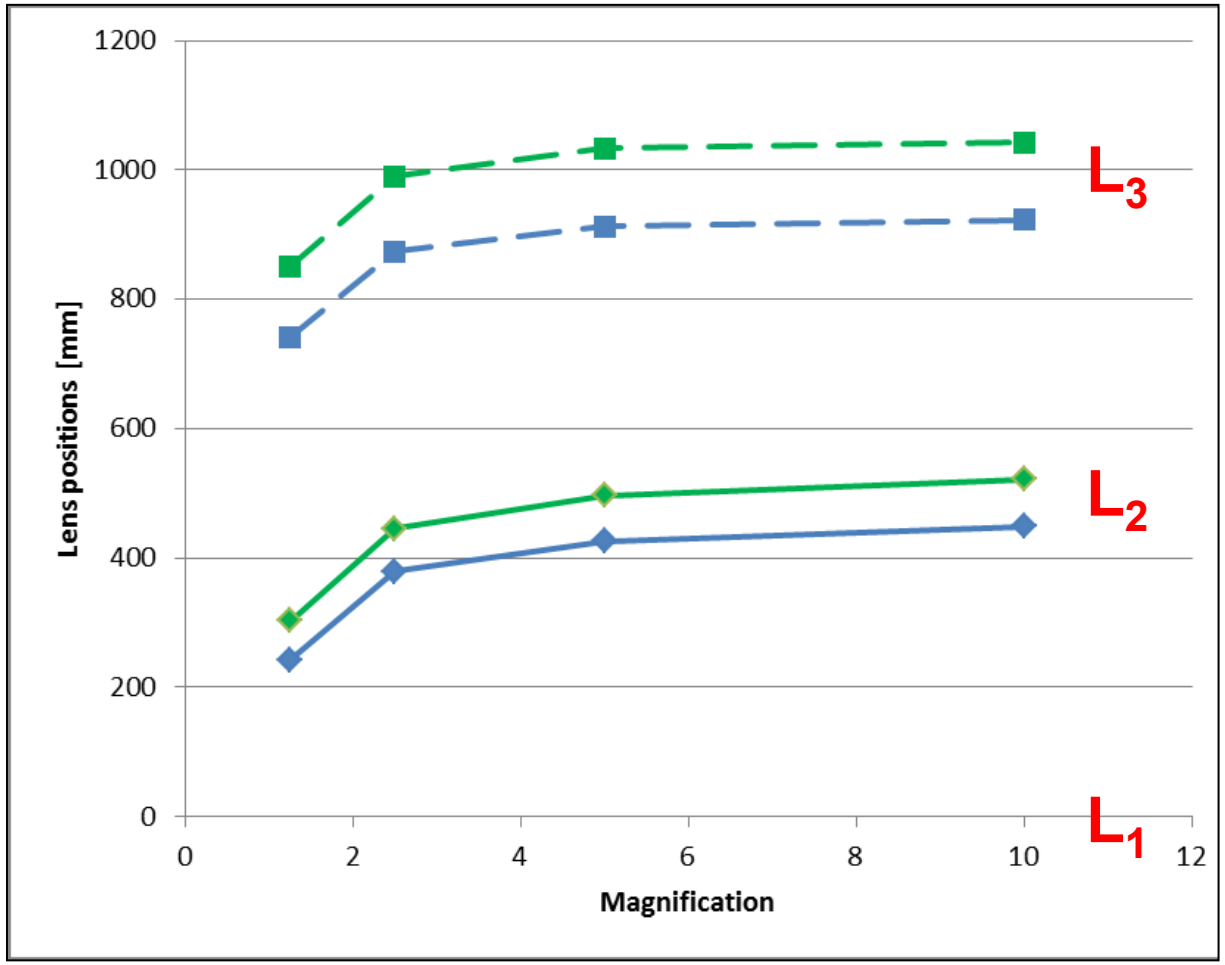
	Magnification	RMS radius 1	RMS radius 2
Current setup	9.6	<1 μm	<1 μm
Telescope config 1	10.0	<1 μm	<1 μm
Telescope config 2	5.0	<1 μm	2.0 μm
Telescope config 3	2.5	2.0 μm	7.9 μm
Telescope config 4	1.27	32 μm	60 μm

- Image quality almost identical to 257 nm case

Moving Range of Lenses in Telescope

Requirement for moving stages

- In all cases: position of first lens is fixed
- Moving range for UV and green is almost identical
- Full range (M between 1.25 and 10)
  - L2(UV): 206 mm
  - L2(green): 219 mm
  - L2(total*): 279 mm
  - L3(UV): 180 mm
  - L3(green): 190 mm
  - L3(total): 300 mm
- Reduced range (M between 2.5 and 10)
  - L2(UV): 70 mm
  - L2(green): 76 mm
  - L2(total*): 143 mm
  - L3(UV): 80 mm
  - L3(green): 52 mm
  - L3(total): 148 mm

