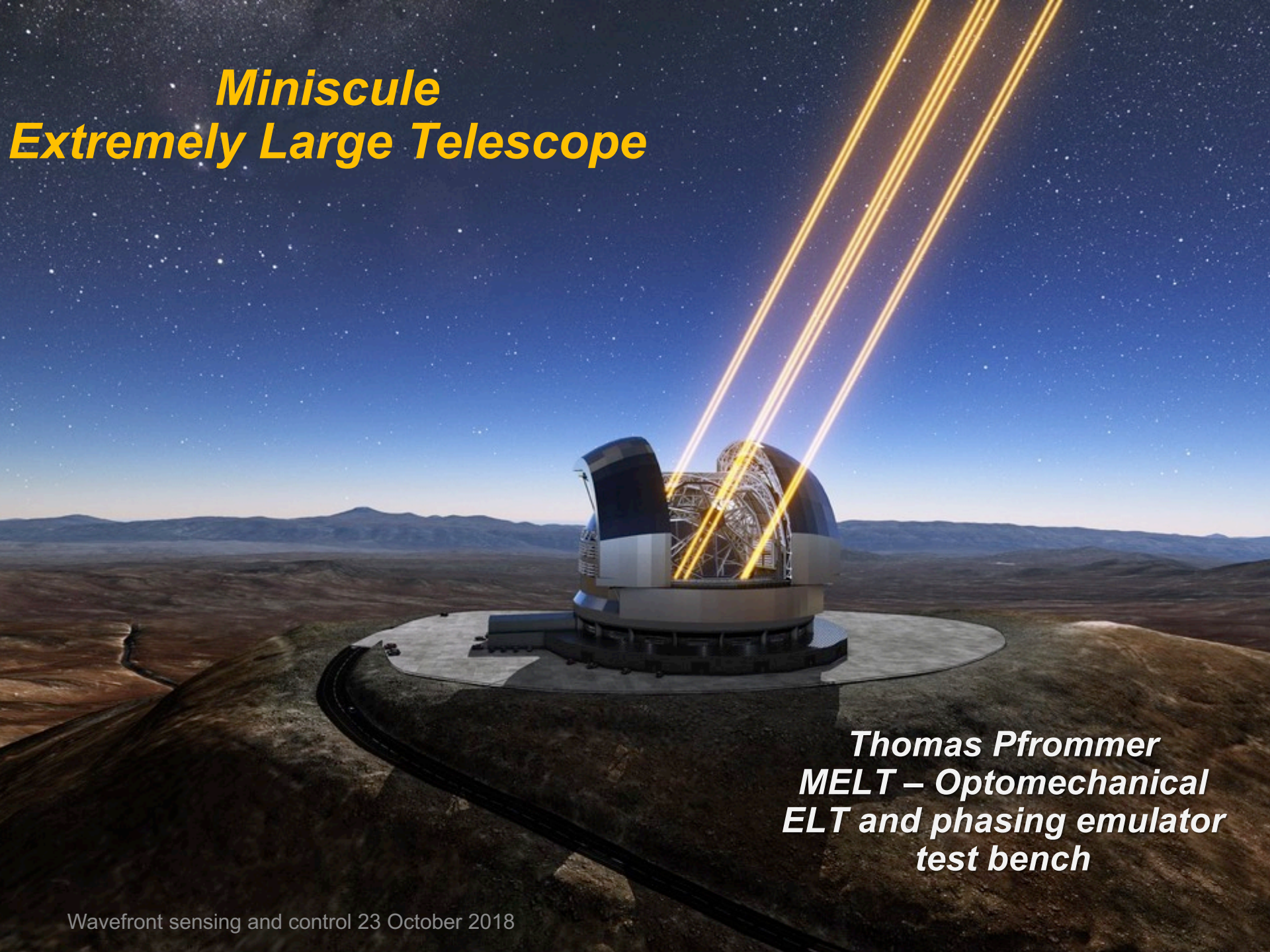


Miniscule Extremely Large Telescope

Thomas Pfrommer
MELT – Optomechanical ELT and phasing emulator test bench

MELT (Miniscule ELT) Optomechanics – Scope

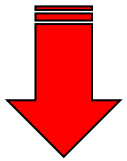
- The miniscule ELT is an **optomechanical testbench**
  - Test and Validation of ELT key functionalities that will be used during periods of

• System verification • Wavefront control commissioning • Handover to science	AIV / Commissioning Phase
• Regular diagonstics • Monitoring • Validation	Operations Phase

