GEMS LGS FACILITY COMMISSIONING RESULTS

CÉLINE D'ORGEVILLE

AO4ELT2 CONFERENCE, VICTORIA, SEP. 25-30, 2011

Commissioning team and core support staff

Up to 23 people at the summit during LGSF commissioning !

Optics/Laser

SSA

PIO

Spotters

Electronics

Systems

Software

AO

Cerro Pachón

Presentation Outline

- ★ Gemini LGS Program: A Brief History
- ★ GS LGS Facility Overview
- ★ GS LGS Facility 2011A Commissioning Results
- ★ GS LGS Facility 2011B On-Going Activities and Plans
- ★ Gemini LGS Program: Lessons Learned

Gemini LGS Program: A Brief History

1999 – François Rigaut started dreaming about MCAO on earth… The Gemini LGS program was born!

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1999 – François Rigaut started dreaming about MCAO on earth… The Gemini LGS program was born!

1999 – MCAO feasibility study

2000 – MCAO CoDR

2001 – MCAO PDR

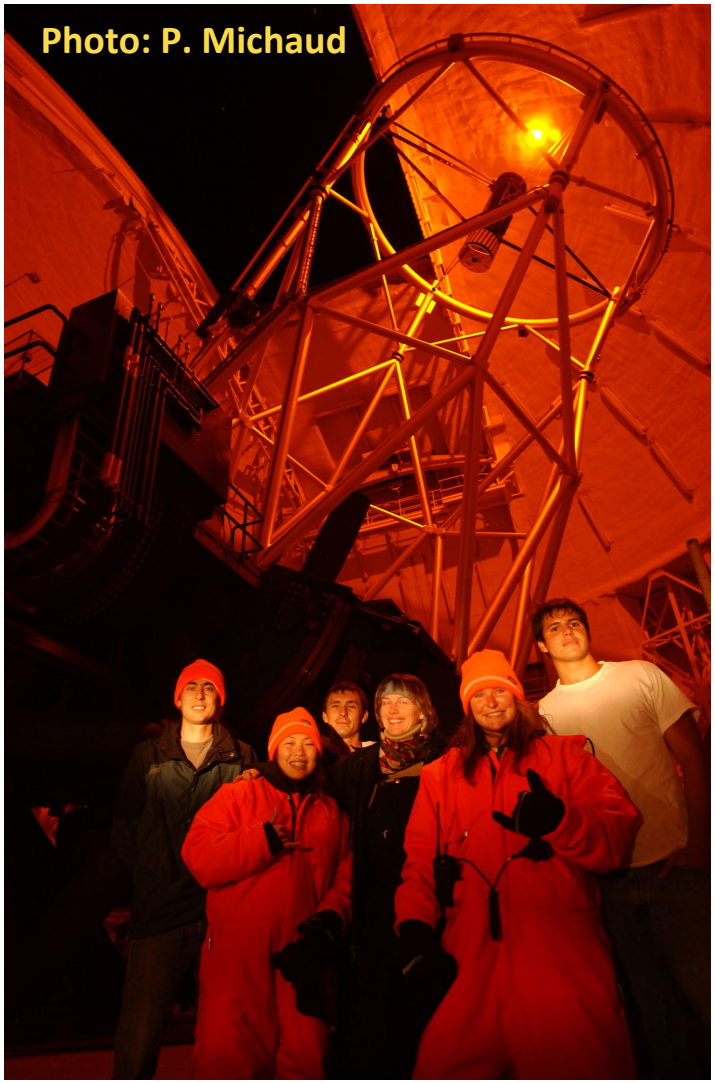
2005 – GN LGSF first light with 14W GN laser

2010 – GS Laser delivery (March) and installation on telescope (July)

2011 – GS LGSF first light (January 22) and commissioning (Jan-April) with 50W GS laser

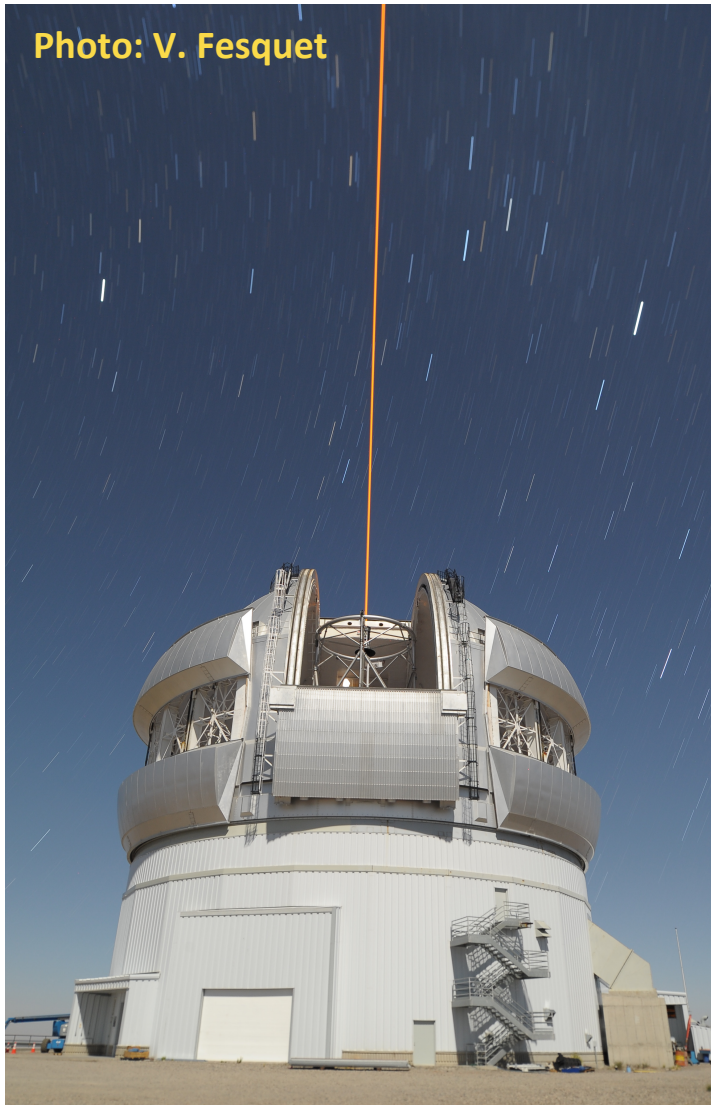
Gemini Laser First Light: Gemini North

2005 May 2 @ 4:15 am: GN laser propagates over Mauna Kea!



Gemini Laser First Light: Gemini South

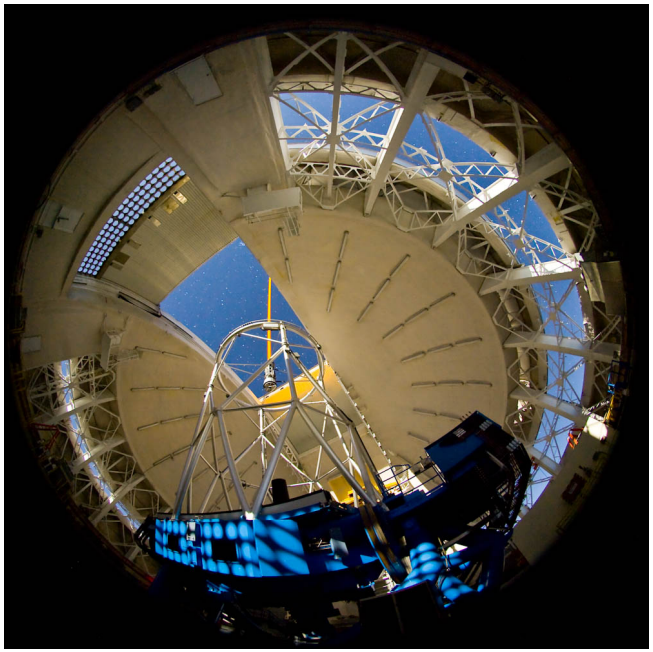
2011 Jan 22 @ 4:38 am: GS laser propagates over Cerro Pachón !!!!!

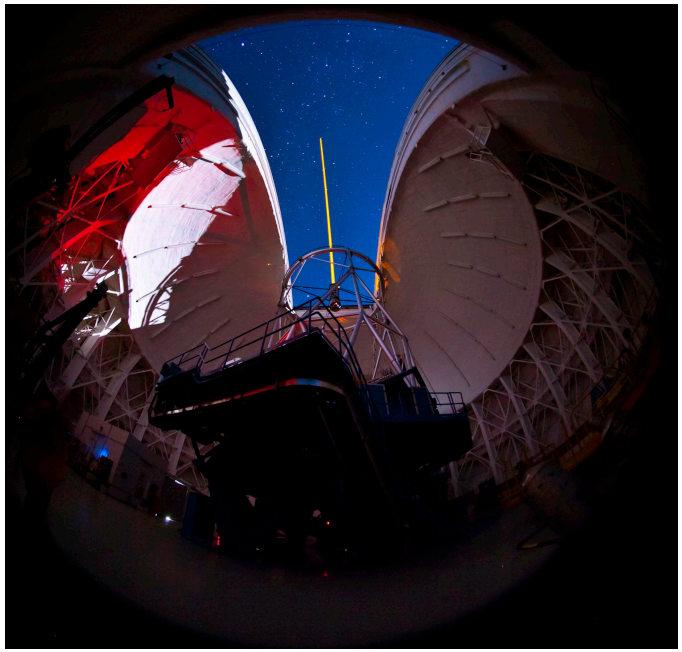


A happy commissioning team of 12 ☺

2005 Gemini North 14W

2011 Gemini South 50W





So…what's the difference and how come it took so long to propagate our second laser ?

