INO
CHALLENGING LIGHT FOR OUR PARTNERS

Design of the Calibration Unit for the MOAO Demonstrator RAVEN

Jean-François Lavigne[1], Frédéric Lamontagne[1], Min Wang[1], Mathieu Tremblay[1], Olivier Lardière[2], David Anderson[3], Reston Nash[2], Patrice Côté[1], Geneviève Anctil[1], Colin Bradley[2], François Châteauneuf[1]

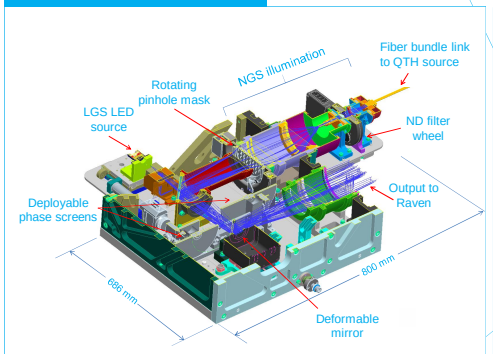
[1] INO, 2740 Einstein Street, Quebec City, Quebec, G1P 4S4, Canada
[2] Adaptive optics Laboratory, Mechanical Engineering Department, University of Victoria, BC, Canada
[3] Herzberg Institute of Astrophysics, NRC-CNRC, Victoria, BC, Canada

ABSTRACT

The UVic AO Lab in collaboration with HIA and the Subaru telescope is currently designing Raven, a multi-object adaptive optics (MOAO) demonstrator that will be coupled to the Subaru Infrared Camera and Spectrograph (IRCS). Its main goal will be to demonstrate MOAO feasibility on the sky while allowing astronomers to beneficiate from the increased observing efficiency associated with such systems.

INO is responsible for the Raven calibration unit design and fabrication. This sub-system consists in a telescope simulator that will allow aligning Raven's components during its integration, testing its AO performances in the laboratory and at the telescope, and calibrating the AO system by building the interaction matrix and measuring the non-common path aberrations (NCPA). This sub-system is described in this poster.

SYSTEM OVERVIEW



SOURCES REQUIREMENTS

NGS parameters	
Source grid	Square grid with 9 x 9 sources (step of ~10.7 mm)
Rotation speed	Up to 10'/s to simulate sky rotation
Waveband	0.6 – 1.8 µm Goal: 0.6 to 2.5 µm
Source width	Possibility to select diffraction limited (in the IR) or seeing limited (0.6 arcsec) sources
Star magnitude	< 10 to 16
LGS parameters	
Wavelength	589 nm
Source width	1 arcsec
Altitude conjugation	85 to 180 km
Star magnitude	6 to 11

EXPECTED OPTICAL PERFORMANCES

Parameter	Requirement	Nominal value	With tolerances
NGS focal plane diameter in the Raven focal plane	64 mm Goal of 112 mm	Up to 86 mm	No significant change with tolerances
Focal plane curvature	< 2.3 m	< 2.3 m up to λ = 1.8 µm	No significant change with tolerances
Coma	< 1.3 µm	< 0.01 µm	No significant change with tolerances
Working F/#	13.6 +/- 0.3%	13.58 @ 1.1 µm	No significant change with tolerances
Rays position variation at exit pupil edge over full waveband at all FoV	1% Goal < 0.6%	1.1%	90% confidence: 1.2% 50% confidence: 1.1%
Edge Fov relative illumination vs the center FoV	> 50%	80% at radii of 35 mm	No significant change with tolerances
Image quality < 1µm	RMS spot size < 100 µm	< 45 µm	No significant change with tolerances
Image quality > 1 µm	Diffraction limited (Strehl > 0.8)	Strehl > 0.90 for FoV < 64 mm	90% confidence: Strehl > 0.8 for FoV < 64 mm
Lateral color between 0.6 < λ < 0.9 µm	≤ 100 µm for Fov < 64 mm	~2 µm for FoV < 64 mm ~40 µm for FoV < 78 mm	No significant change with tolerances
Lateral color between 0.9 < λ < 1.8 µm	≤ 20 µm for FoV < 64 mm	Max of ~ 15 µm	No significant change with tolerances
Axial color	< 580 µm	λ < 1.8 µm: 186 µm	90% confidence: 220 µm 50% confidence: 160 µm
		λ < 2.5 µm: 581 µm	90% confidence: 637 µm 50% confidence: 550 µm

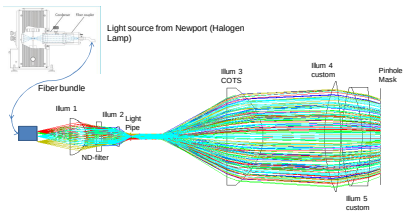
INTRODUCTION

- Raven:
  - 3 natural guide stars (NGS),1 laser guide star (LGS) and 2 science fields,
  - NGS wavefront sensing in R-band,
  - IRCS used science waveband: 0.9 to 2.5 µm.
- Raven CU:
  - Provides 9x9 NGS over a 2.7' FOV,
  - Provides an on-axis LGS,
    - Altitude conjugation: from 85 to 180 km,
  - Provides a bright on-axis alignment source,
  - 2 deployable phase screens:
    - Conjugated to 5 km and 10 km,
  - DM conjugated to ground level,
  - Remotely selectable NGS pinhole sizes:
    - Diffraction limited and seeing limited (0.6"),
  - Rotating NGS pinhole mask to simulate sky rotation,
  - Adjustable sources brightness,
  - Status: In fabrication,
  - Expected delivery: January 2012.