  - MELT deploys optomechanical key components with its control interfaces that are emulated from
    - **Telescope** (Segmented M1, M2 on Hexapod, adaptive M4, …)
    - **Phasing and Diagnostic Station** (several WFSs in VIS and NIR)

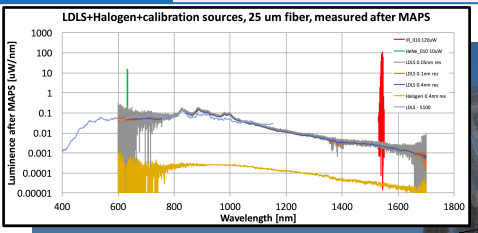
MELT Objectives

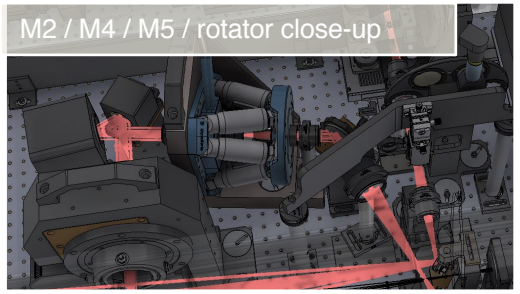
- Deploy and validate Control system
- Develop and validate wavefront control for commissioning and operations
- Get and validate requirements for the PDS



- Transform PEACE bench into ELT emulator
- Diagnostics that ressemble functionalities needed for
  - Commissioning
  - Phasing (first time and during operations)
  - Telescope validation

MELT Bench Layout





Turbulence generator

Source (main axis emulator)

M5 – fast T/T

M4 – 277 actuators

Rotator / Derotator

M2 on hexapod

Spider mask

M1 (61 segments)