First sodium laser constellation first light ☺

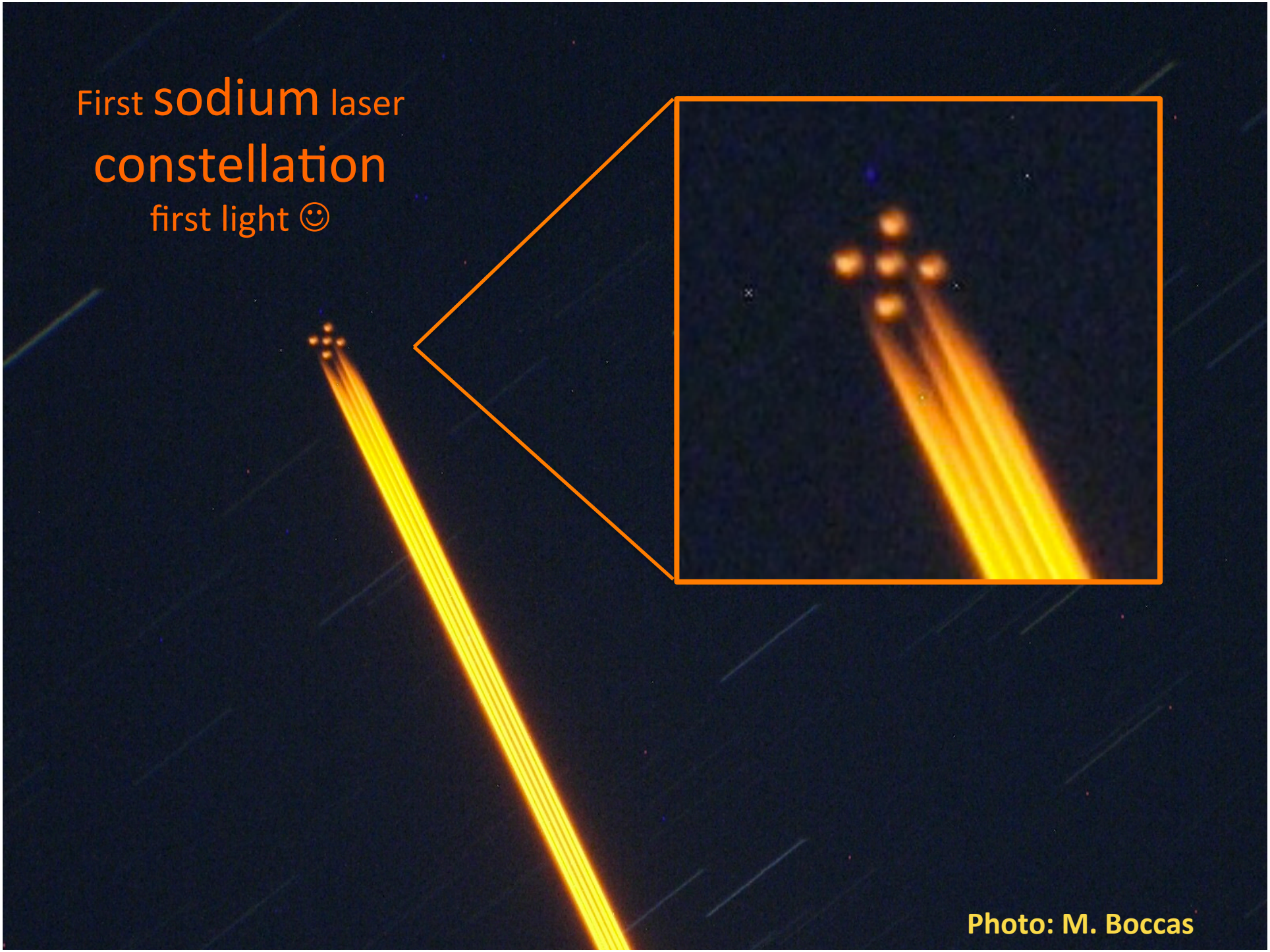
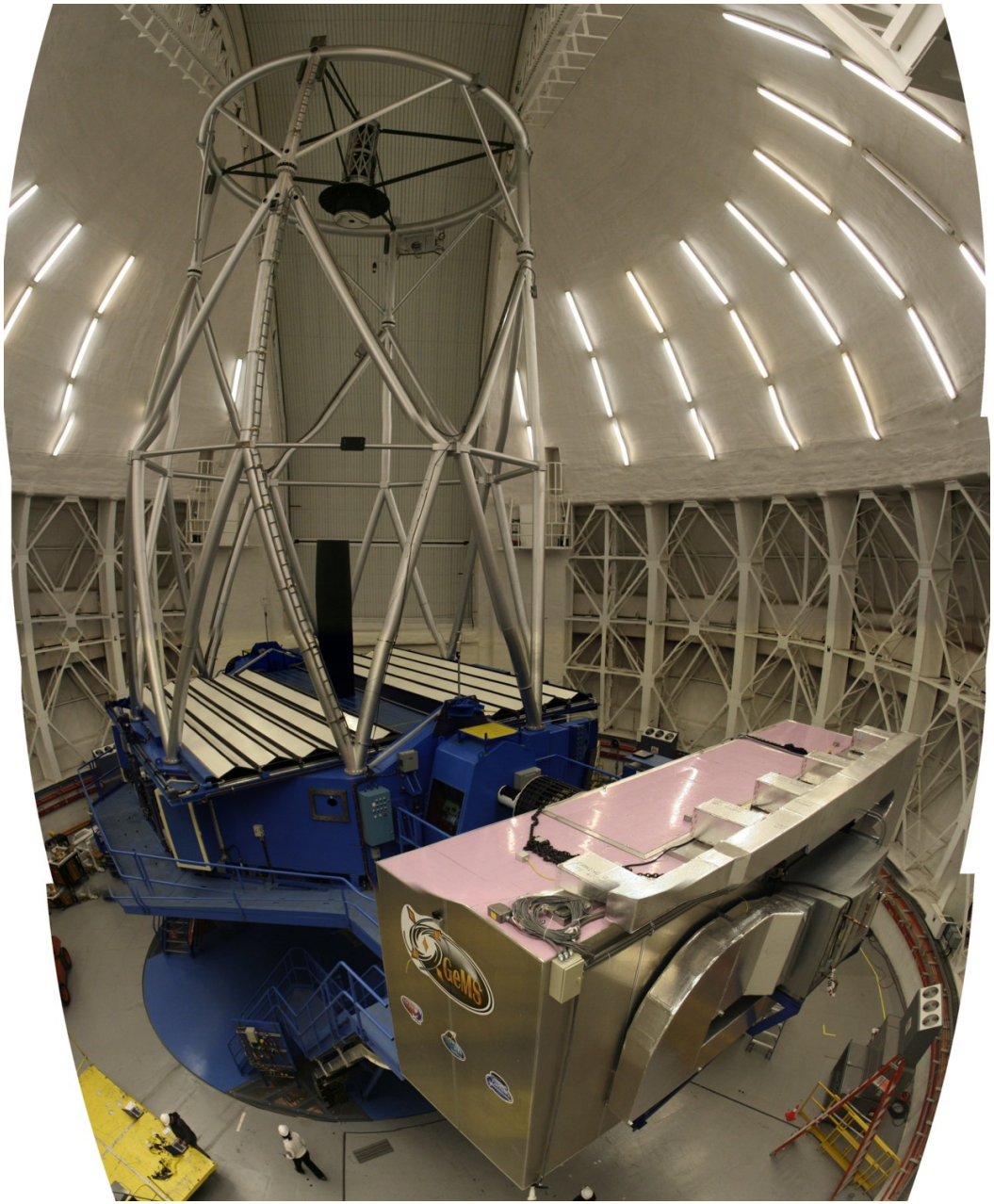


Photo: M. Boccas

GS LGS Facility Overview



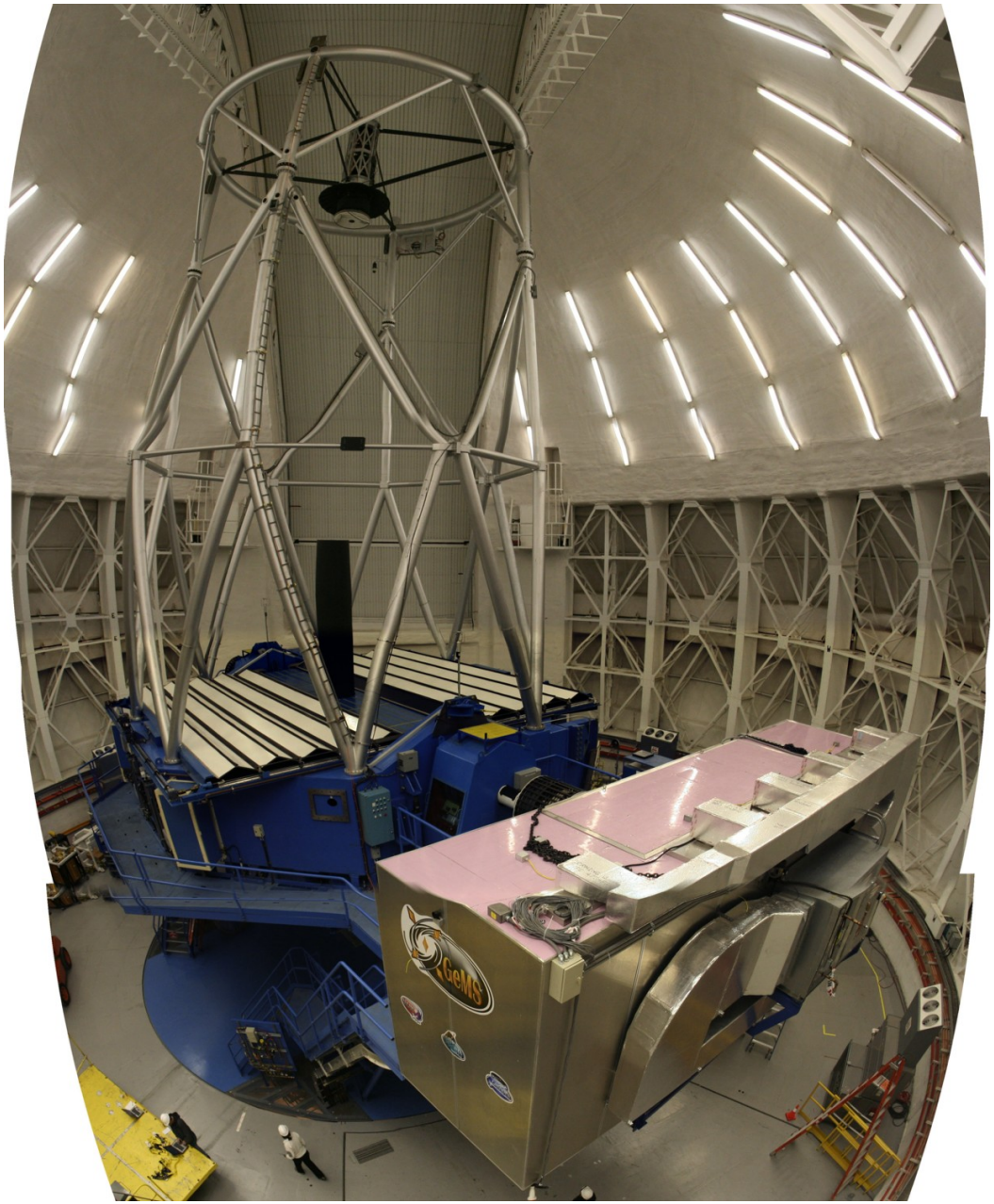
★ Laser Service Enclosure (LSE)

GS LGS Facility Overview

★ Laser Service Enclosure (LSE)

