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This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

WP6

JRA2 Advanced Instrumentation Development

M. Collados and WP6 participants

12/February/2021

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

Work package number	WP6		Lead beneficiary		IAC	
Work package title	JRA2: Advanced instrumentation development					
Short name of participant	**KIS**	**IAC**	**SU**	**INAF**	**UNITOV**	**MPG**
Person months per participant:	1	74	3	2	24	54
Short name of participant	**USI/IRSOL**	**WO**	**NINS**	**ADS**	**BPP E&M**	
Person months per participant:	48	20	20	7	16	
Start month	1		End month		48	

Objectives

Development of instrumentation to improve the existing solar telescopes and with possible application to the future large aperture solar telescopes. The instrumentation developments included in this WP are the following:

- Improvements of techniques of image slicers for 2D spectroscopy
- Microlens-fed spectrograph
- Design concept of a Narrow-Band Tunable-Filter Imager for EST
- Absolute high precision polarization measurements

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Integral Field Units (IFU) for 2D solar spectroscopy

sWP6.1

Improvements of techniques of image slicers

(IAC lead, WO, NINS)

sWP6.2

Microlens-fed spectrograph

(MPG)

(Heritage of previous SOLARNET and GREST projects and fundamental for the definition of innovative instrumentation for EST)

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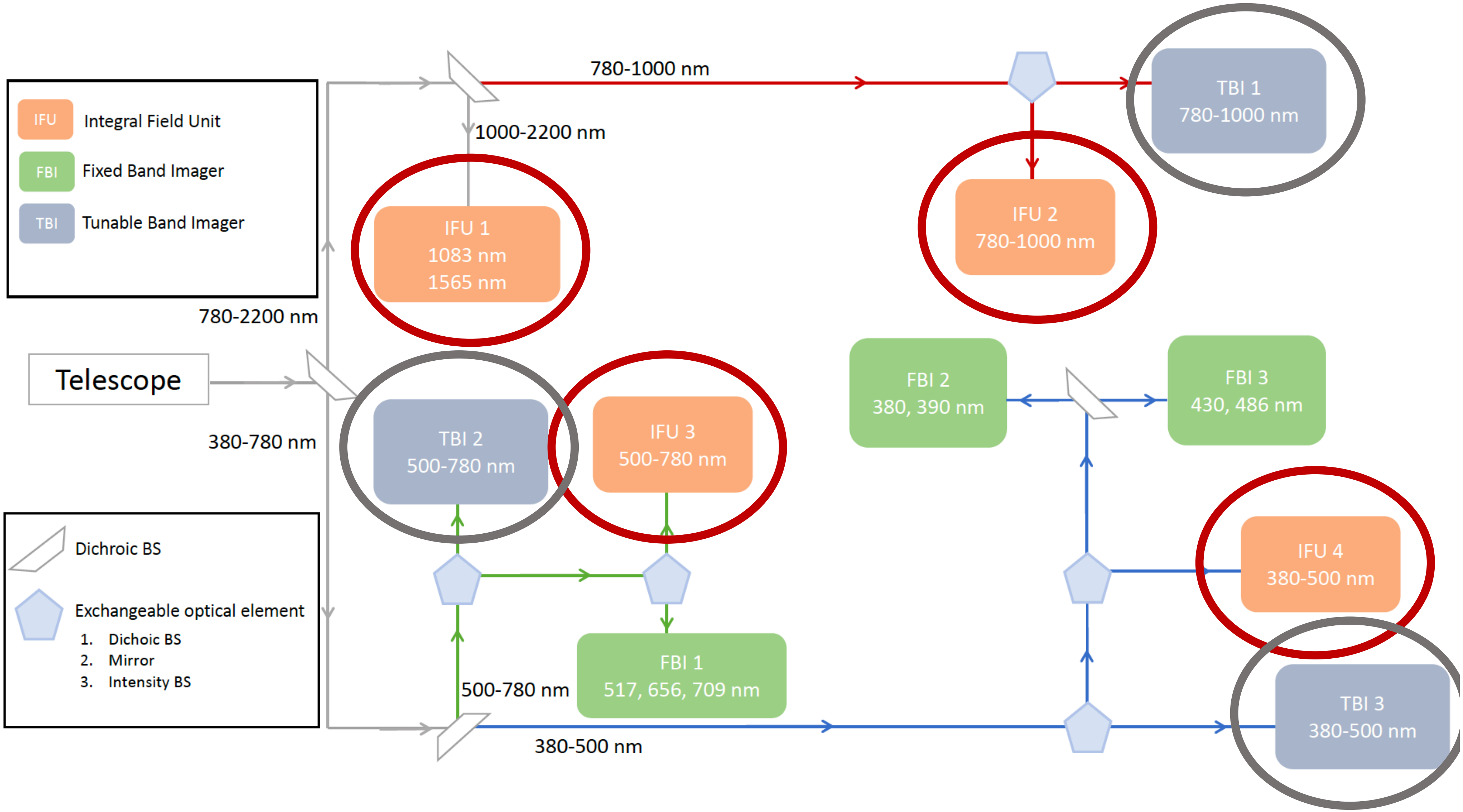