Guest WFS path

VIS / NIR

NIR path

Sensor arm path

NIR

NIR imager

VIS

Zoom optics for SH pupil

VIS

SH phasing path

SCAO WFS

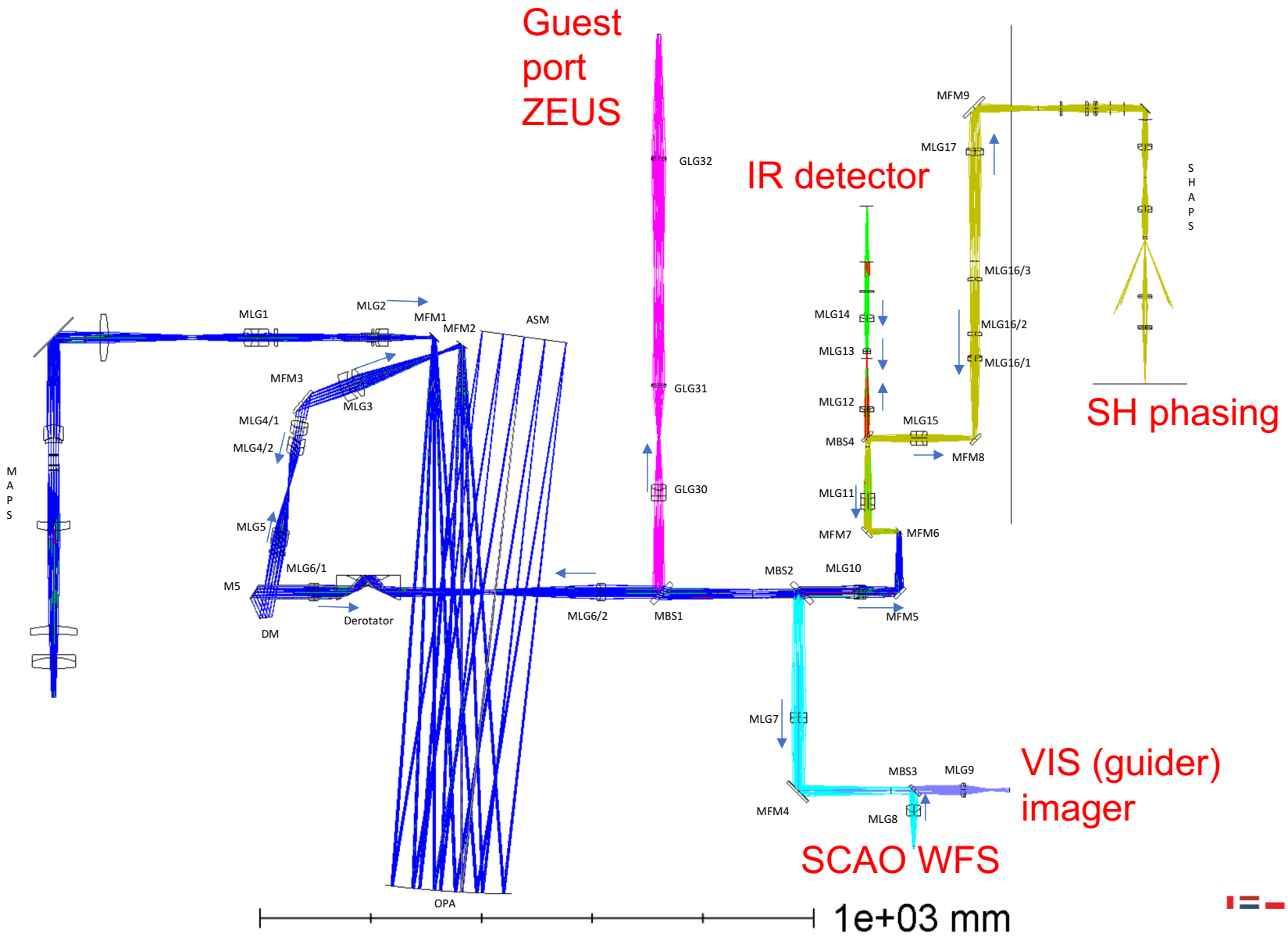
VIS / NIR

VIS imager

SH lenslet and detector

Pupil steering

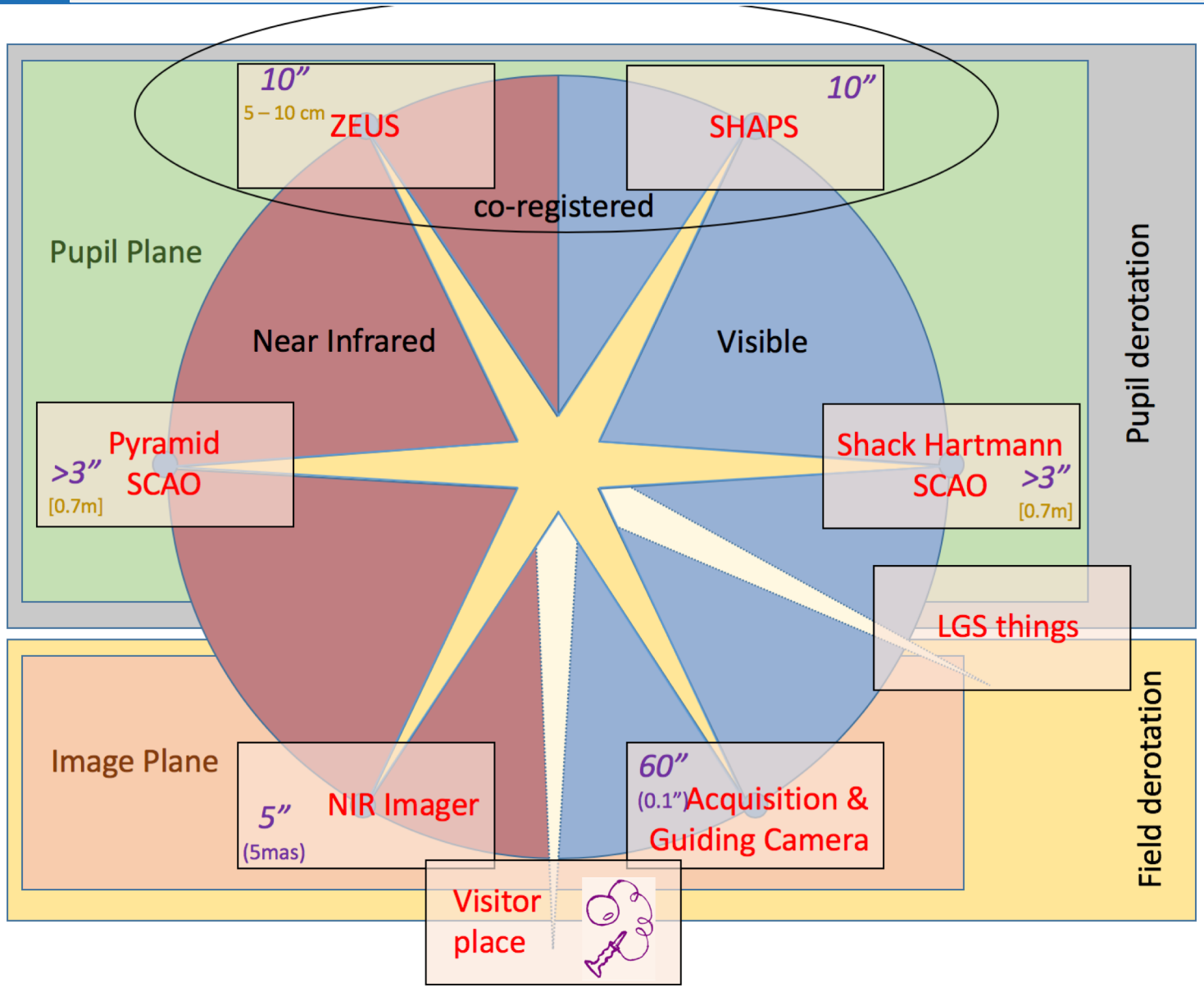
MELT Optical Design



MELT – Design

- MELT as precursor for PDS user requirements
  - Specifications ready by 08/2019
- **Design Driver:**
  - **WHAT DOES IT TAKE TO BRING THE TELESCOPE AT THE END OF AIV TO DELIVER DIFFRACTION-LIMITED PERFORMANCE?**
- Design approach
  - Near diffraction limited performance w/ SCAO IR (1400:1700 nm)
