OPTICON WP4

OPTICAL-IR Interferometry

Project Status and Forward Plan

D. Mourard OCA-F

Main axes of WP4

- **Enhancing the scientific output of interferometry**
  - 4.1.1: Evaluation of Paranal atmospheric parameters. *(ESO-F)*
  - 4.1.2: MIDI and AMBER with PRIMA *(ESO-F-P-NL-D)*
  - 4.1.3: VLTI for the 2nd generation instruments *(D-F-ESO)*

- **Reaching the fundamental limits**
  - Contribution to the development of an optimum cophaser for the VLTI
  - 4.2.1: Analysis of FINITO and PRIMA commissioning data *(ESO-F)*
  - *Other points have been cut during the negotiation process*
    - *Development of fringe detection and tracking algorithms*
    - *Integration and testing of the new cophaser for the VLTI*

- **WP4 budget: 425k€ (1M€ expected at the time of deposit)**

Progress report - Summary

- WP4.1.1:
  - Position started on jan. 1st 2011 (P. Schuller)
  - “Atmospheric properties for optical interferometry”: Observatoire de Paris and ESO
  - Review of literature and work on FINITO+AMBER data

- WP4.1.2:
  - MPIA + ESO (Andre Mueller) for MIDI+PRIMA
  - FAUp (Nuno Gomes) on astrometry and phase reference imaging
  - ESO + New position (B. Jursten): PRIMA + AMBER, PRIMA

- WP4.1.3:
  - Delayed at that time

- WP4.2.1
  - FINITO and PRIMA commissioning data analysis (ESO+CNRS)

Progress meeting on may 24th, 2011 (Paris)

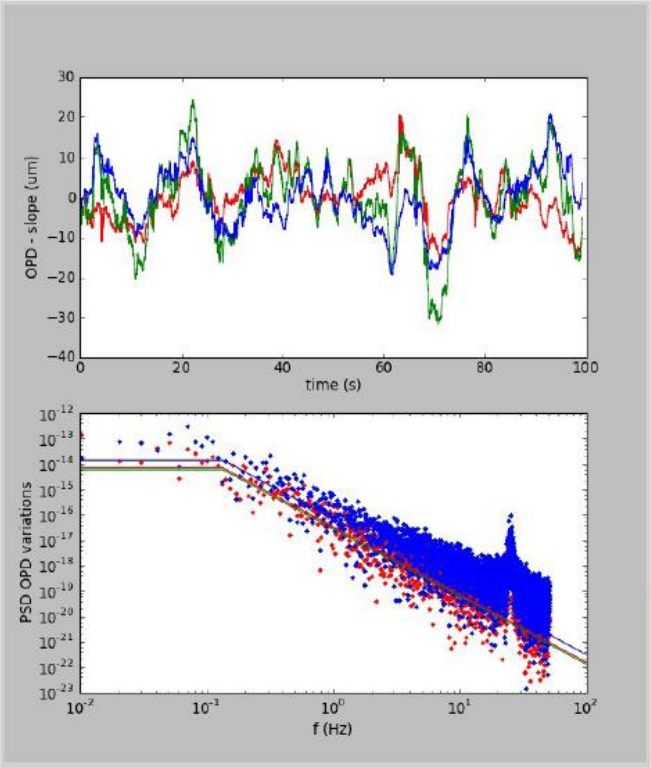
http://www.european-interferometry.eu/joint-research

Paranal atmosphere conditions

AMBER/FINITO Data

- FINITO data saved along with AMBER data since March 2011
- Initial software tool provided by AMBER instrument scientist (Antoine Merand)

- Python learning curve
- Retrieve larger amount of archived data (on calibrators!)
- Analyze statistically
- OPD(v), OPD(λ), $\langle OPD \rangle_{\Delta T}(t)$
- Categorize (e.g., “good”, “average”, “poor”)



WP 4 Progress Meeting, 24 May 2011 P. A. Schuller / P. Kervella: Paranal's Atmosphere for IFM 4