★ 50W Laser System

GS LGS Facility Overview

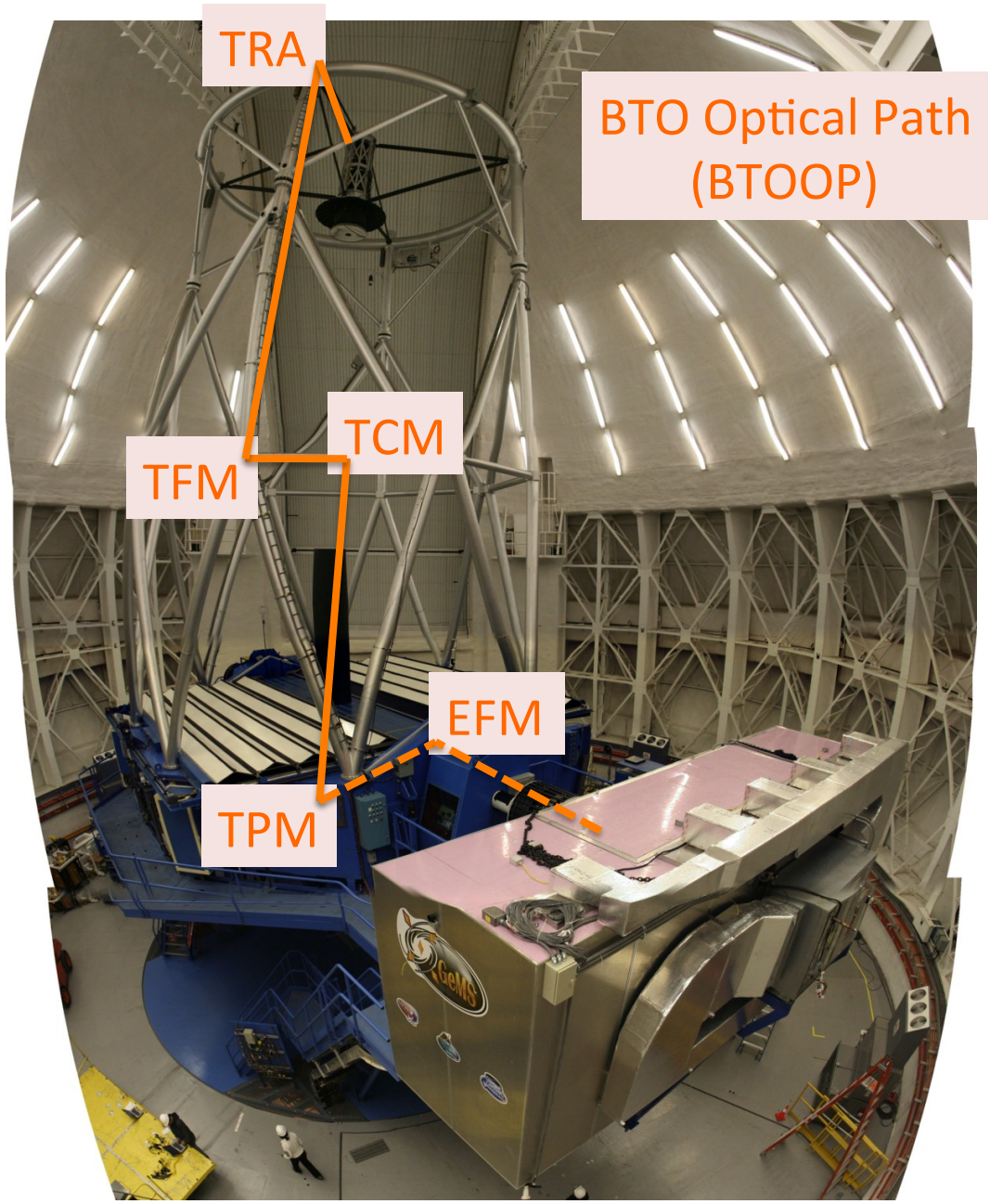


★ Laser Service Enclosure (LSE)

★ 50W Laser System

★ Beam Transfer Optics (BTO)

GS LGS Facility Overview

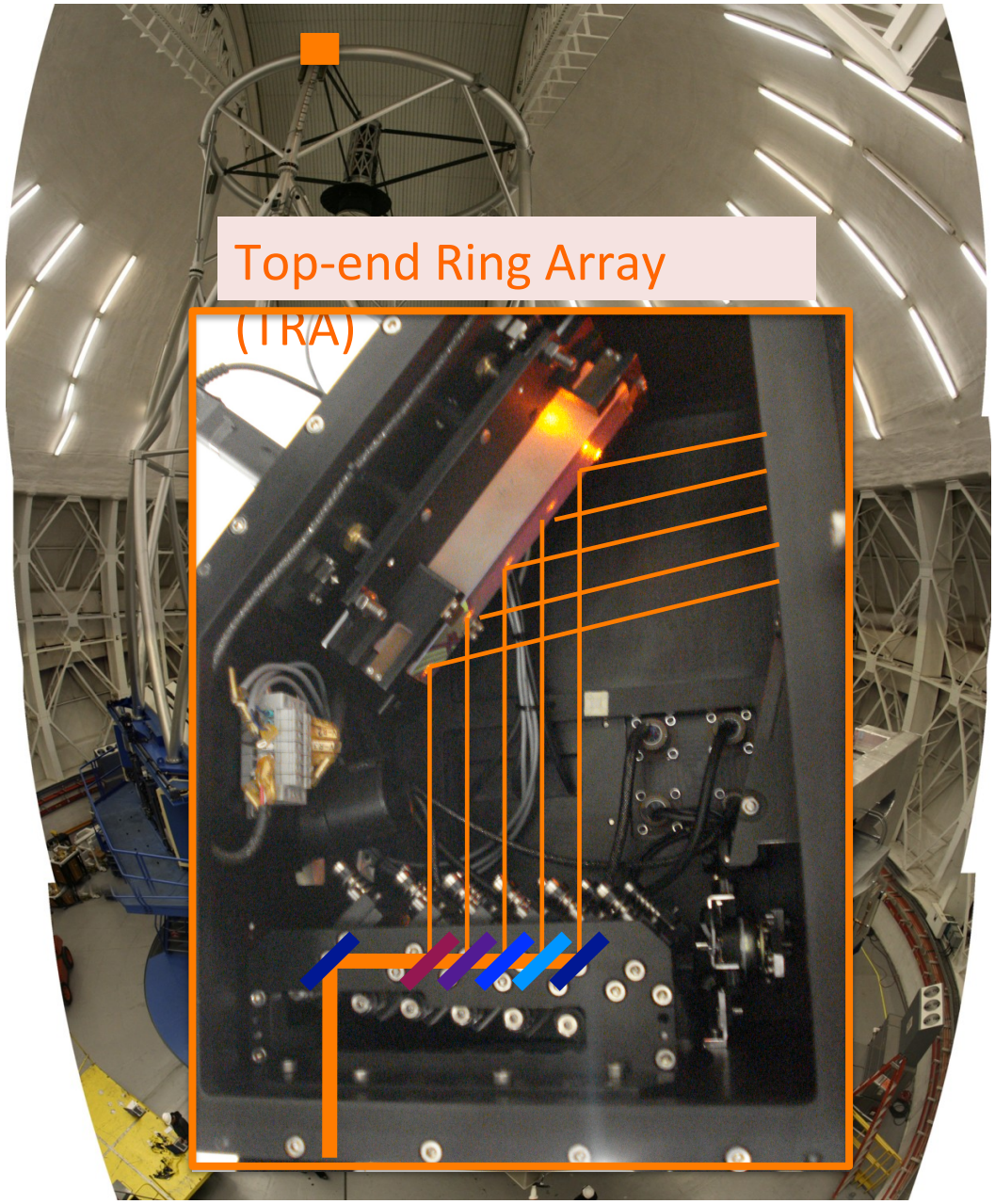


★ Laser Service Enclosure (LSE)

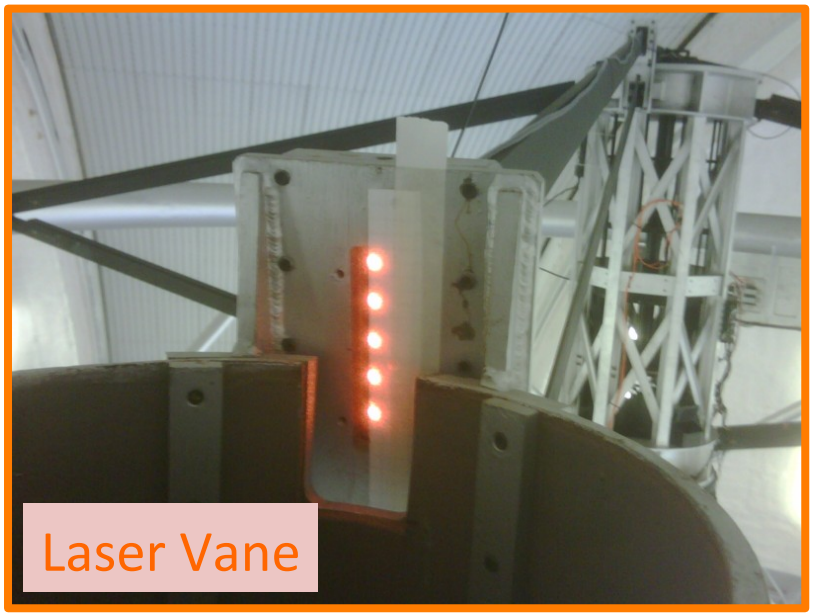
★ 50W Laser System

★ Beam Transfer Optics (BTO)

GS LGS Facility Overview



- ★ Laser Service Enclosure (LSE)
- ★ 50W Laser System
- ★ Beam Transfer Optics (BTO)