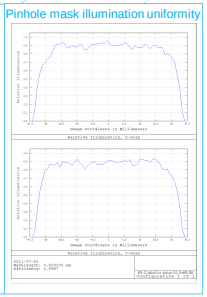
METHODOLOGY

- Optical tolerances to meet requirements
  - Generation of 100 statistical Monte Carlo realizations including positioning and manufacturing errors on optical elements using Zemax
  - Expected parameters value with a 50% and 90% confidence are evaluated from the MC files
- Mechanical tolerances to meet optical tolerances
  - Lenses are aligned within tolerances using INO's Trioptic centering machine
  - Groups are aligned within tolerances by manufacturing tolerances (see INO mechanical tolerance model)
  - Finite element analysis to include deflections
- Adjustments: available on DM, on fiber bundle and on light pipe

NGS ILLUMINATION



Pinhole mask illumination uniformity



OPTICAL RELAY

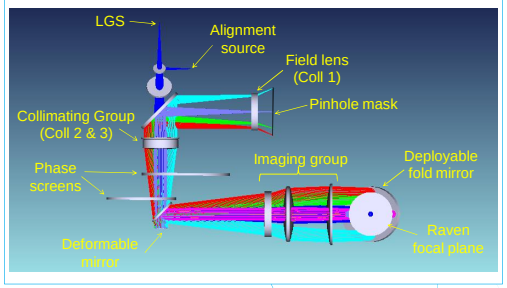
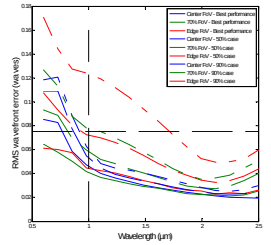


IMAGE QUALITY



Expected wavefront error at different FoV at different confidence levels. Edge FoV is at 1.35' (43 mm) from the center.

INO MECHANICAL TOLERANCE MODEL

- Goal:
  - Eliminate unnecessary adjustments to reduce risks and costs while achieving required positioning precision
- Methodology:
  - Replace linear and RSS sums of mechanical tolerances with Monte Carlo statistical model based on real statistical data
  - Update Zemax Monte Carlo model with realistic mechanical statistical values
  - Iteratively adjust tolerances to achieve optimal optical performances vs cost

TOLERANCES

Illumination Positioning Tolerances Requirements

		Thickness (mm)	Decenter (mm)	Tilt (°)
	FB	0.2	ADJ	ADJ
Group 1	Illum 1	0.5	0.2	0.2
	filtre ND	0.5	-	0.3
	Illum 2	0.2	0.2	0.2
	Light pipe	ADJ	ADJ	0.3
Group 2	Illum 3	0.3	0.2	0.1
	Illum 4	0.25	0.2	0.2
	Illum 5	0.5	0.2	0.1

Illumination Expected Positions Variations

		Thickness (mm)	Decenter (mm)	Tilt (°)
	FB	ADJ	ADJ	ADJ
Group 1	Illum 1	0.5	0.1	0.1
	filtre ND	0.5	-	0.25
	Illum 2	ADJ	0.1	0.1
	Light pipe	ADJ	ADJ	0.15
Group 2	Illum 3	0.15	0.1	0.1
	Illum 4	0.1	0.1	0.1
	Illum 5	0.25	0.1	0.1

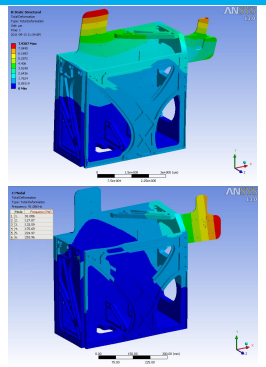
Optical Relay Positioning Tolerances Requirements

		Thickness (mm)	Decenter (mm)	Tilt (°)
	PH mask	0.05	1	0.2
Group 1	Coll 1	0.05	0.05	0.1
	M1	0.25	0.05	0.015
	Coll 2	0.075	0.015	0.03
	Coll 3	1	0.015	0.03
	PS 11 km	1	-	1
	PS 5 km	0.25	-	1
	BS	DM: 0.05 Ima1: 0.05	0.03	0.01
	DM	-	0.05	0.01
Group 2	Ima1	0.03	0.015	0.02
	Ima2	0.25	0.015	0.03
	Ima3	0.25	0.05	0.2
	M3	comp		
Group 1	Coll 1, 2 & 3	-	0.05	0.02
Group 1A	Coll 2 & 3	-	0.025	0.05
Group 2	Ima 1, 2 & 3	-	0.05	0.02

Optical Relay Expected Positions Variations

		Thickness (mm)	Decenter (mm)	Tilt (°)
	PH mask	0.05	0.5	0.15
Group 1	Coll 1	0.050	0.039	0.037
	M1	0.035	0.027	0.015
	Coll 2	0.025	0.015	0.015
	Coll 3	1.000	0.015	0.015
	PS 11 km	1.000	-	1.000
	PS 5 km	0.032	-	1.000
	BS	ADJ 0.045	0.013	0.010
	DM	-	ADJ	ADJ
Group 2	Ima1	0.015	0.010	0.010
	Ima2	0.015	0.012	0.009
	Ima3	ADJ	0.027	0.009
	M3	comp		
Group 1	Coll 1, 2 & 3	-	0.03	0.018
Group 1A	Coll 2 & 3	-	0.023	0.025
Group 2	Ima 1, 2 & 3	-	0.034	0.019

FINITE ELEMENT ANALYSIS



CHALLENGES

- System with many optical interfaces with focal and pupil plane requirements.
- Control NGS chromaticity over a broadband (0.6 to 2.5 µm) in the focal and the exit pupil plane.
- Fast track project: 7 months from PO to delivery time.

SUMMARY

- All requirements are expected to be met when considering manufacturing and alignment tolerances.
- Small number of adjustments necessary.
- Expected delivery: January 2012

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