  - Hexapod (M2) provides up to >8um aberrations
  - Rotator provides pupil plane movement
  - Active pupil stabilization via T/T mirror for SH/NIR path

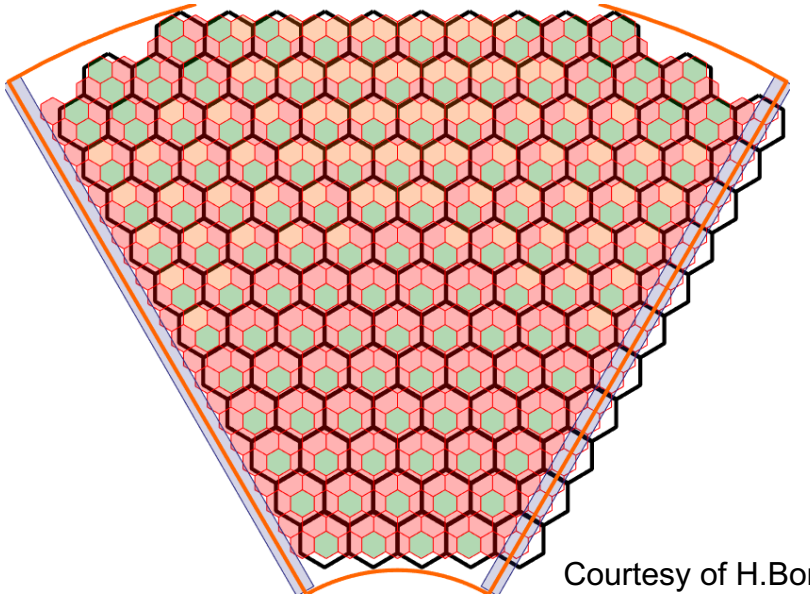
MELT – Path to PDS



Courtesy of H.Bonnet

MELT – Main Functionalities

- **Sensor arm function** for on-axis performance before PFS takes over after field performance is verified
  - VIS imager with FoV 12” (MELT) / 1’ (PDS) with T/T guider
  - VIS SCAO SH high order WFS in closed loop via ELT RTC
  - Segment capture and stacking / Guiding / descalloping

