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Wavefront Sensing and Control Work Package

Alessio Rocchi - INFN Roma Tor Vergata
WP Co-chair (with Martin von Beuzekom)

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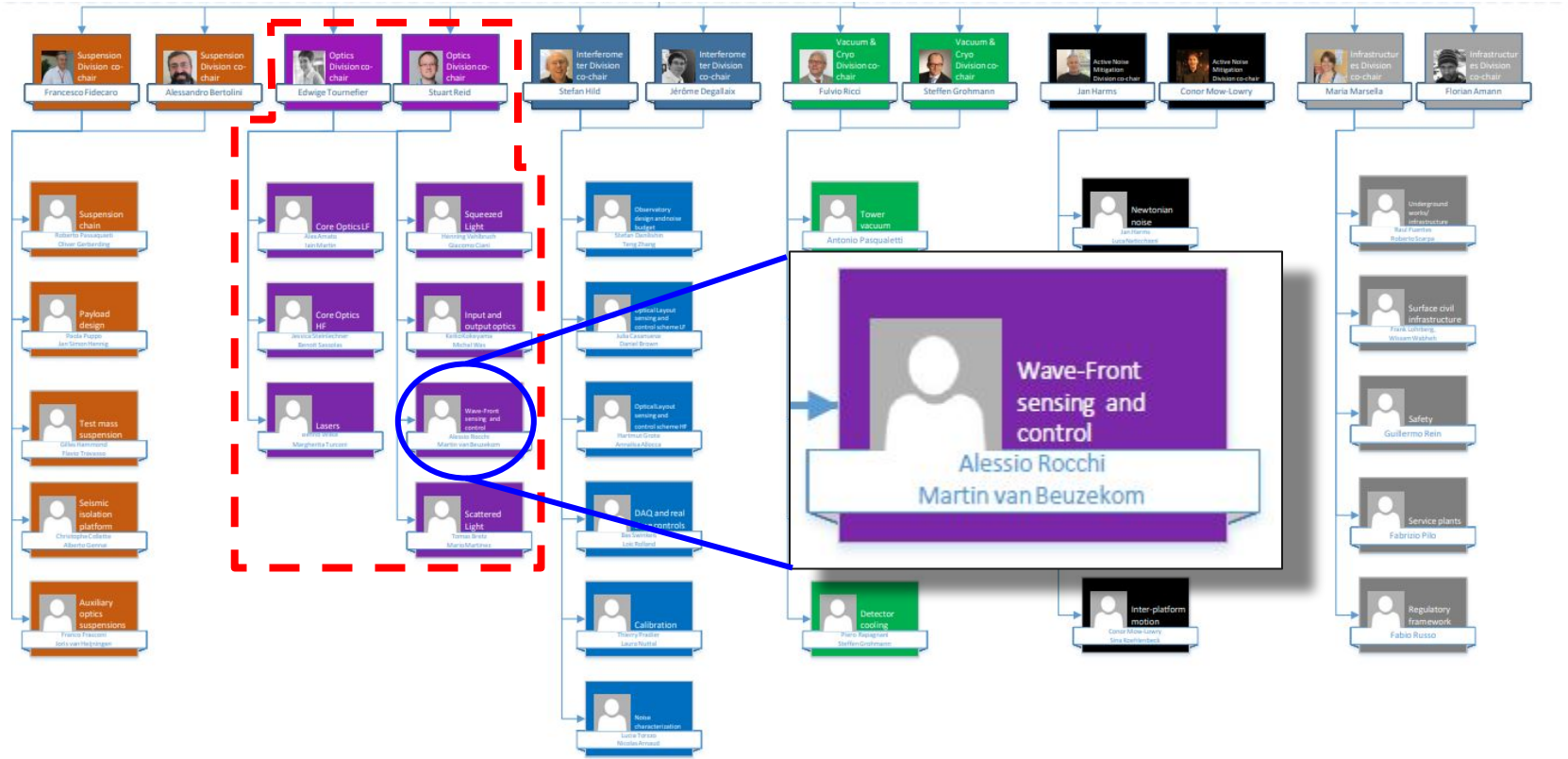
WP in the Optics Division of the ET-ISB



Scope of the Work Package

The WP deals with the correction and optimization of the wavefronts in the whole interferometer: all activities concerning wavefront sensing and correction in general at all locations where this is possible have been included.

There are many kind of distortions and several parts of the ITF are involved, here is an (in-)complete list:

- **mirror surface figure error** (reflected WFE): core optics and recycling cavities optics, filter cavity optics, IMC optics, both on ET-HF and ET-LF;
- **substrate refractive index non-homogeneities** (transmitted WFE): ITMs, BS and CPs (if any), both on ET-HF and ET-LF;
- **distortions due to optics self heating**, only in ET-HF:
  - thermal lensing: ITMs, BS and CPs - input Faraday isolator;
  - thermoelastic deformation of HR surface: core optics and recycling cavities optics, IMC optics;
- **mode-matching distortions**: from input optics to arm cavities; from output optics to OMC; from squeezing source to filter cavity/ITF. Both on ET-HF and ET-LF;
- **wavefront errors due to optics mis-alignment**;

Interfaces with other WPs and Divisions

Optics Division:

- **Core Optics LF/HF**: HR/AR coating absorption, mirror surface figure error (reflected WFE), substrate refractive index non-homogeneities (transmitted WFE); point absorbers (?) → Information to build up the “Aberration Budget”.
- **Input and output optics**: requirements on mode-matching distortions from input optics to arm cavities and from arm cavities to OMC; requirements for Phase cameras.
- **Squeezed light**: mode-matching distortions from squeezing source to filter cavity/ITF.
- **Stray light control**: procedures and practices for baffling in-vacuum/in-air optics, coatings on viewports/optics.