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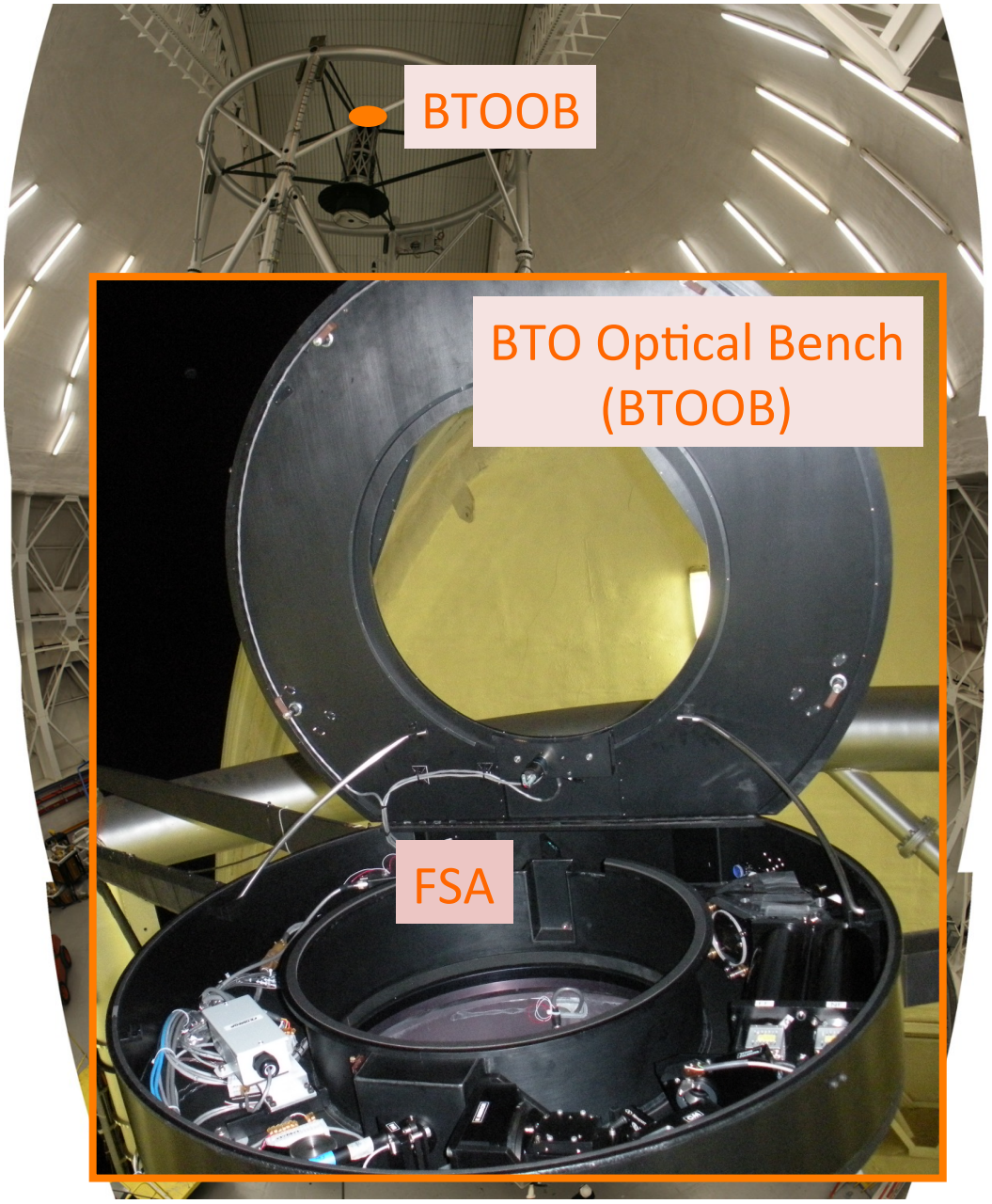

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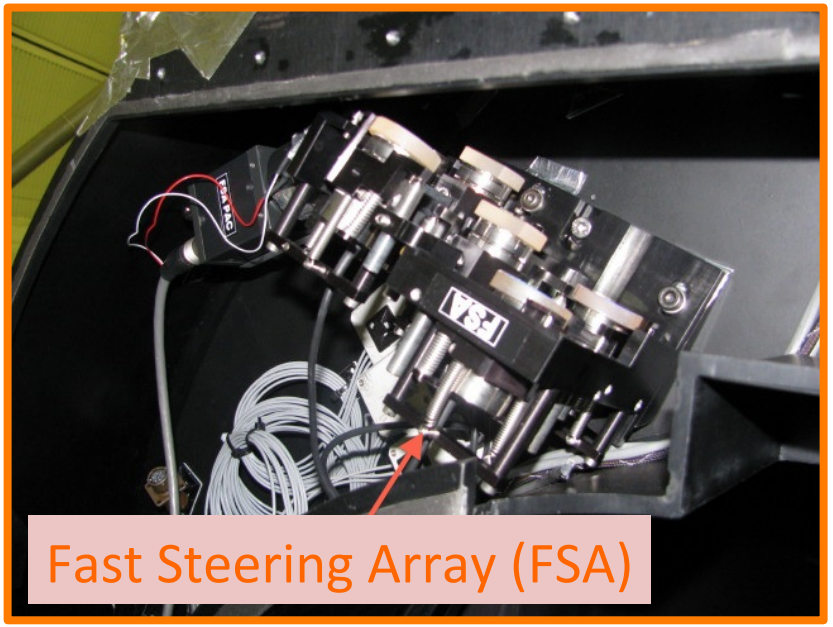

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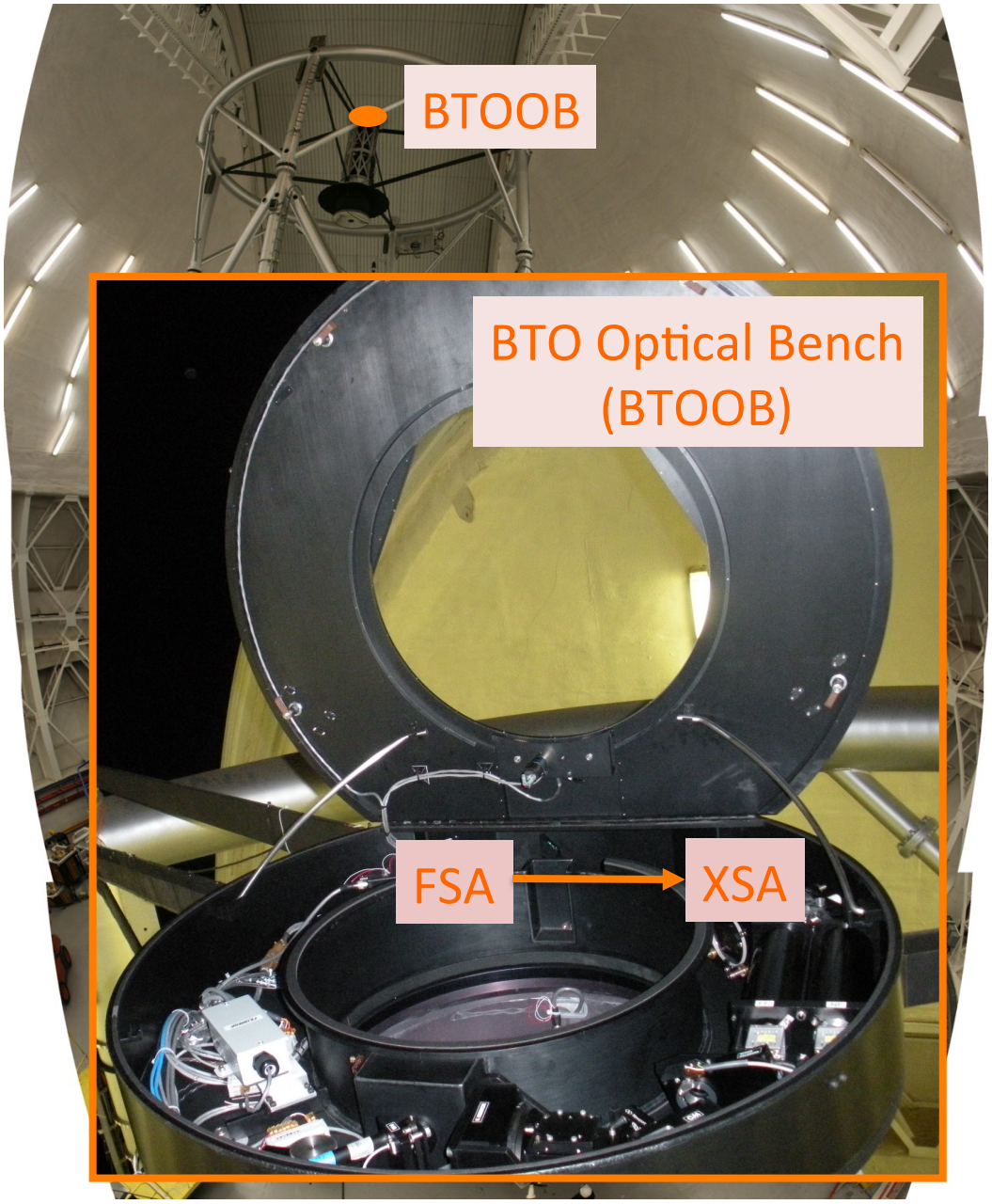

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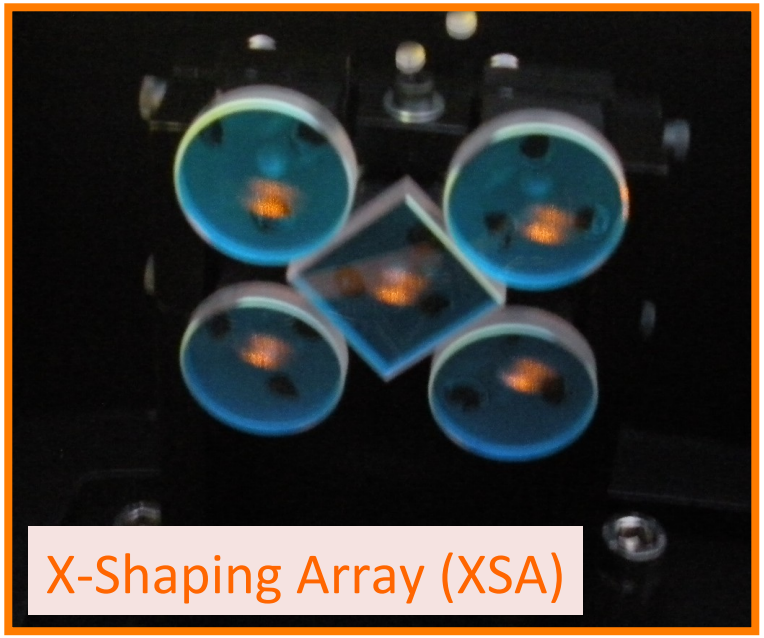
★ 50W Laser System

★ Beam Transfer Optics (BTO)