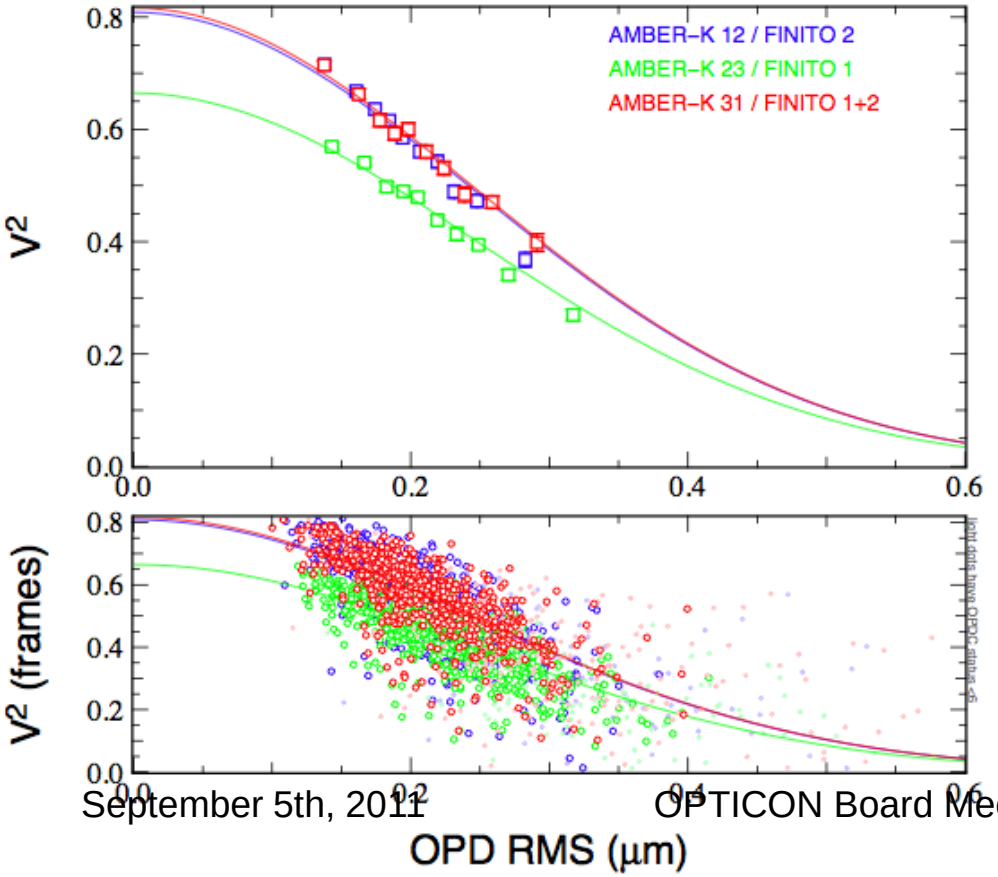
MIDI + FSU on-axis

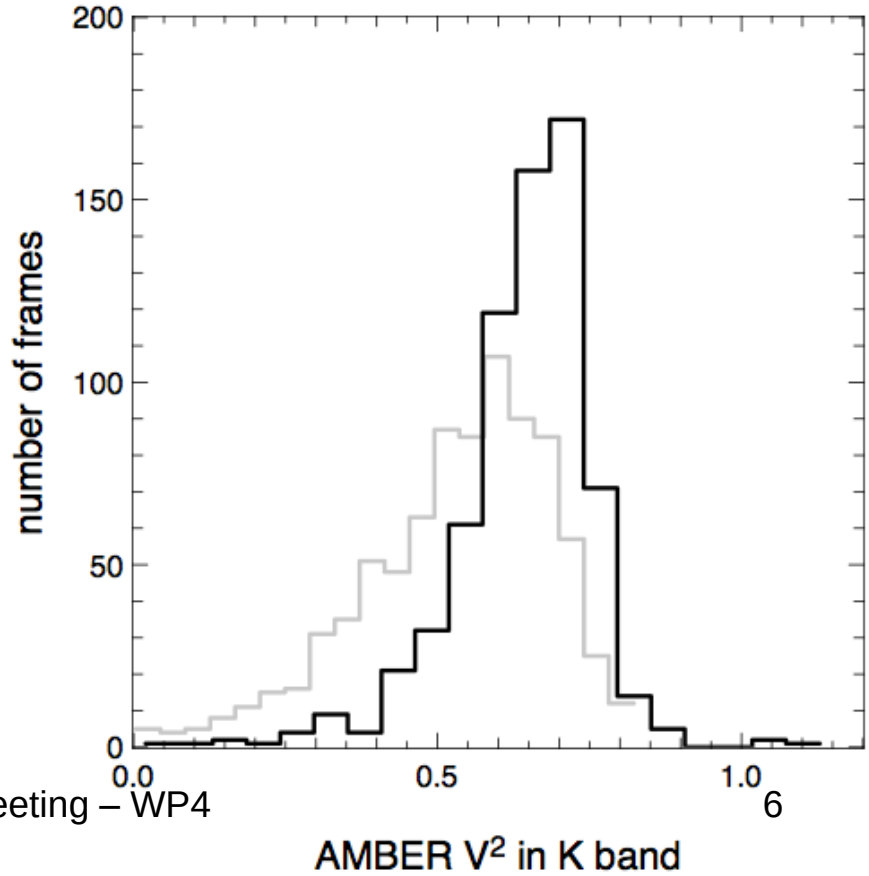
- MIDI data with FSU-A on-axis can be reduced with a good fidelity
  ➔ great increase of the limiting magnitude on the correlated flux
- Reliable estimation of photometry correction by using VISIR spectra taken closely in time (variable targets).
- GTO run MIDI+FSUA in September 2011
- Several scientific topics with possibly an interesting number of targets.
- Studies are needed for off-axis cases
  ➔ more fainter sources available