Interferometer Division:

- **Optical layout, sensing and control scheme LF/HF**: requirements on minimum recycling cavities gain for control sidebands and carrier and on RoC accuracy (recycling and arm cavities, IMC) after compensation. Specifications on wavefront sensing for quadrant photodiodes used for alignment; requirements for Phase cameras.

Infrastructure

- Position of the optical benches and isolation from environment

Tasks within the scope of the WS&C Work Package 1/2

The scope of this activity is to define the optimal corrective strategy **for each aberration and each location of the detector**, based on the development of both sensing and actuation devices and schemes. Furthermore, the **development of optical simulations** to derive error signals for aberration control and to predict the behavior of the detector, evaluating figure of merits to assess the efficiency of the control, must be included within the scopes of this activity

- **Simulations**: build optical simulations to translate locking requirements into requirements on aberration budget and guide design of actuators; optical simulations to derive error signals for aberration control;
- **Sensing**:
  - **Phase cameras**: definition of requirements and development of new devices;
  - **Hartmann Wavefront Sensors**: optical schemes and requirements for the device;
  - **Quadrant photodiodes**: definition of requirements and production;
  - **Mode Converter telescope**: definition of requirements and development of the device;
  - **Electro-optical lens**: definition of requirements and development of the device.

Tasks within the scope of the WS&C Work Package 2/2

- **Actuation**:
  - **Ring heaters**: definition of requirements and design of the device;
  - **Corrective pattern projectors**: definition of requirements and of the laser beam shaping technique; investigate possibility to use heaters arrays;
  - **Deformable mirrors (Thermo-mechanical actuator/MEMS based devices)**: definition of requirements and development of the device;
  - **Heaters arrays**: useful to correct residual aberrations; definition of needs and requirements and development of the device;

Radiative cooling: option cannot be neglected, given the cryogenic environment.

WP Organization

- All info available in the ET Wiki:

  https://wiki.et-gw.eu/ISB/Optics/Wavefrontsensingandcontrols/WebHome

- Semi-regular monthly meetings (second Monday of the month, at 9:30 CET/CEST);
- Announcements on dedicated mailing list:
  - Link for subscription: https://mail.ego-gw.it/mailman/listinfo/et-isb-opt-wsc
- Main task: delivery of TDR.

Main activity so far: ET Project PBS

Subsystem:					
Project Name					
Level	**PBS code**	**Level 3**	**Level 4**	**Level 5**	**Level 6**
4	1.1.2.5		Wavefront sensing and control		
5	1.1.2.5.1			Hartmann Wave-front sensing	
6	1.1.2.5.1.1				Hartmann sensors
6	1.1.2.5.1.2				On-axis imaging telescopes
6	1.1.2.5.1.3				Off-axis imaging telescopes
6	1.1.2.5.1.4				Frames acquisition system
5	1.1.2.5.2			Auto-Alignment quadrant photodiodes	
6	1.1.2.5.2.1				Diodes
6	1.1.2.5.2.2				Electronics
6	1.1.2.5.2.3				Vacuum-tight airboxes
5	1.1.2.5.3			Phase Cameras	
6	1.1.2.5.3.1				Imaging telescope
6	1.1.2.5.3.2				Reference beam (frequency shifted)
6	1.1.2.5.3.3				Photodetector(s)

Persons/groups that have contributed so far

Group name	contact	expertise
Nikhef	Martin van Beuzekom	Wavefront Sensing (Phase Camera/Quadrant Photodiodes)
Adelaide University	Peter Veitch/Daniel Brown	Wavefront Sensing (Hartmann and Phase Camera) and mode matching control (Deformable Mirror)
University of Western Australia	Aaron Jones	Wavefront Sensing and Control
Cagliari University/INFN	Andrea Contu	Wavefront Sensing (Phase Camera)
Tor Vergata University/INFN	Alessio Rocchi et al.	Wavefront Sensing and Control
Padova University/INFN	Giacomo Ciani	Mode matching sensing and control
Fraunhofer IPT	Andreas Ulm	Wavefront Sensing (Hartmann)
GEO600	Severin Nadji	Wavefront Sensing and Control
Trento University/INFN	Antonio Perreca	Mode matching sensing and control (Deformable Mirror)
UC Louvain	Ricardo Cabrita	Wavefront Sensing (Phase Camera)
Finesse Simulation Group	Andreas Freise	ITF simulations

Known ongoing R&Ds (in/out ETIC)

Group name	Funding	Main topic
Nikhef	N/A	Phase Camera/Quadrant Photodiodes
Adelaide University	N/A	Hartmann sensors, Phase Camera and Deformable Mirror
Cagliari University/INFN	INFN - CSN2	Phase Camera
Tor Vergata University/INFN	AiLoV-ET (ETIC)	Wavefront Sensing and Control
Padova University/INFN	INFN - CSN2	Mode matching sensing and control
Fraunhofer IPT	N/A	Hartmann sensors
Trento University/INFN	INFN - CSN2	Mode matching sensing and control
UC Louvain	N/A	Phase Camera