Wavefront sensing with PHASONG: The Phase Gradient Analyzer

François Hénault[1], Yan Feng[2], Jean-Jacques Correia[1], Alain Spang[3], Laura Schreiber[4]
[1] Institut de Planétologie et d'Astrophysique de Grenoble, Université Grenoble-Alpes, CNRS, B.P. 53, 38041 Grenoble – France
[2] Laboratory of Biology, Engineering and Imaging for Ophthalmology (BiiO), Faculty of Medicine, Jean Monnet University, Saint-Etienne – France
[3] Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS, Laboratoire Lagrange – France
[4] INAF - Osservatorio di Astrosica e Scienza dello Spazio di Bologna, Via Gobetti 93/3, 40129 Bologna – Italy

Summary

- PHASONG (PHase Analyseur de Surface d'Onde de Nouvelle Génération in French) is a next generation wavefront sensor made of an optical measurement head and a computing unit (Fig. 1)
- The measurement head records simultaneous images of the pupil of the tested optics, originating from four off-axis point sources
- The four beams cross a Gradient phase filter (Fig. 2) at different points F_i ($1 \leq i \leq 4$), generating intensity variations inside the pupil images
- The wavefront error (WFE) slopes are determined digitally from the images, and then the wavefront itself from its slopes
- The optical design of the measurement head is firstly described with a thin lens, first-order model, then simulated using the Zemax software in order to optimize it and evaluate performance. is made of a conventional 2 x 2 lenslet array combined with a telecentric lens L2

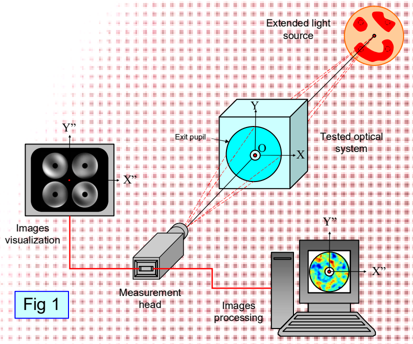


Fig 1

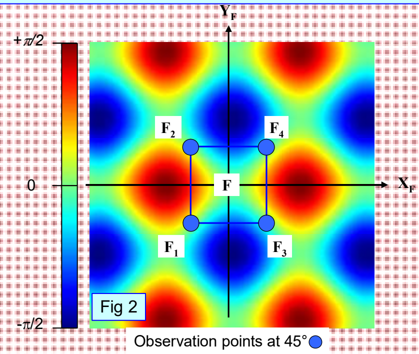
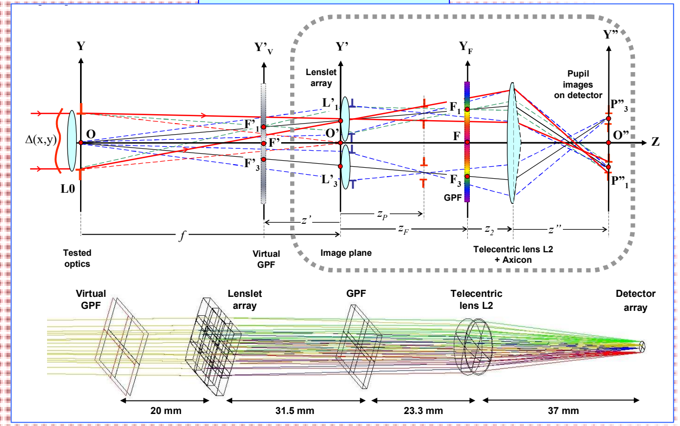