AMBER + FINITO

SPIE Proceedings, vol 7734 (2010)

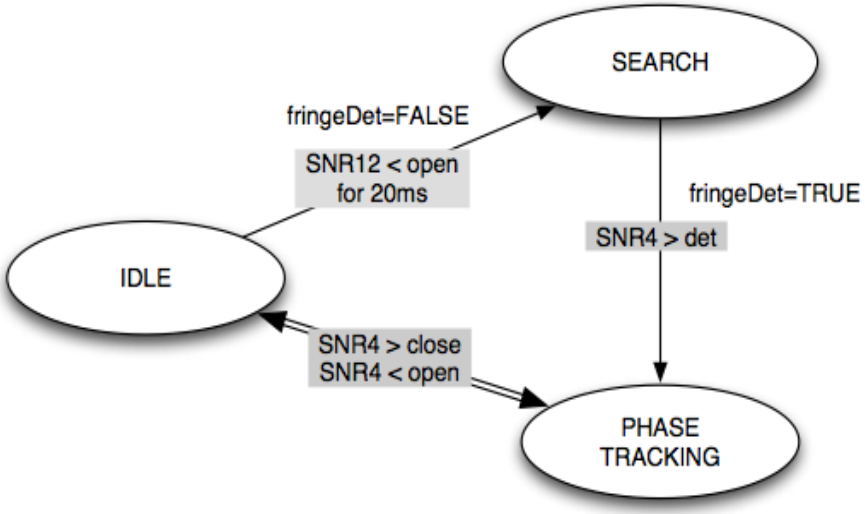
AMBER visibility calibration bias correction