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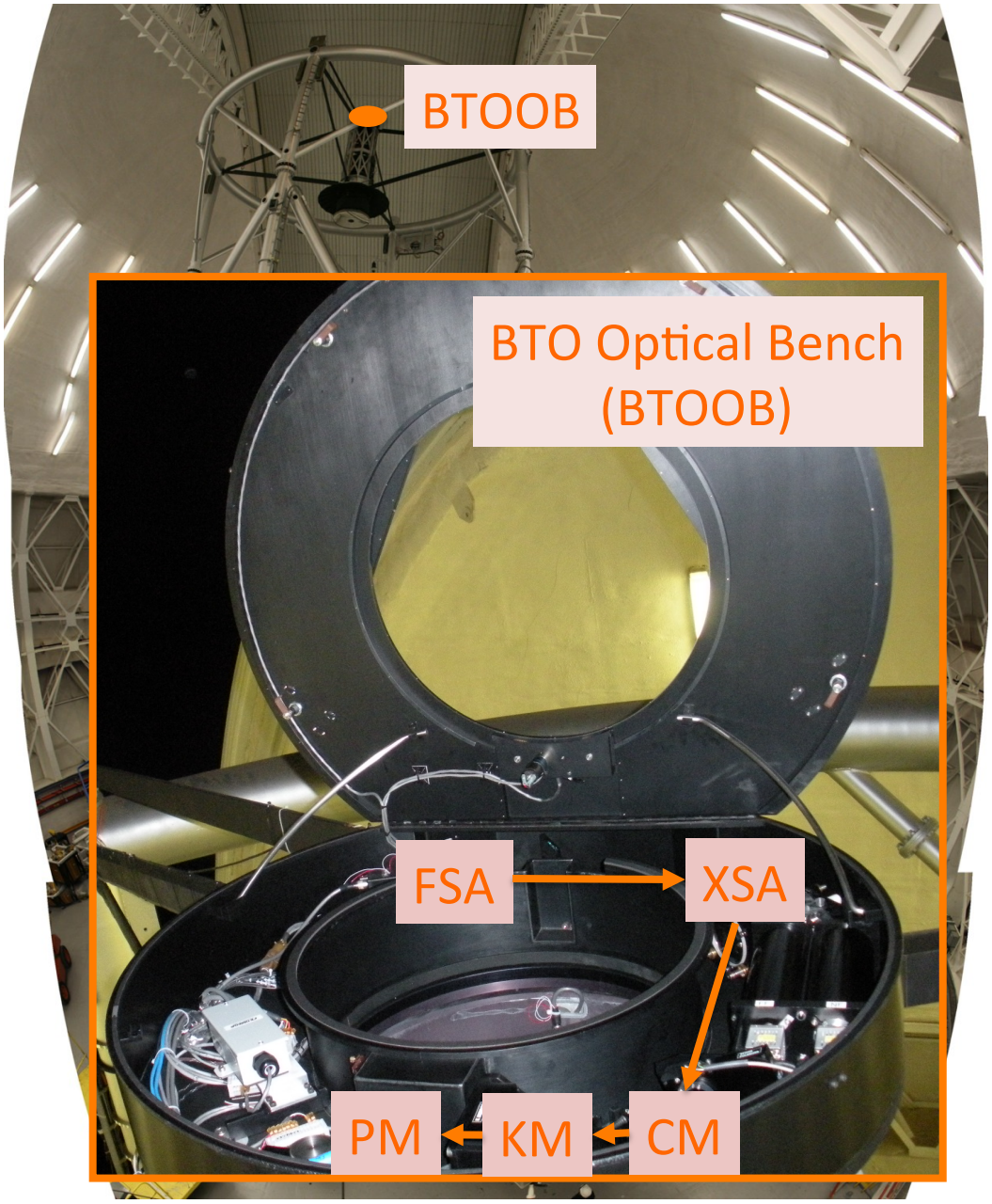

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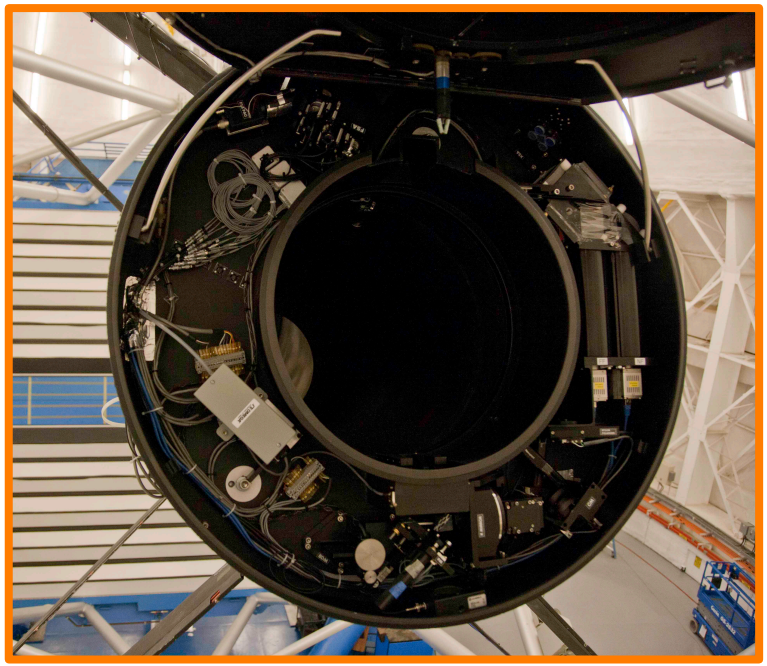

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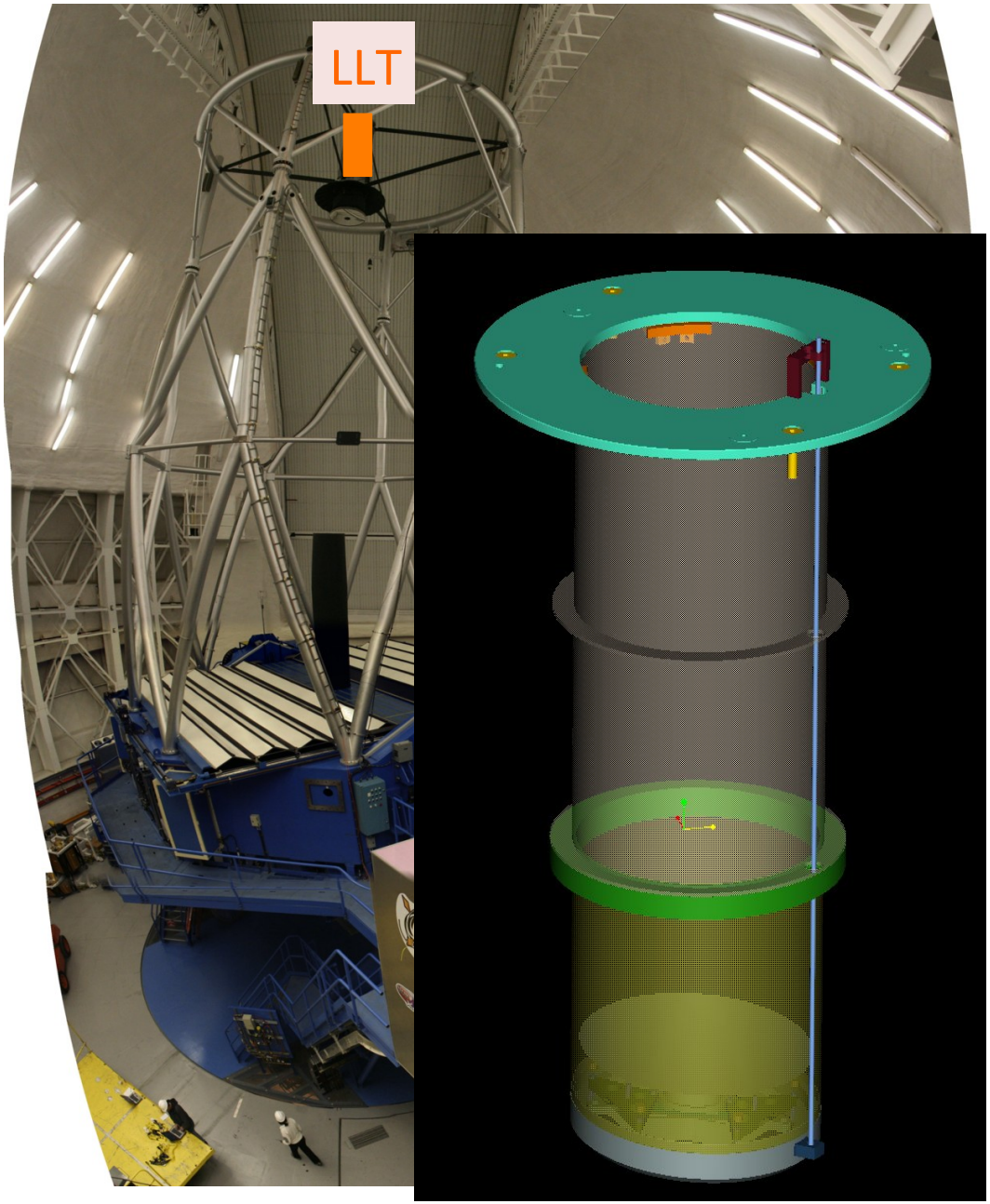

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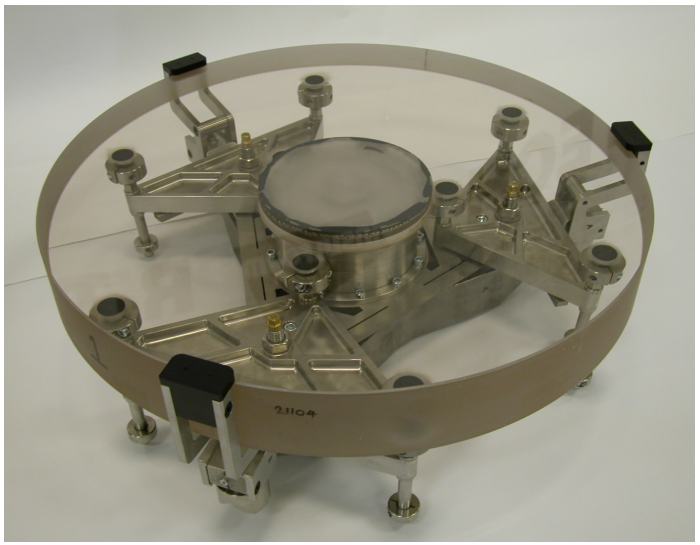
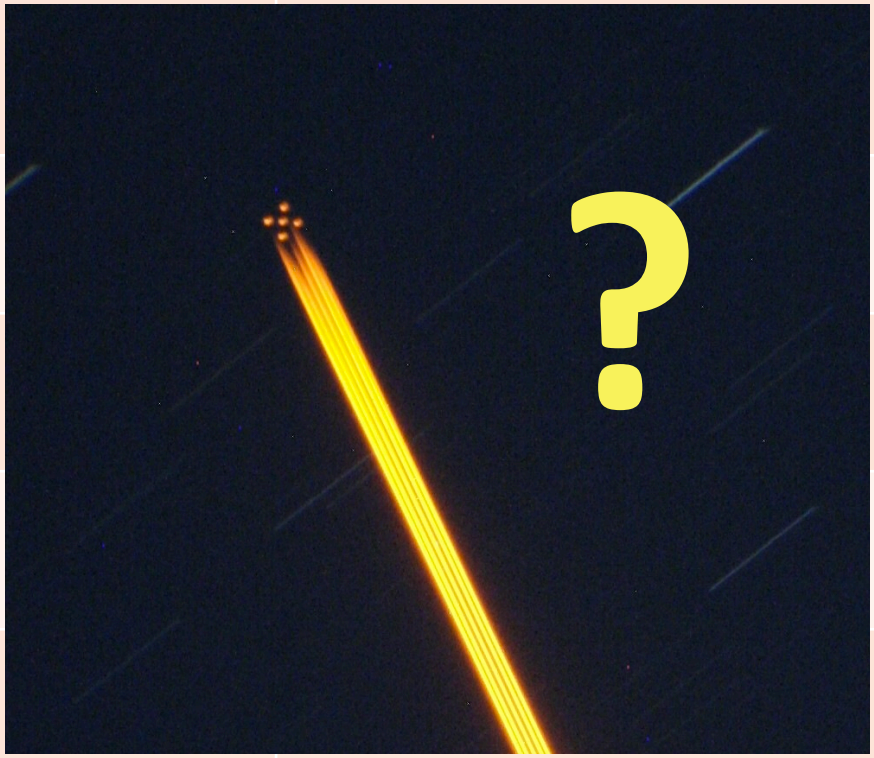