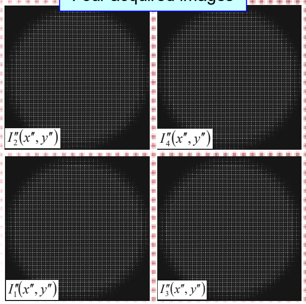
Fig 2

Observation points at 45°

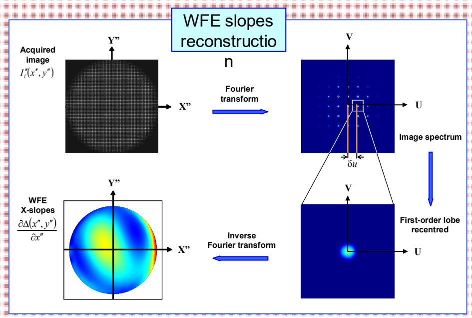
Thin lens and Zemax models



Four acquired images

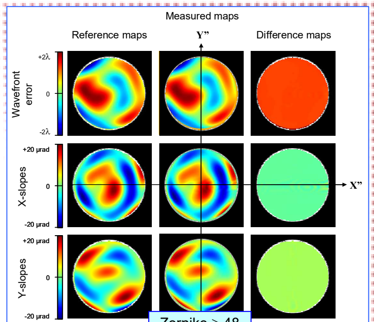


WFE slopes reconstruction



Numerical simulations / Data processing

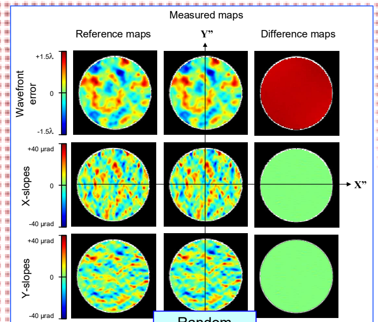
- The four acquired pupil images $I''_i(x'',y'')$ with $1 \leq i \leq 4$ are simulated using a complex amplitude propagation model of Fresnel diffraction
- The wavefront slopes $\partial\Delta(x,y)/\partial x$ and $\partial\Delta(x,y)/\partial y$ are reconstructed using a double FFT algorithm:
  - ✓ Take the Fourier transform of each pupil image,
  - ✓ Re-centre their first satellite peaks onto the origin,
  - ✓ Take the inverse Fourier transforms of the results and extract their phases,
  - ✓ Combine the four phase functions together and convert them into X and Y slope errors.
- Finally reconstruct the WFE $\Delta(x,y)$ from its slopes using a Roddier & Roddier algorithm.



Zernike ≥ 48

Error type	Reference	Measured	Difference	Relative Difference (%)	
X-slopes (mrad)	0,0330	0,0333	0,0048	15	PV
	0,0076	0,0076	0,0002	3	RMS
Y-slopes (mrad)	0,0457	0,0454	0,0022	5	PV
	0,0086	0,0086	0,0001	1	RMS
Wavefront Error (waves)	3,991	3,990	0,074	2	PV
	0,844	0,844	0,005	1	RMS

Error type	Reference	Measured	Difference	Relative Difference (%)	
X-slopes (mrad)	0,0737	0,0733	0,0057	8	PV
	0,0101	0,0101	0,0004	4	RMS
Y-slopes (mrad)	0,0827	0,0807	0,0078	9	PV
	0,0103	0,0103	0,0004	4	RMS
Wavefront Error (waves)	2,645	2,647	0,080	3	PV
	0,412	0,412	0,010	2	RMS



Random

Conclusion

- PHASONG simultaneously achieves high measurement accuracy comparable to those of laser-interferometers, (> λ/100 RMS typically) with high spatial resolution at the surface of the tested optical system (≥ 1000 x 1000 pixels)
- It can be operated on spatially or spectrally extended light sources, either of the natural or artificial types
- It comes out under the form of a small and compact measurement head insensitive to environment disturbance

Contact: henaultfbm@gmail.com

IPAG Institut de Planétologie et d'Astrophysique de Grenoble · Université Grenoble Alpes · CNRS · Observatoire de la Côte d'Azur · INAF Istituto Nazionale di Astrofisica · Université Jean Monnet Saint-Étienne · Faculté de Médecine Jacques Lisfranc Saint-Étienne · biio biology, engineering and imaging for ophthalmology