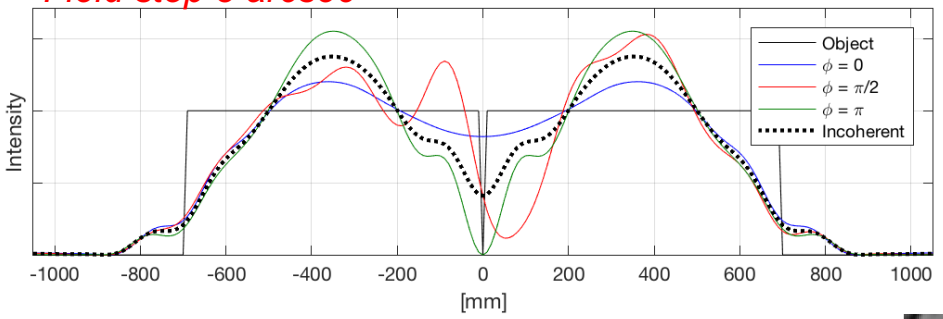


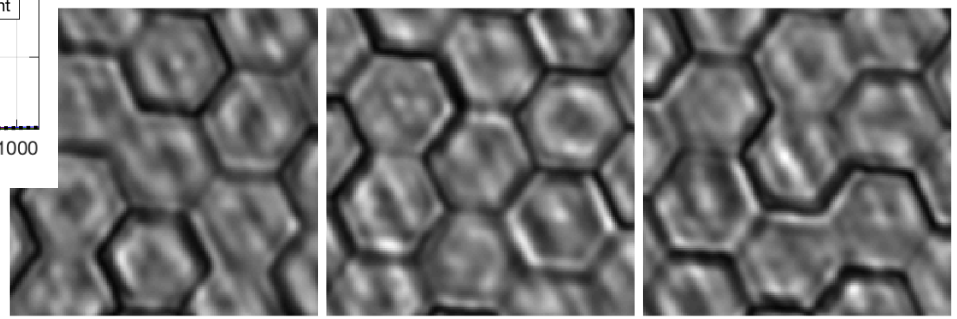
Courtesy of H.Bonnet

MELT – Main Functionalities

- **NIR focal plane imager** J,H (MELT) / J,H,K (PDS)
  - Diff-limtd focal plane sampling 9mas (MELT) / 4mas (PDS)
  - Strehl measurement / Phasing non-adjacent segments / M4
- **NIR pupil plane imager** J,H (MELT) / J,H,K (PDS)
  - Support of SH phasing via phase mask in pupil imaging
  - Coherencing / Phasing
  - Sampling ~4cm in (ELT) M1 space

Field stop 3 arcsec



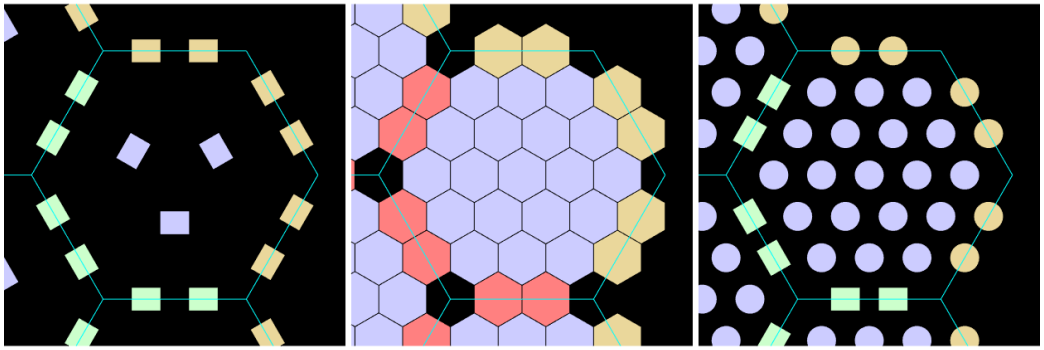


Courtesy of H.Bonnet

MELT – Main Functionalities

High-order SH Phasing

- 19 SA per seg. /pupil shape control to relative accuracy 10^{-4}
- TCCD 512 x 512 (MELT) / 4k x 4k (PDS)
- Capture / Stacking / Descalloping
- Phasing / Coherencing / Segment shaping



Courtesy of H.Bonnet

MELT – Main Functionalities

- **Pyramid WFS ? (later)**
  - M4 petal phasing strategy development
  - Telescope performance verification (pupil fragmentation)
  - Match of instrument NGS WFS approach (SCAO)
  - Short K-Band
  - Phasing? / Descalloping?