GS LGS Facility Overview

- ★ Laser Service Enclosure (LSE)
- ★ 50W Laser System
- ★ Beam Transfer Optics (BTO)
- ★ Laser Launch Telescope (LLT)
- ★ Safety Systems
  - ★ Laser Interlock System (LIS)
  - ★ Laser Traffic Control System (LTCS)
  - ★ Satellite Avoidance System
  - ★ Aircraft Avoidance System
    - ★ Spotters
    - ★ VITRO

GS LGSF Commissioning: Results to Date

	Specification	Achieved to date	Comment
Photon return @ M1 per LGS at zenith	168-263 ph/cm^2/s		
Photon return balance	+/- 5%		
Spot size	1.0” FWHM on AqCam		
Blind pointing accuracy	1” peak		
Dynamic pointing	0.05” rms		



Photon Return: Results to Date

The specifications below were derived from those presented at the MCAO PDR in 2001:

Photon return per LGS at zenith	Specification (*) ($P_{projected\ per\ LGS}$= 7.2 W)	Best result to date	Comment
@ LGS WFS	**250-390 ph/subap/ frame**		**@ 800Hz with (50cm)^2 subapertures**
@ LGS WFS	62-97 ph/pix/frame		4 pixels per subaperture
@ LGS WFS	80-125 ph/cm^2/s		
@ LGS WFS per Watt of projected power	11-17 ph/cm^2/s/W		
@ M1	**168-262 ph/cm^2/s**		**Assumes: QE=0.85, T_{AO}=0.7, T_{tel}=0.8**
@ M1 per Watt of projected power	23-36 ph/cm^2/s/W		
(*) Assumes: T_{BTO}= 0.8, T_{LLT}= 0.9, P_{laser}= 50W → $P_{projected\ per\ LGS}$= 7.2 W			

Photon Return: Results to Date

During the March-April-May 2011 runs the LGS WFS received up to **35 photons/pixel/frame @ 800Hz** with **~4W projected to the sky** per laser beam.

Photon return per LGS at zenith	Specification (*) ($P_{projected\ per\ LGS}$= 7.2 W)	Best result to date ($P_{projected\ per\ LGS}$~ 4 W)	Comment
@ LGS WFS		~137 ph/subap/frame	@ 800Hz with $(50cm)^2$ subapertures
@ LGS WFS		**~35 ph/pix/frame**	**4 pixels per subaperture**
@ LGS WFS		~44 ph/cm^2/s	
@ LGS WFS per Watt of projected power		~11 ph/cm^2/s/W	Best result with $P_{projected\ per\ LGS}$ ~ 4 W
@ M1		~92 ph/cm^2/s	Assumes: QE=0.85, T_{AO}=0.7, T_{tel}=0.8
@ M1 per Watt of projected power		**~23 ph/cm^2/s/W**	**Comparable to GN laser first light results (27 ph/cm^2/s/W with 6W projected)**

(*) Assumes: T_{BTO}= 0.8, T_{LLT}= 0.9, P_{laser}= 50 W → $P_{projected\ per\ LGS}$= 7.2 W

Photon Return: Results to Date

Results are comparable to GN laser first light results but marginal for GeMS operation due to larger laser spectral BW and lower BTO throughput

Photon return per LGS at zenith	Specification (*) ($P_{projected\ per\ LGS}$= 7.2 W)	Best result to date ($P_{projected\ per\ LGS}$~ 4 W)	Comment
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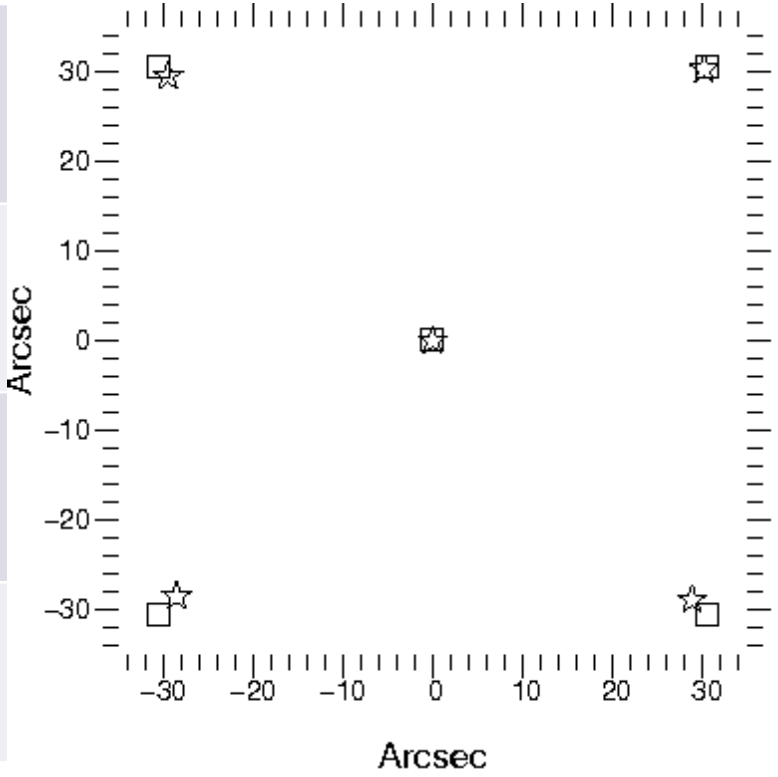
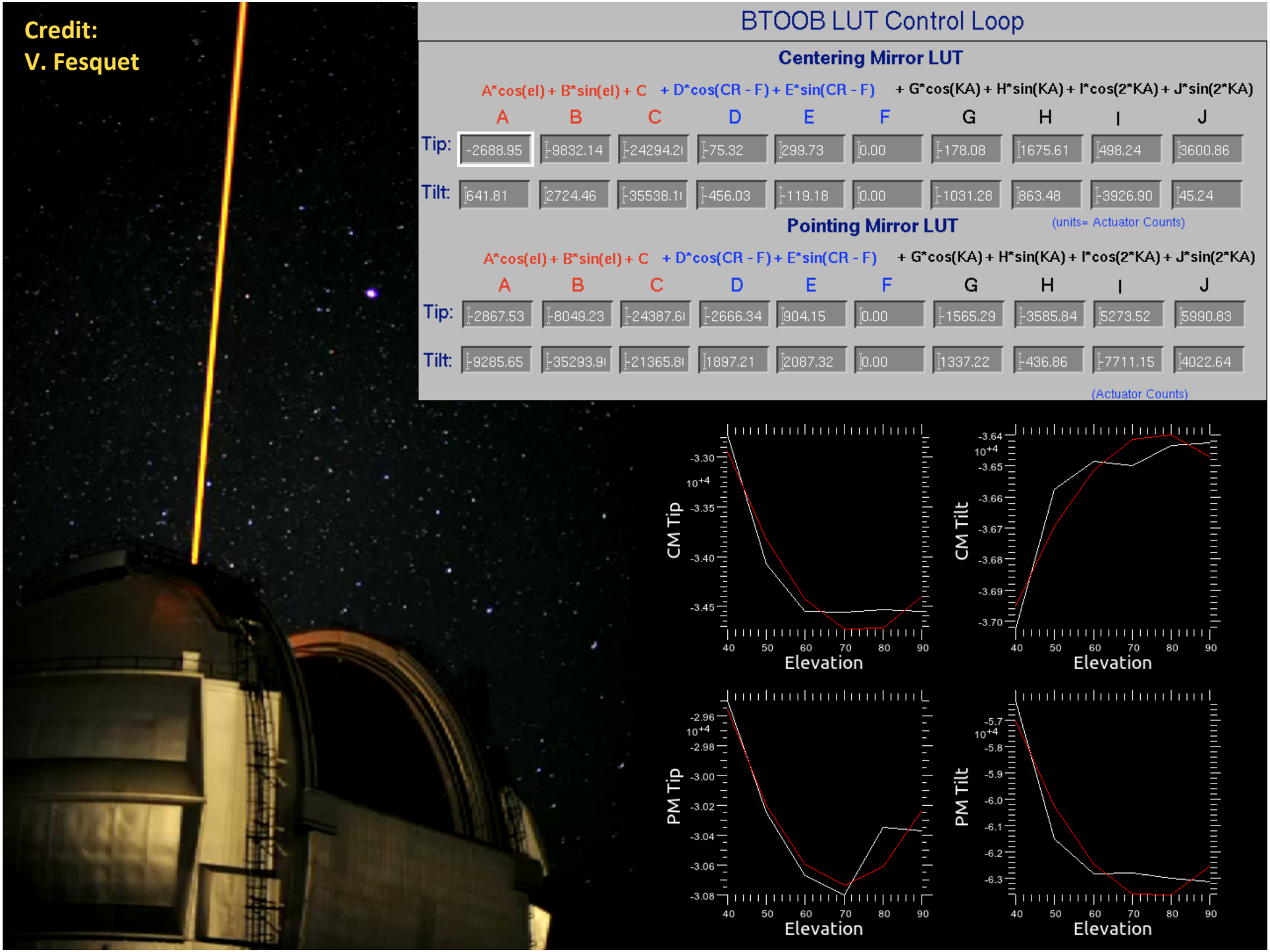
Pointing Accuracy: Results to Date

- EFM, TPM, TCM, TRA: LUTs vs Elevation
- PM, CM: LUTs vs Elevation, Cass Rotator, KM angle
- KM angle: LUT vs Cass Rotator
- FSA closed loop on LGS WFS + offloads to PM, CM, KM

On-sky pointing	Specification	Achieved to date	Comment
Constellation geometry	5 LGS at center and corners of 60” square		
Constellation blind pointing accuracy	1” peak		
LGS differential position accuracy	1” peak		
LGS dynamic pointing	0.05” rms		