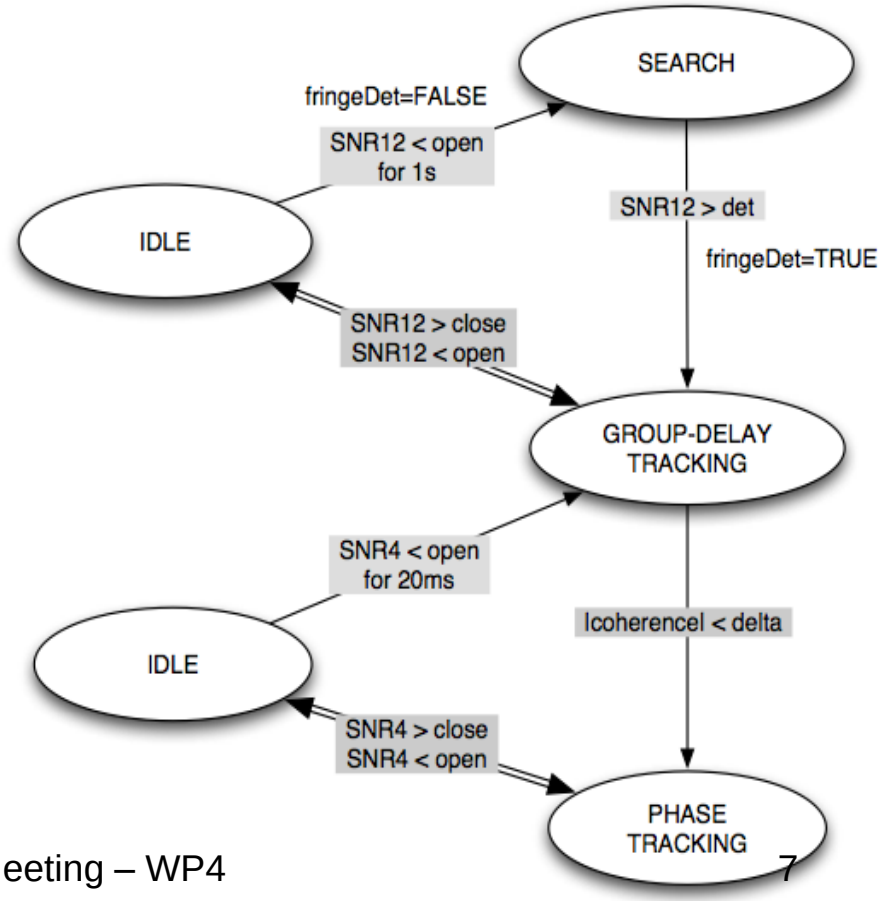




WP4.2.1
FINITO performance (J-B. le Bouquin)

=> improved state machine (also used in FSU)