MELT – Main Functionalities

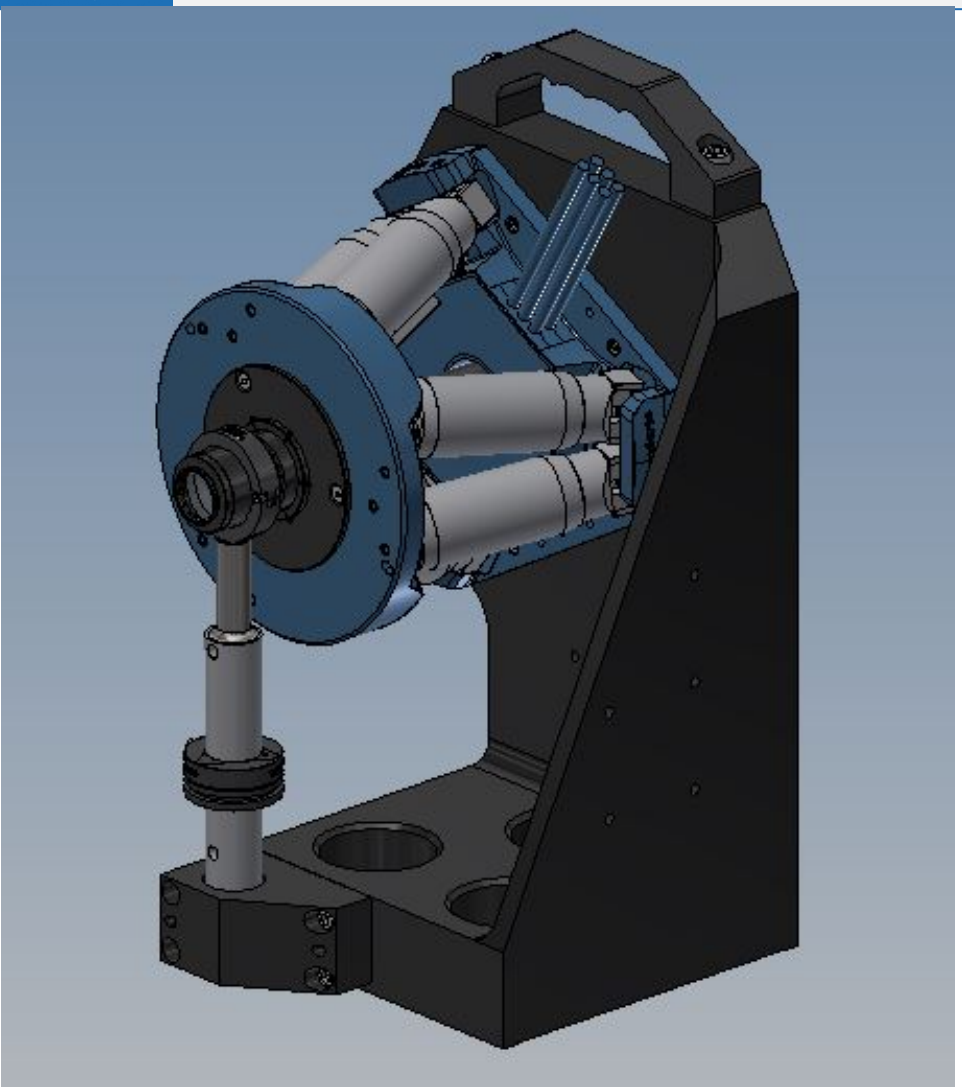
- Objectives are broken down into tasks, consisting of use cases and operational scenarios

Tasks	MELT	PDS
Support in populating look-up tables during initial telescope mirror alignment (main axis actuators, M1 PACTs, M2 RBM, M3 RBM, M4 RBM, M5 RBM)	(✓)	✓
M1 active control functions characterization (LOO characterization)	(✓)	✓
M1 phasing measurement (includes segment capture, stacking, coherenceing, …)	✓	✓
Blind slew performance characterization	×	✓
M1 scalloping measurement	✓	✓
M2 active control functions characterization	✓	✓
M3 active control functions characterization	×	✓
M4 response (static and dynamic)	✓	✓
M4 phasing	✓	✓
M5 response (static and dynamic)	✓	✓
Stroke management and offloading schemes (M4, M5, main axis)	✓	✓
SCAO + control handover (cascade, sequential)	✓	✓
SCAO performance (characterization of M4-5 latency, pupil motion, CCS I/F, ...)	✓	✓
Verification of field/pupil stabilization, including low order AO for wind correction	(✓)	✓
Seeing-limited performance plus acquisition sequence (pointing, focus correction)	(✓)	✓
Offsetting/nodding	(✓)	✓
Non-sidereal tracking performance	×	✓
LGS pointing and field/pupil tracking validation	×	✓
LGS performance characterization (jitter, instantaneous PSF, return flux at Nasmyth, elongation, LGS scattering, …)	×	✓