Credit:
V. Fesquet
BTOOB LUT Control Loop
Centering Mirror LUT
A*cos(el) + B*sin(el) + C + D*cos(CR - F) + E*sin(CR - F) + G*cos(KA) + H*sin(KA) + I*cos(2*KA) + J*sin(2*KA)
A B C D E F G H I J
Tip: -2688.95 -9832.14 -24294.2 -75.32 299.73 0.00 178.08 1675.61 498.24 3600.86
Tilt: 641.81 2724.46 -35538.1 -456.03 119.18 0.00 1031.28 863.48 -3926.90 45.24
Pointing Mirror LUT
(units= Actuator Counts)
A*cos(el) + B*sin(el) + C + D*cos(CR - F) + E*sin(CR - F) + G*cos(KA) + H*sin(KA) + I*cos(2*KA) + J*sin(2*KA)
A B C D E F G H I J
Tip: -2867.53 -8049.23 -24387.6 -2666.34 904.15 0.00 1565.29 -3585.84 5273.52 5990.83
Tilt: -9285.65 -35293.9 -21365.8 1897.21 2087.32 0.00 1337.22 -436.86 -7711.15 4022.64
(Actuator Counts)
CM Tip
CM Tilt
PM Tip
PM Tilt
Elevation

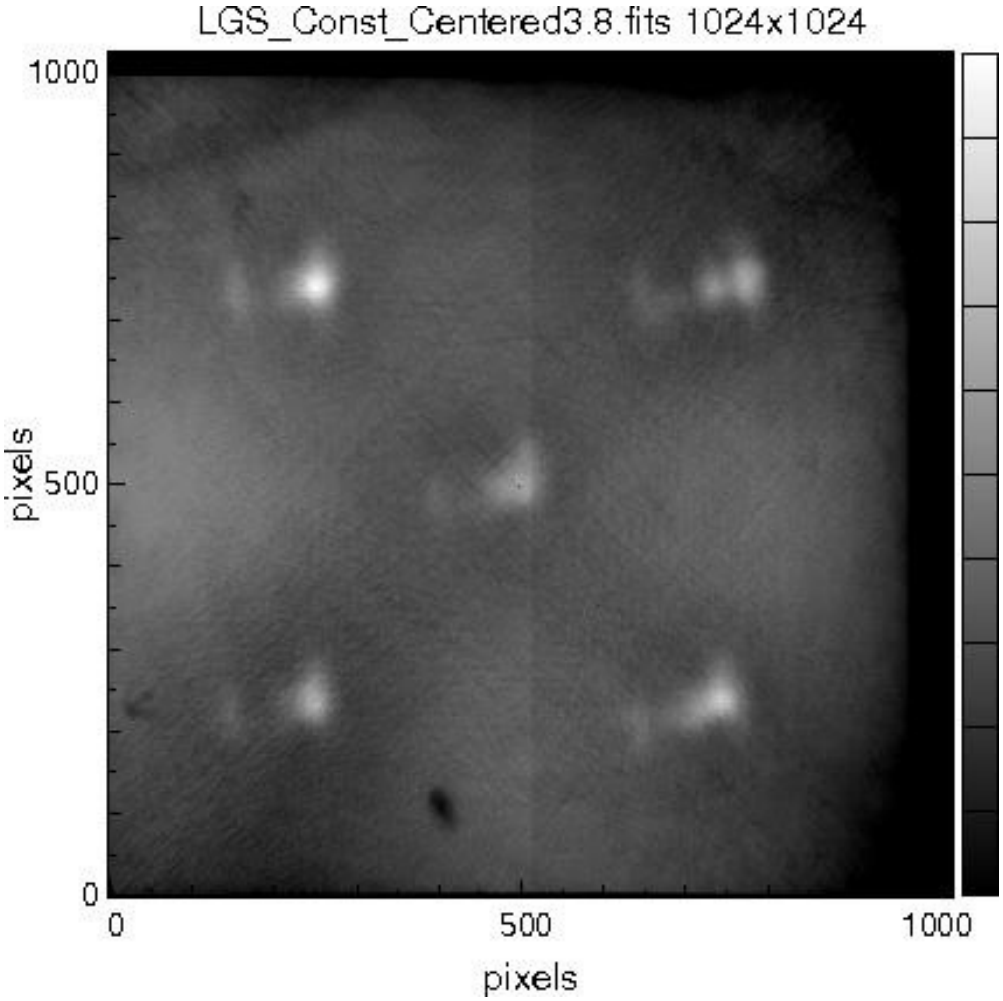
Pointing Accuracy: Results to Date

Alignment technique using fratricide on LGSF WFS mitigates BTO shortcoming caused by inadequate PM/CM LUT vs KM angle

On-sky pointing	Specification	Achieved to date	Comment
Blind pointing accuracy	1” peak	1-60”	Post BTO alignment with all LUTs enabled; issue with PM/CM LUT vs KM angle
Pointing accuracy after repointing using fratricide	N/A	~10% of required move	Constellation is centered on GeMS hot spot in a few iterations
Constellation geometry accuracy	1” peak	1-2”	Differential adjustments for each LGS in constellation
Dynamic pointing	0.05” rms	0.1” rms	FSA loop to be optimized

LGS spot size: Results to Date

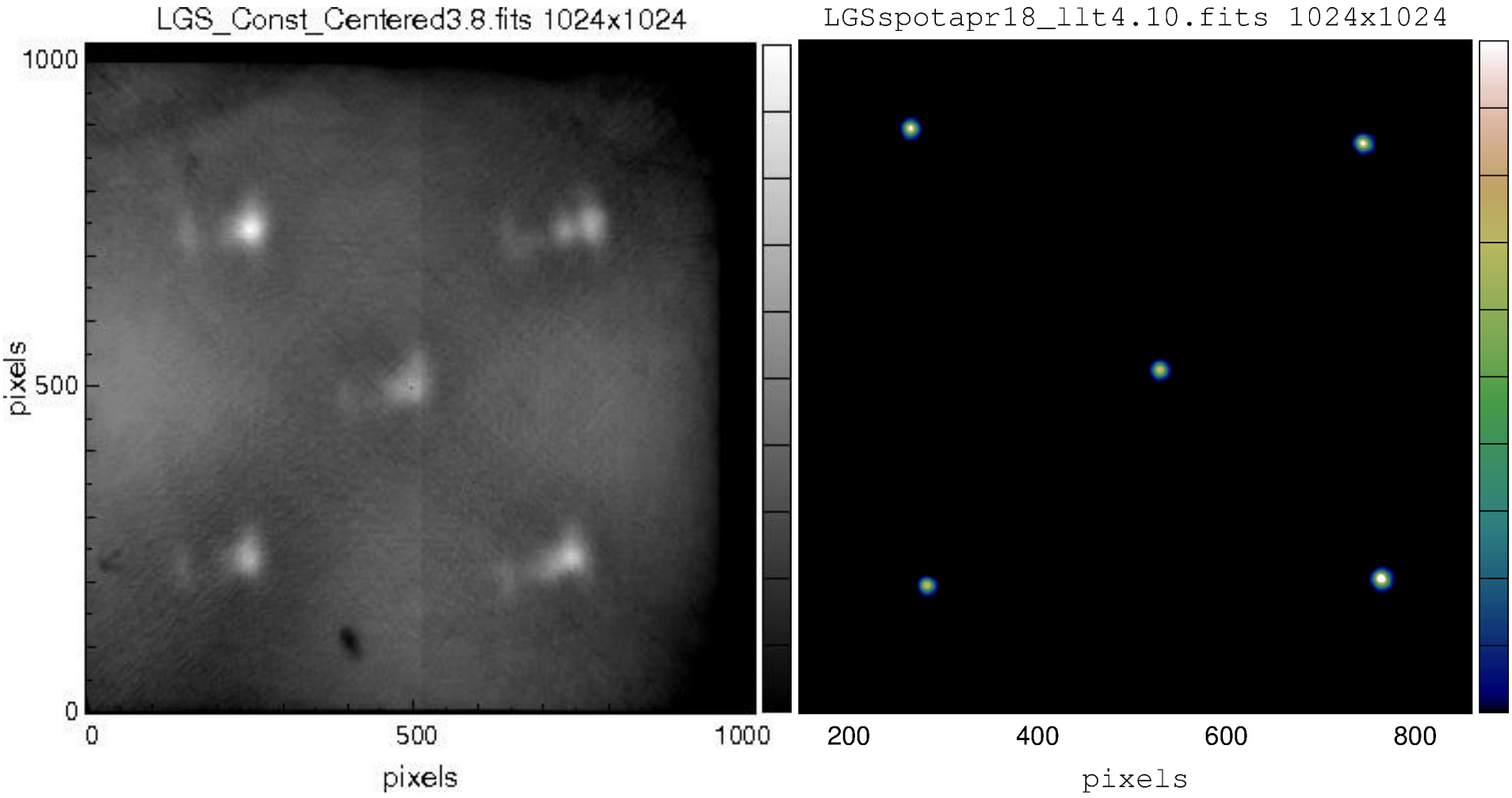
Our first LGS constellation looked more like a constellation of double stars…