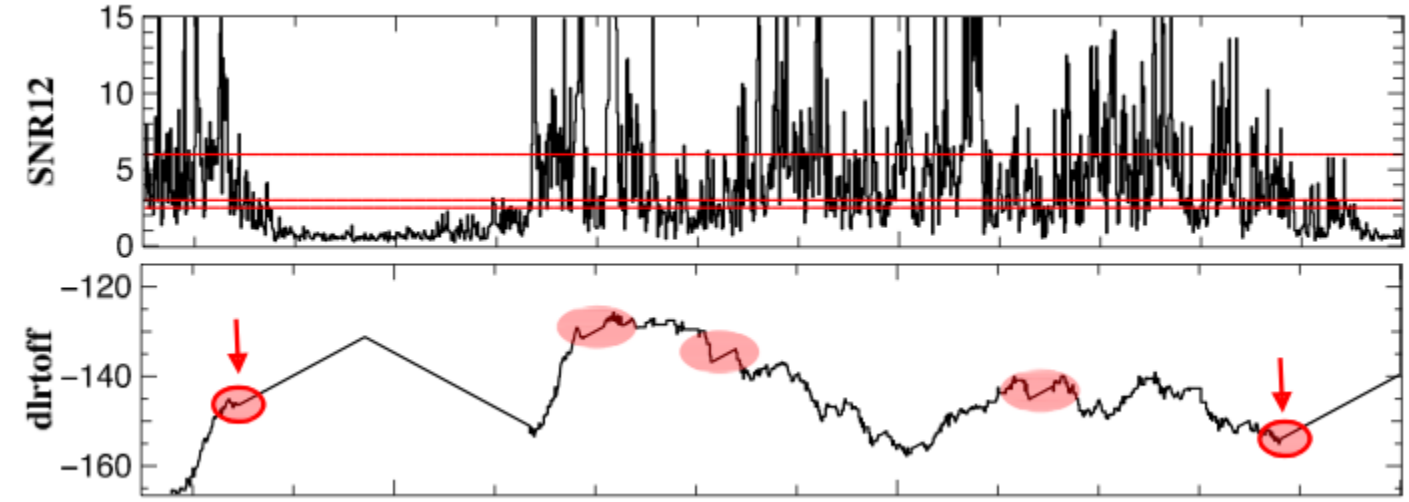




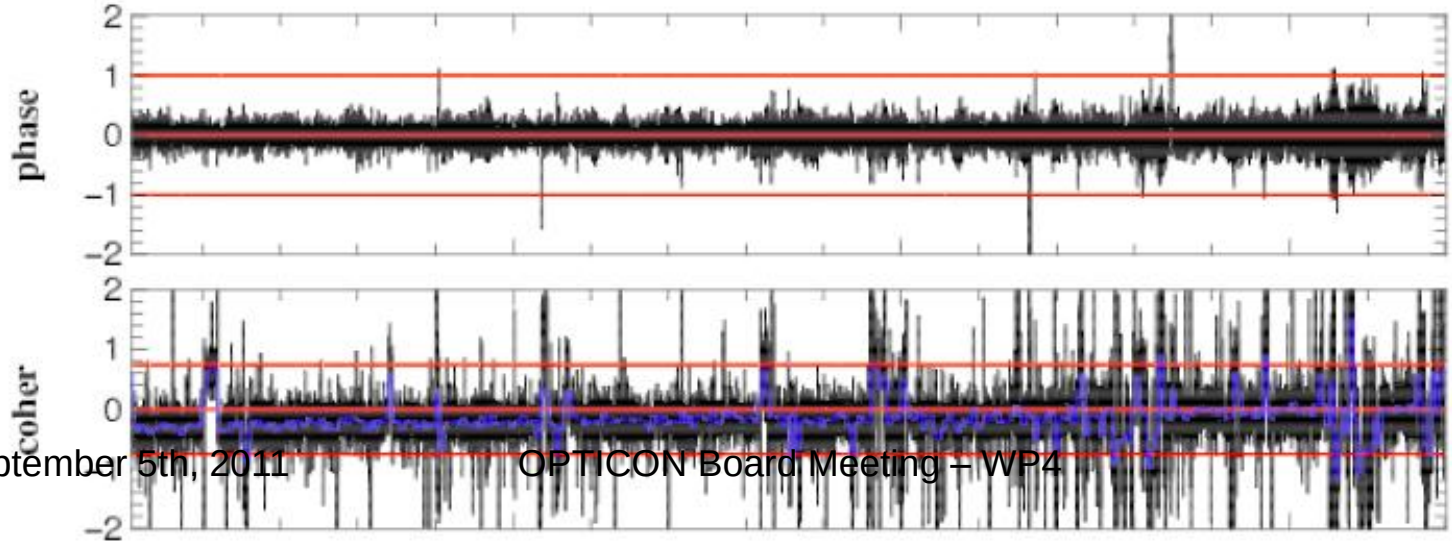
FINITO performance

- Tracking performance

Old



New



$\varphi = 0$

GD drift

PRIMA-FSU performance

- FSUs were not behaving as originally expected:
  - non linearity in phase and group delay estimations
- Extensive analytical study by S. Ménardi to estimate the sensitivity of the FSU to several instrumental imperfections:
  - detector noise (correlated or not)
  - bad calibration (wavelength, phase)
  - imperfect components (beamsplitters…)
  - imperfect alignment (internal camera, warm optics)
- Good phase if accuracy is better than:
  5% on flat, 10% on dark, 5º on phase and 5% on λ
- Group delay even more sensitive

Consequences of FINITO & FSU analyses

- **triggered new ways of:**
  - calibrating the FSU
  - computing the phase / group delay
  - computing the SNR and its thresholds

- **lessons learned for 2GFT in // to phase A studies (ESO):**
  - interest of photometric information (state machine)
  - no spatial filtering after beam combination
  - computation of sensitivity to hardware imperfections
  - importance of calibration and stability
  - linearity is essential
  - be careful with polarization

- **ESO Plans on 2GFT**
  - Wait for new detector tests
  - mid-2012: write specs and choose concept
  - Development 2013-2014
  - Installation 2016

Interferometry context

VLTI: ESO + national agencies

		2010				2011				2012				2013				2014				2015			
GRAVITY	P						F										E								
MATISSE								P					F										E		
PRIMA Qualification																									
2GFT feasibility																									
2GFT development										C				P				F							
WP4 OPTICON-FP7-1																									
WP4 OPTICON-FP7-2																									
Current WP4.1																									
Current WP4.2																									

Other involvements at the national level:

- ‘OHANA: (F) CFHT-GEMINI
- CHARA: (F) FLUOR, VEGA + New development with AO and instruments
- MROI: (UK)
- LBT: (D)
- + conceptual studies, prospective (coordination EII)

Situation of VLTI

- High impact of VLTI on science in
  - stellar physics (pre main-sequence stars, LBV, WR, Ae-Be…)
  - circumstellar disks, protoplanetary disks
  - stellar evolution
  - AGN dust tori

  ⇒ more than 170 papers in refereed journals, > 50% of all interferometric papers

- Good h-index evolution but saturating for MIDI

- Broad field of applications (compared to Keck and CHARA) thanks to diverse instruments & wide user base

- Unique in astrometry, (almost) unique in N-band and spectral resolution

- But has not been as good for imaging (CHARA) and for sensitivity (Keck-I) + some technical limitations