MELT – Design Details

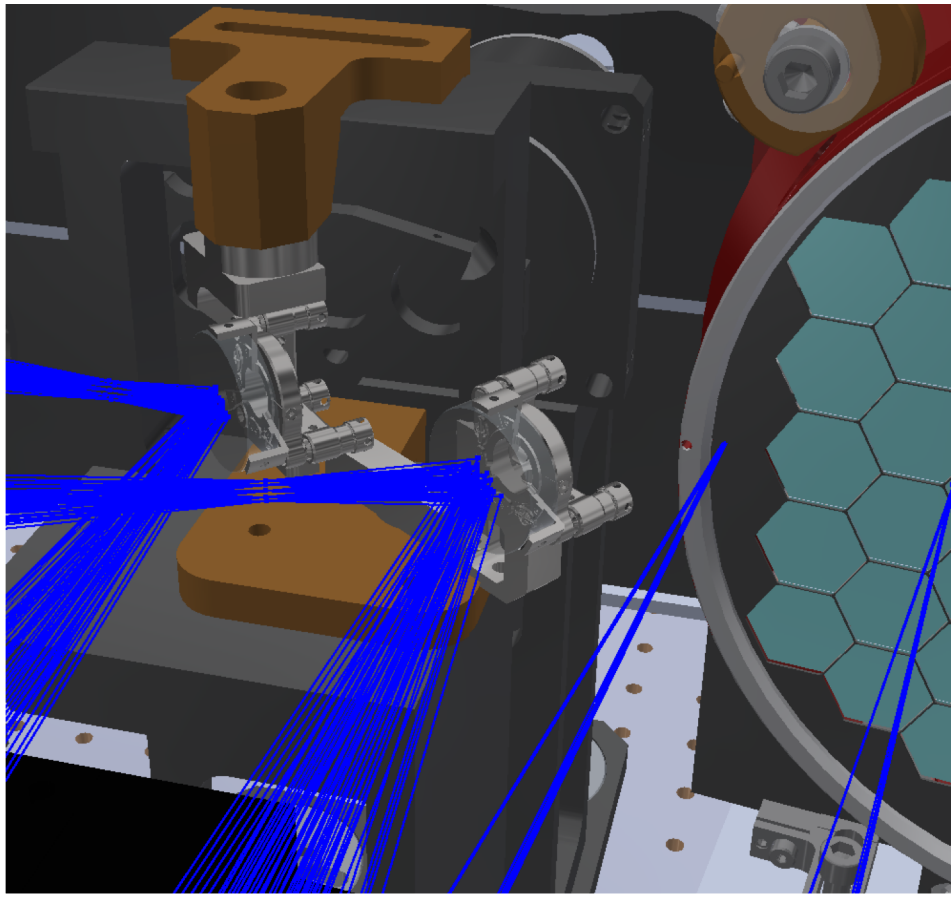
- Reuse most of optomechanical mounts from PEACE
- Reuse filter wheels from PEACE
- Add translation stages where necessary
- Optics to be purchased new
- 22 lenses or lens groups
- 4 beam splitters
- 5 fold mirrors
- 4(5) diagnostics paths (VIS imager and WFS, IR diagnostics, SH phasing, pyramid IR WFS)

MELT Optomechanical design



Fold mirrors clearing IM and ASM path

Hexapod (M2) with intermediate focus



MELT – Alignment Strategy

- Goal NOT to achieve best possible bench alignment
- Replicate situation when first star photons are transferred through full ELT 5 mirror system
- Proper alignment of diagnostics path alone (Sighting telescope / laserpointer)
- Definition of optical diagnostics beam via mirror/target
- All telescope optics placed on bench without light (mechanical tolerances)

MELT – Alignment Strategy

- Option to merge the two beam with periscope, but first: Let WV commissioning begin!!
- Is there light at all? Is it aberrated?
- The PDS with its sensor arm functionality (or, later on the sensor arms in the PFS) with its SH WFS define(s) the optical beam of the ELT. The 5 ELT mirrors are expected to adjust to this reference.

