GeMS 2.0 begins: Results of a successful new laser commissioning and beyond

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SEG2018, San Francisco, CA, USA
Outline

- GeMS instrument
  - Brief presentation & Status
  - Performance achieved with GeMS (2013-2018)

- New laser integration: TOPTICA
  - Performance of the laser
  - Science performance

- Direct comparison Lockheed Martin Coherent Technologies (LMCT) –Toptica lasers
  - Photometry
  - Na return analysis
  - AO analysis

- Conclusions
GeMS Intro.

**GeMS** = Gemini (South) MCAO system

**GeMS** = Facility instrument delivering AO corrections in the NIR, and over a 2arcmin diameter FoV

**GeMS** = Multiple sub-systems.
1 x 50W laser is divided in 5 x 10W beams placed on the corner and center of a 1’ FoV
- 5 (16x16)SHWFS - 3DMs (totaling 917 actuators) - 800Hz
- 3 APDs based NGS TT WFSs - 800Hz - Plate scale modes - Slow Focus Sensor
- 2 dedicated NIR instruments (GSAOI 4k²-80”-20mas, F2 MOS-2”)
- Many 2nd loops, LUT, offloads…
Science instruments

GSAOI
IR Imager 4k
20 mas/px

FLAMINGOS 2
MOS IR
R = 1200-3000
Slit 1-8px

GMOS-S
MOS+IFU vis
R=4440-8800 R=150-1200
Overall performance 2013-18

1 DM missing
LGS loop @ [100-600] Hz
800 Hz max
NGS up to mag = 15.5

But still
a lot of science can be done!
128 science nights
Performance on science

Eng. Target NGC 1851
GeMS/GSAOI
December 2014
K-short
10s exp.
3 NGS
Loop @ 300Hz

70 mas
73 mas
74 mas
72 mas
Overall performance 2013-18

1 DM missing
LGS loop @ [100-600] Hz
800 Hz max
NGS up to mag = 15.5

Working point
SR = [15-20]%
FWHM = [75-85]mas

But still a lot of science can be done!
128 science nights
Ex. of science: Westerlund 1

5' squared FoV
85” squared
GSAOI FoV

Andersen et al, 2017
Ex. of science: Westerlund 1

HST
H-band
150mas
2094s

GeMS-GSAOI
Ks-band
85mas
900s

Courtesy G. Lawrence & M. Andersen
LMCT status

- Operating at GS from 2011
- Demanding in terms of FTE hours (40-80 hrs before each laser run + several maintenance a year (~3) )
- Services required:
  - Coolant: 4.7 gl/min (~18 l/min)
  - Compressed air: 66 psi
  - Power consumption: 8 KW
- Sensitive to misalignment and aging issues
Main requirements:

- Photon return ≥ $5 \times 10^6$ photons m$^{-2}$
- Central wavelength: 589.159nm with repumping option (589.157nm)
- Stability better than 100 MHz over 14 hours (if pure D2a CW)
- Beam quality: M2 < 1.4
- Demonstrated robustness (long term operations without power drops)
- Operational at 2700m in altitude
- Total mass shall not exceed 1000kg

After the revision and selection process, the Toptica SodiumStar 20/2 laser was selected.
Toptica output power/$\lambda$ stability
Toptica on-sky

Courtesy A. Lopez
Optimization on-sky: wavelength scan

- Scan seed laser wavelength (before doubling) ➔ find best value for D2a line peak
Optimization on-sky: Bpol scan

Scan of polarization angle optimum by rotating Bpol ➔ 4 peaks
AO performance using Toptica laser

But still a lot of science can be done!
12 science nights
AO performance using Toptica laser

But still a lot of science can be done! 12 science nights
Performance on science

85mas

89mas

91mas

The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
K-short
30s exp.
3 NGS
Seeing: 0.7”
Performance on science

The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
K-short
30s exp.
3 NGS
Seeing: 0.7"

75mas
78mas
78mas
79mas
78mas
Performance on science

The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
J
30s exp.
3 NGS
Seeing: 0.7"