FIRST LIGHT: ~7” FWHM

LGS spot size: Results to Date

…but we eventually improved ☺

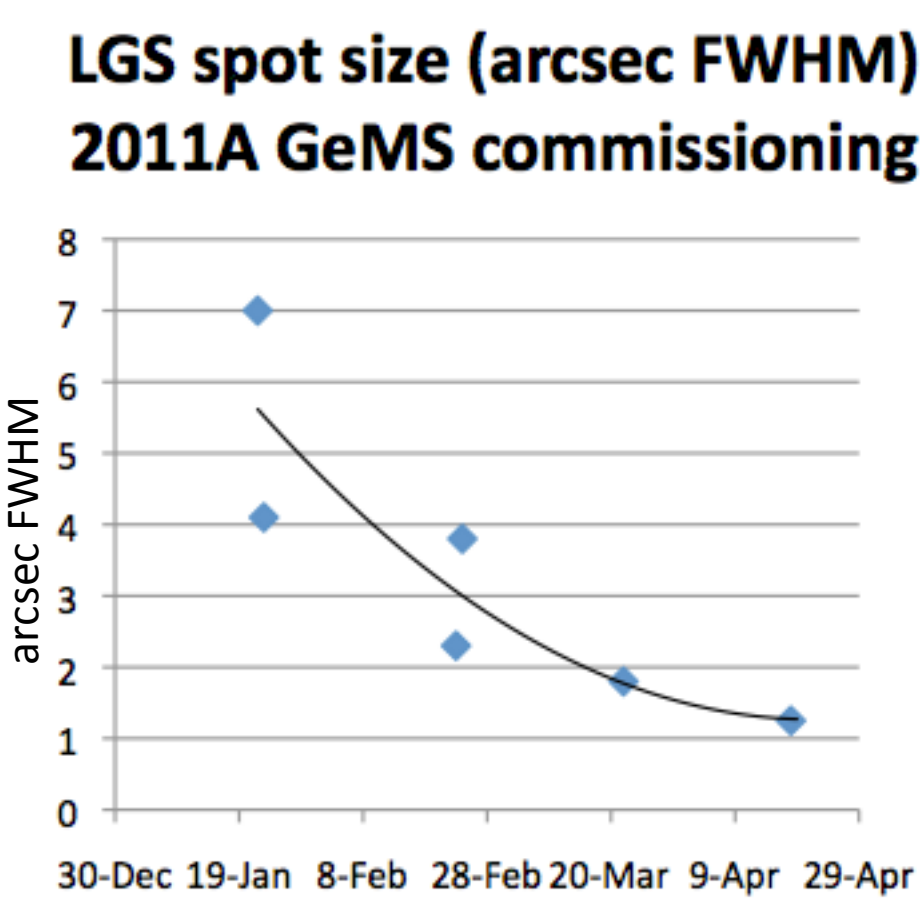


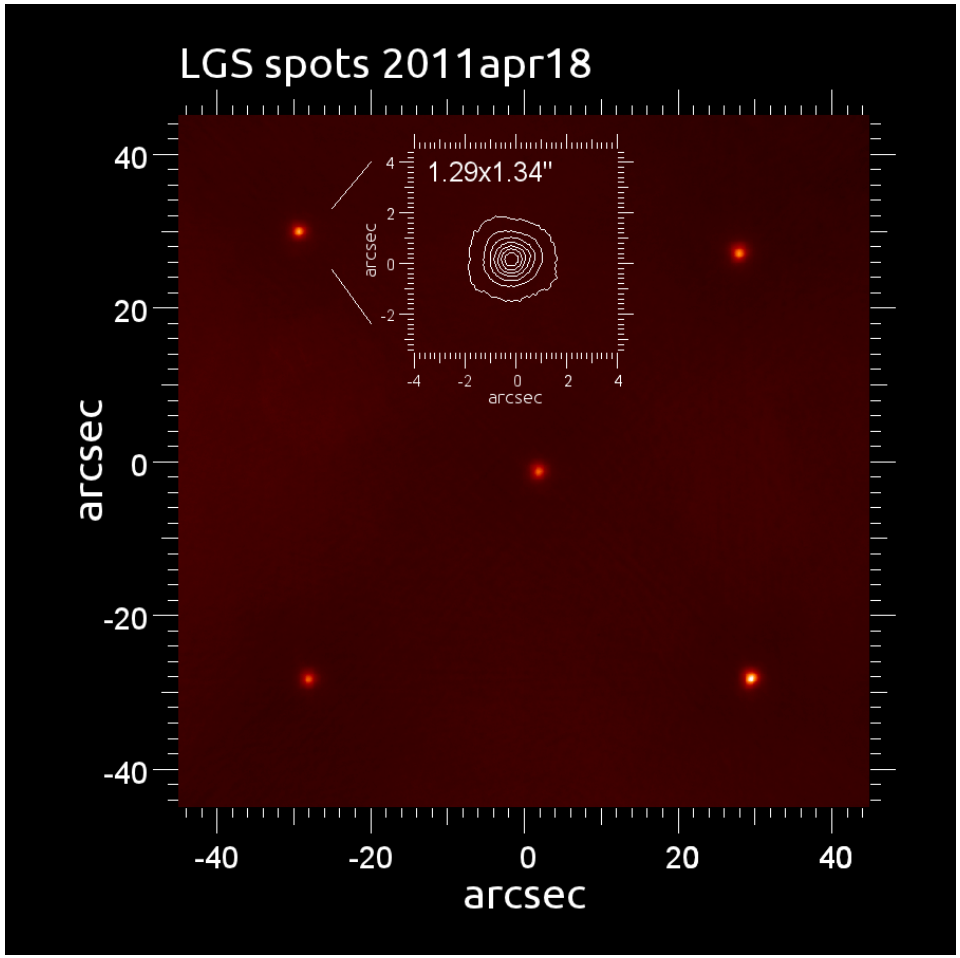
FIRST LIGHT: ~7” FWHM

BEST: 1.25” FWHM

LGS spot size: Results to Date

LGS spot size in good seeing is now of same order of magnitude as typical spot sizes obtained at GN (1.3” FWHM typical on AqCam)

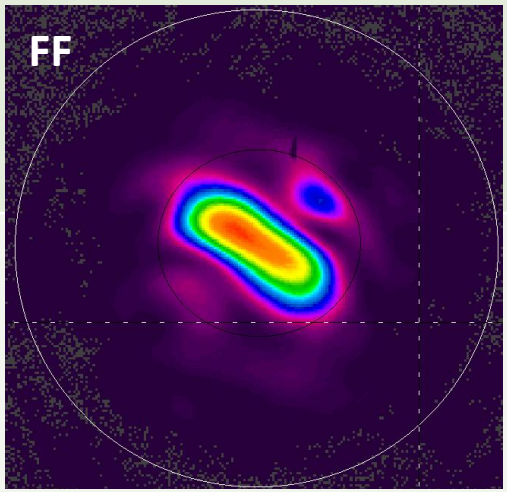




TYPICAL: ~1.3” FWHM

LGS spot size: Results to Date

Laser, BTO and LLT subsystems are currently performing somewhat worse than specified, however laser and BTO can be improved…

	Specification	Achieved to date	Comment
Laser	M^2 <1.4 5mm dia @ $1/e^2$		M^2 <1.4 demonstrated in lab BUT degraded by laser output telescope thermal aberrations
BTO	1:1 relay		Suboptimal laser to LLT pupil conjugation lead to small laser footprint on LLT (~half of 300mm design value @ $1/e^2$)
LLT	Low order WFA: <88 nm rms High order WFA: <35 nm rms over 450mm aperture	WF Aberrations over 450mm diameter aperture: 100-130 nm rms (Yields ~0.6" FWHM with NGS on sky)	Measured in the lab and on-sky with NGS; local defects due to poor M1 support; best results when laser decentered "up"

GS LGSF Commissioning: Results to Date

Must improve photon return and commission polarization control in order to maintain power balance between the 5 LGS at all elevations…

	Specification	Achieved to date	Comment
Photon return @ M1 per LGS at zenith	168-263 ph/cm^2/s	~92 ph/cm^2/s	Best result with ~4W of projected power per LGS (March-April-May 2011)
Photon return balance	+/- 5%	+/- 10%	At zenith only! Polarization control not commissioned yet
Spot size	1.0” FWHM	~1.3” FWHM	LGS imaged on AqCam in 0.7” seeing
Blind pointing accuracy	1” peak	~0.5” peak	Use fratricide-based on-sky alignment technique instead
Dynamic pointing	0.05” rms	0.1” rms	FSA loop to be optimized

GS LGS Facility On-Going Activities

★ PERFORMANCE improvements

★GS laser

- ★ Repair of failed 1319 WAM diode
- ★ Full bench realignment to regain full power (55-65W)
- ★ Replacement of output telescope optics to improve BQ

★ Beam Transfer Optics

- ★ Throughput optimization (replace first offenders)
- ★ LBBS commissioning (closed loop pointing control between TPM and TRA)
- ★ Polarization control I&T (maintain circularly polarized beam at LLT output at all elevations)

★ Laser Launch Telescope

- ★ In-situ wash (increase throughput)

GS LGS Facility On-Going Activities

- ★ OPERATIONAL upgrades
  - ★ GS laser
    - ★ IR wave plate automation and in-line power diagnostics
    - ★ Remote control of IR beam co-alignment in SFG crystal
    - ★ Remote adjustment of output telescope collimation
    - ★ Remote adjustment of output periscope
  - ★ Beam Transfer Optics & Laser Launch Telescope
    - ★ Improve BTO SW+HW reliability
    - ★ Repair damaged components (Epol, BDM, LLT cover)
    - ★ Retrofit FSA design
    - ★ Fine-tune BTO mirror control PIDs
    - ★ LLT focus automation
  - ★ Laser Interlock Systems
    - ★ Implement missing RTC, AOM, LBBS input signals
    - ★ Remove bypasses wherever possible

GS LGS Facility On-Going Activities

- ★ MAINTENANCE activities
  - ★ GS laser
    - ★ LSE and laser bench cleaning
    - ★ Coolant flush
    - ★ Laser technician training
    - ★ Spare procurement
  - ★ Beam Transfer Optics
    - ★ Seal BTO and apply positive pressure (dust protection)
    - ★ Spare procurement
    - ★ Documentation (red-line drawings and write procedures)

GS LGS Facility 2011B Commissioning

GeMS commissioning will resume in 2011B with 4 more laser runs planned in Nov-Dec-Jan-Feb

Post-shutdown GS LGSF commissioning goals are to provide:

★Enhanced performance (higher photon return, smaller LGS spot size)

★ Reliable operations (stable BTO, safe laser propagation, LTCS accuracy confirmed)

★ Efficient laser operations (laser operator training of 1 laser specialist + 2 laser technicians + 1 optical engineer)

GS LGS Facility Lessons learned

For example…

- ★ Project management
  - ★ Difficulties inherent to working observatory
    - ★ Resource conflicts (normal ops support always get priority over development)
    - ★ Telescope access (day time as well as night time)
  - ★ Risks if projects run for too long:
    - ★ Loss of personnel and associated expertise
    - ★ Parts become obsolete or deteriorate before start of operations
  - ★ Large overheads (resources and schedule) caused by export control restrictions and other rules and regulations that must be complied with
    - ★ Laser technology access limitations based on citizenship
    - ★ Close coordination w/ shipping department re: import/export
    - ★ Plan for the unexpected (e.g. earthquake)

GS LGS Facility Lessons learned

For example…

- ★ BTO/LLT/Safety Systems
  - ★ Shorten the BTO as much as possible
  - ★ Spend $$$ on coatings in order not to waste expensive laser photons!
  - ★ Include diagnostics (e.g. alignment cameras) and automate components that are difficult to access (e.g. BTO/LLT focus)
  - ★ Prefer LLT achromatic designs to compare NGS/LGS imaging
  - ★ Carefully specify LLT image quality requirements
  - ★ Carefully and consistently test components → sub-systems → systems
  - ★ Complying with laser safety standards takes time and effort
    - ★ Appoint dedicated Laser Safety Officer early
- ★ Laser procurement
  - ★ Build strong ties with the vendor's technical team during design and fabrication
    - ★ Repeated visits including hands-on participation if possible
  - ★ Better yet: buy a laser that won't require alignment !

Thank you! Any questions?

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Credit: M. Paredes