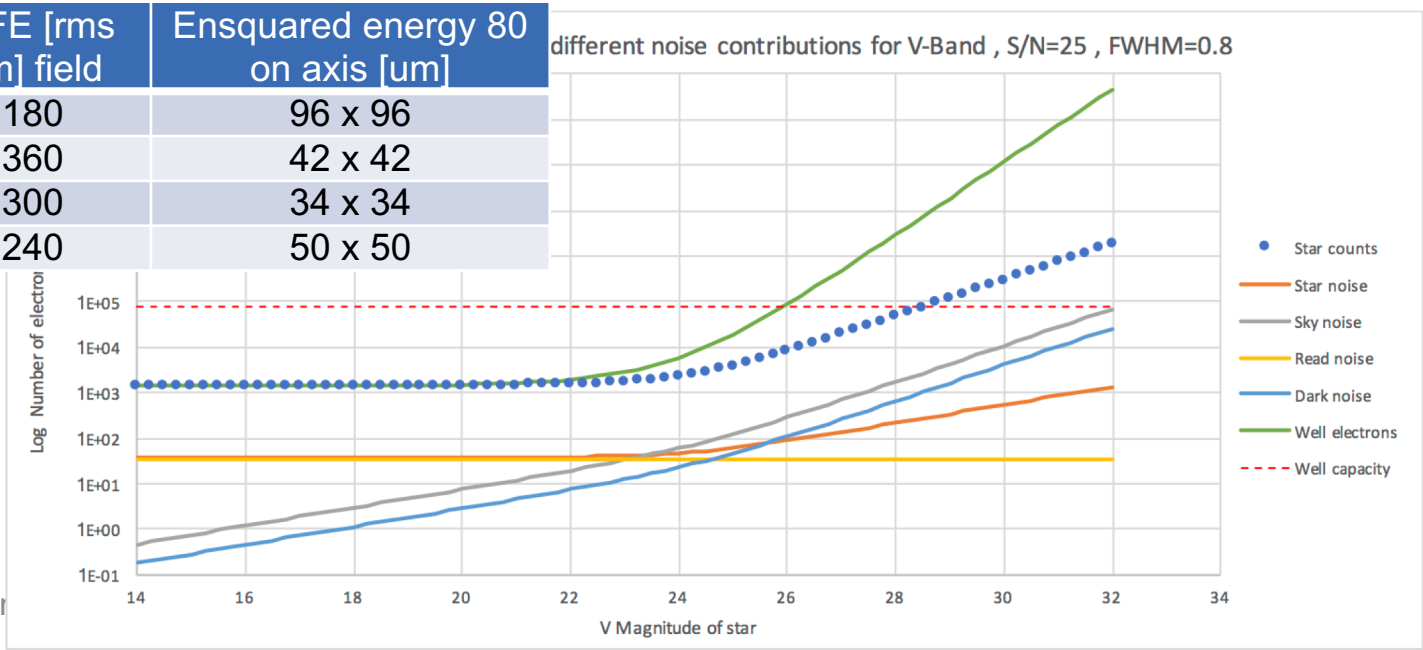
MELT – Schedule

- Optics procurement ongoing (shipment 5th Nov.)
- Mechanical detailed design finished, all drawings in production (first week November)
- Electronics design (Beckhoff PLC-based) finished, manufactured until first week November
- PEACE bench in use until End October
- Alignment ends Mid December
- In December the MELT control team can fully work with light
- End 2018 all parts are to be controlled stand-alone

MELT Guide Probe – VIS imager

- No imager for now (Potential COTS sCMOS candid.)
- 8mm x 8mm focal plane, 10” FoV, 1k x 1k and 500Hz on ROI
- 807um/arcsec, f/14.38, 3.5% distortion (edge of field)
- WFE:

WL [um]	WFE [rms nm] On axis	WFE [rms nm] field	Ensquared energy 80 on axis [um]
0.5	180	180	96 x 96
0.6	103	360	42 x 42
0.7	80	300	34 x 34
0.8	150	240	50 x 50



MELT Guide Probe – SCAO WFS

- Currently: ALPAO 256 x 256 with 207um lenslets, 16 x 16 subapertures on 3.3 x 3.3 mm pupil
- Potential COTS? 800 x 800 to run at 700 Hz
- Pupil blur: 3.8% of SA on axis, 9%/8% of SA in field
- Lenslet plate scale on detector: 11 mas/um
- +/-1.1arcsec field per SA
- WFE:

WL [um]	WFE [rms nm] On axis	WFE [rms nm] field
0.5	80	120
0.6	88	215
0.7	28	126
0.8	136	50

MELT – IR pupil and field imager

- Phasing via pupil imaging
- Diffraction limited field imaging (9.5 mas/px)
- Support SH phasing by measuring pupil movement and controlling
  - Pupil steering mirror
- Currently Xenics130 with 320x256 px at 85 Hz, 30um pitch
- 6.7 mm pupil image

Focal plane WFE:

WL [um]	WFE [rms nm] On axis	Ensquared energy 80 on axis [um]
1.4	117	260 x 260
1.5	114	280 x 280
1.6	128	320 x 320
1.7	175	360 x 360

Pupil plane WFE:

WL [um]	WFE [rms nm] On axis
1.4	96
1.5	100
1.6	111
1.7	143

MELT – SH phasing / Pyramid

- Zoom optics (manual)
- Reuse SHAPS (from PEACE) with currently TCCD with 512x512px non-sync frame rate
- WFE:

WL [um]	WFE [rms nm] On axis
0.5	122
0.6	176
0.7	200
0.8	300
0.9	470

- NIR Pyramid not in current design, but upgrade foreseen in 2019/2020, via beamsplitter in NIR path