131mas
136mas
135mas
140mas
Performance on science

The GeMS/GSAOI Galactic Globular Cluster Survey (G4CS)

ID: GS-2017B-Q-25
PI: T. Puzia (PUC)
J 30s exp.
3 NGS
Seeing: 0.7"

96mas
120mas
101mas
110mas
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5 images stacked and Rayleigh subtracted

Smaller spot on sky!
For both lasers, AcqCam images were recorded at:

- $AZ = [0, 90, 180, 270]$
- $EL = [90, 80, 70, 60, 50]$
Back to laser requirements

Main requirements:

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- Central wavelength: 589.159nm with repumping option (589.157nm)
- Stability better than 100 MHz over 14 hours (if pure D2a CW)
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- Demonstrated robustness (long term operations without power drops)
- Operational at 2700m in altitude
- Total mass shall not exceed 1000kg
AO performance using Toptica laser

**Centroid gains comparison (centroid to arcsec conversion)**
- Cent gains Toptica < cent gains LMCT (~15%) ➔ Toptica spot ~15% smaller in the quadcell
- Noise ∼ FWHM/sqrt(N) ➔ 15% smaller spot ➔ noise measurement decrease by 30%
AO performance using Toptica laser

- Centroid gains comparison (centroid to arcsec conversion)
  - Cent gains Toptica < cent gains LMCT (~15%) ➔ Toptica spot ~15% smaller in the quadcell

- Structure of centroid gains

Toptica cent gains more structures thanks to smaller spots

Cent gains

Toptica

LMCT

X Y
GeMS roadmap

GeMS is in “regular” operation since 2013

- Performance under specs but still very good and unique
- Provide good science, more and more papers being published

GeMS 2.0 has started

- New laser is commissioned
  - Improved reliability, stability and performance
  - Unique comparison has been done with older technology
- NGS2 on its way
  - Commissioning 2019?
- New DM0 is built
  - Electronics is almost ready
  - FAT sometime in 2018
GeMS roadmap 2

- New RTC considered
  - Looking at options
  - Preparing requirements → Facility RTC, non-black box

- Reduction number of person to operate GeMS at night
  - From at least 4 → at most 3
  - BTO upgrade feasibility study started
    - Looking at possible upgrades
    - Increase FSA range
    - Motorize XSA
    - Polarization control?

GeMS to GN?
The end

Thank you

© Eduardo Marín
LGS WFS

5 16x16 SHWFS

- 204 subapertures
- 2x2 pix / subap
- 1.38”/pix
- Up to 800Hz (depending on Na return)
- Constellation (0,0) and (±30, ±30)
LGS WFS (RTD)
LGS WFS centroid gains

Centroid gains calibrations:

- Provides a response of the quadcell to a spot position
- Spot size changes with seeing, Na characteristics

Error on centroid gains produce

- Wrong loop gain in closed loop
- Wrong NCPA
- Differential aberration between all WFSs
- Wrong tomography

Need to calibrate centroid gains online
Quad-cells transfer function & centroid gain

=> Centroid gains need to be calibrated on-line

Method: Apply a “sine wave” on the DM at a given frequency and do a lock-in detection.

- Pattern of small amplitude and known shape ➔ Filtered through reconstruction
- Pattern is enough to create a synchronous detection and give an estimate of spot size
- Pattern small enough to be unseen on science image
- Slow update of centroid gain
- Insensitive to vibrations
- Not (really) seen by the WFSs, so not corrected
- Small amplitude required (20nm rms)
- Would create satellite spot on the images, but lost in noise.
LGS WFS centroid gains

Initialization
- Open RTD
- Loops opened
- CCD dark default file loaded
- TTM centered

Close loop

Freeze loop

Set
- step size
- number of points

TTM zero-point registration

X direction:
1. Move TTM to lower tip and zero-point fit
2. Setting slopes step by step

Fit of transfer functions on recorded data

Same in y

TTM zero-point