ESO long range plan STC Apr-11

- Continue to maintain and develop Paranal
- Deliver ALMA
- Construct and operate the E-ELT

- Short-term implementation plan in place
  - Focused on science enabled by the unique angular resolution/sensitivity combination
    - MIDI, AMBER and PIONIER (visitor)
    - PRIMA, MATISSE and GRAVITY
- Longer term: White Paper being developed
  - Currently no funding identified
  - Add two (fixed) AT's and six-beam instrument?
    - AT construction cost would be ~10 M€
    - Plus instrument cost (5M€) and additional operational costs (2 FTEs and 1M€/year)
  - Requires trade-off between science enabled and costs
  - Requires additional funding.

Forward Plan ➔ 2020

- Capitalize on the existing infrastructures (VLTI, CHARA, MROI)
  - Improve accuracy & stability
  - Improve sensitivity: on- and off-axis fringe tracking
  - Improve general user access

- Improve imaging capability
  - more baselines, more flexible operations

- Prepare the future
  - Technological development on components, on prototypes.
  - Take benefit of new detectors.
  - Conceptual definition at the worldwide level (next decadal plan in the US)

Main activities at the EU level

- PRIMA, Gravity, MATISSE OK: ESO management.
- 2GFT: ESO + community + end of WP4/FP7-I
- Support to science programs ➔ capitalize on FP6 devpt. + **EII networking**

- Design studies of next generation
  - Too early at that time. Need more home work
  - **Support for networking**

- R&D:
  - Large funding necessary for new generation optical fibers, 3D integrated optics components: **Participation to WP-Instr. To be discussed**
  - New detectors: interferometric community is not specialist but strong links with WFS activities for near-IR detectors. New generation of visible photon counting detectors are also important. **Tests on interferometric prototypes (to be discussed)**

- Access to interferometry: **WP programme**
  - **Improve reliability of measurements**
  - **Offer general user tools for data analysis and image reconstruction**

Proposed plan for WP4 - Part II
Image reconstruction

- **rationale**
  - with from 4 to 6 telescopes recombiners, 2nd generation VLTI instruments and recent optical interferometers (e.g., CHARA) are clearly targeted <u>at imaging objects at multiple wavelengths</u> (up to high spectral resolution with VEGA)
  - for the scientific returns of these instruments and to promote the use of interferometry, it would be very beneficial to have the required tools for image reconstruction <u>usable by non-expert</u> astronomers
  - image reconstruction algorithms for interferometry (BSMEM, WISARD, MiRA, *etc.*) are mature but:
    - require <u>substantial expertise</u> to be used by non-experts astronomers
    - mostly provide <u>monochromatic image reconstruction</u>
    - lack of documentation
    - are not necessarily freely available

- **summary of the project**
  - make the R&D and software development to provide image reconstruction algorithms from <u>optical interferometry data to general users</u>

Objectives and Deliverables

- **objectives**
  - Development of statistical tools for improving the measurement's reliability
  - R&D on image reconstruction algorithms for interferometric imaging with particular focus on issues for non-expert users (unsupervised algorithms) and multi-wavelength data
  - selection of state of the art methods
  - validation on experimental data from existing instruments

- **deliverables**
  - prototypes (in high level languages like IDL) for robust and simple to use image reconstruction algorithms
  - specifications of the algorithms (in the form of scientific publications and technical reports)
  - tutorials and cookbooks based on real and typical cases
  - implementation of image reconstruction algorithms with a simple user interface (command line) for in-line and batch processing and with settings suitable for the available instruments

Partnership and Money

- potential participants (the idea is to have ~ 4-5 labs)
  - F-CNRS Lyon: CRAL (Éric Thiébaut), IPAG, LESIA, Nice
  - P-Porto (Paulo Garcia)
  - UK-Cambridge (John Young)
  - MPG Bonn/Garching/Heidelberg (on-going discussions)
  - US-Univ. Michigan (Fabien Baron)

- funding
  - For the development: 4 post-doc for 2 years each ~ 360 k€
    - *Measurement's realibility*
    - *Multi-spectral reconstruction*
    - *Blind optimization of reconstruction*
    - *Tutorial, diffusion, graphical user interface*
  - For the software development: 4 FTE ~ 160 k€
  - For the coordination, travels, meetings: ~ 60 k€
  - Total: ~ 580 k€

Summary of WP4 forward plans

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