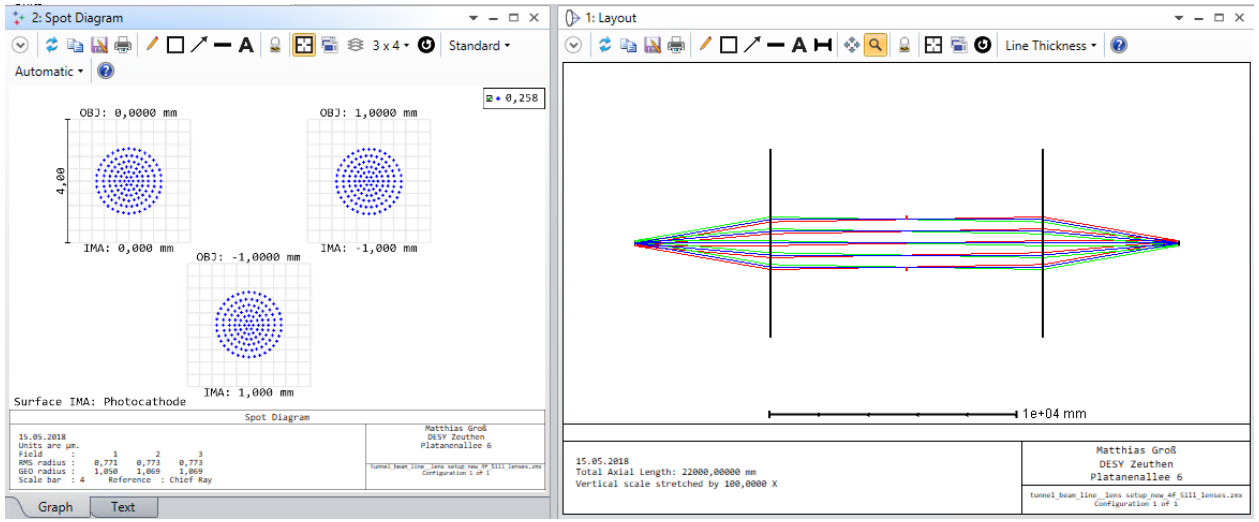


*one setup for both wavelengths

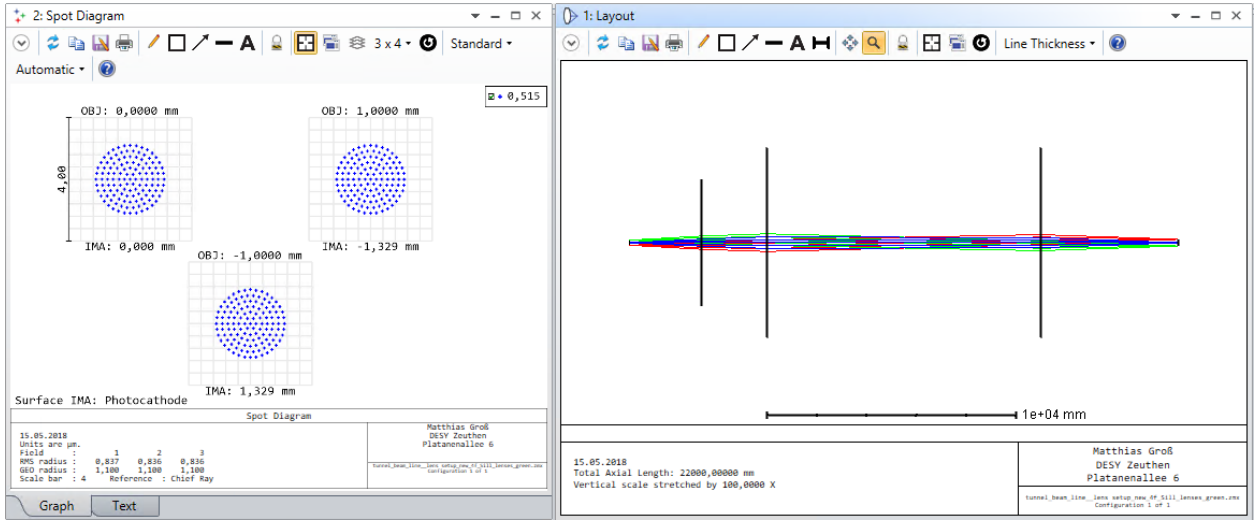
Transport from BSA to Photocathode

Comparison of setups for UV and green

- UV baseline:
  - Standard 4f system
  - Magnification M = 1
  - RMS radius <1μm for all spots



- Adaptation for green:
  - No solution found with two original lenses → add third lens
  - Magnification M = 1.3
  - RMS radius <1μm for all spots
  - Position of two original lenses is unchanged



Cost estimation

Options

- Exchange of mirrors (must for green option)
  - MBI / ELLA / Pharos on laser table: ≈10 mirrors — 1500 €
  - Shaft / tunnel beamline: 12 mirrors — 5800 €
  - Laser trolley: 7 mirrors — 1750 €

- Lenses / vacuum window with AR coating for UV and green (not necessary for first tests)
  - MBI / ELLA / Pharos on laser table: 3 lenses — 350 €
  - Shaft / tunnel beamline: 4 lenses + vacuum window — 6500 €

- Telescope
  - 3 lenses — 350 €
  - 2 translation stages — 5000 €

Summary

- Variable beam size: adding telescope to beam line is possible – good solution was found for a zoom range of 4x (M = 2.5…10) with 8x possible (deteriorating beam quality, strongly increasing travel range). **Is 4x enough? If not: further design studies.**
- Beam line with current shaft lenses can be adjusted for different magnifications, e.g. M = 1 for ELLA
- Transport of green line without image quality loss is possible by adjusting lens positions on laser table only (shaft lenses are unchanged)
- Telescope size and travel range suitable for setup on laser table
- Beamline from BSA to photocathode can be adjusted for green light by adding one lens
- Total cost estimation for hardware given

- It is possible to use current lens setup for all lasers simultaneously (only one beamline in shaft and tunnel!)
  - Shaft: exchange of lenses with optimized AR coating; tunnel: one movable lens needed