EST light distribution system and instruments

WP6: JRA2 Advanced Instrumentation Development

Solarnet GA
12 February 2021

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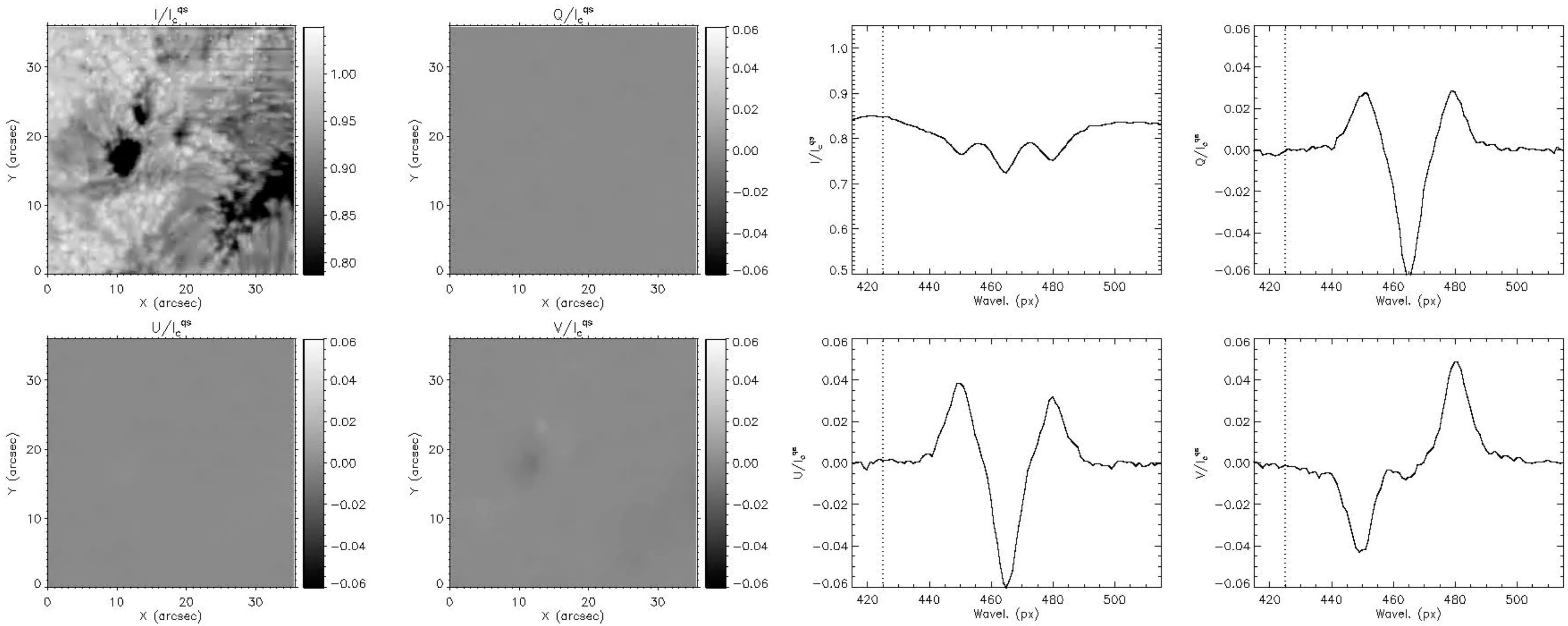
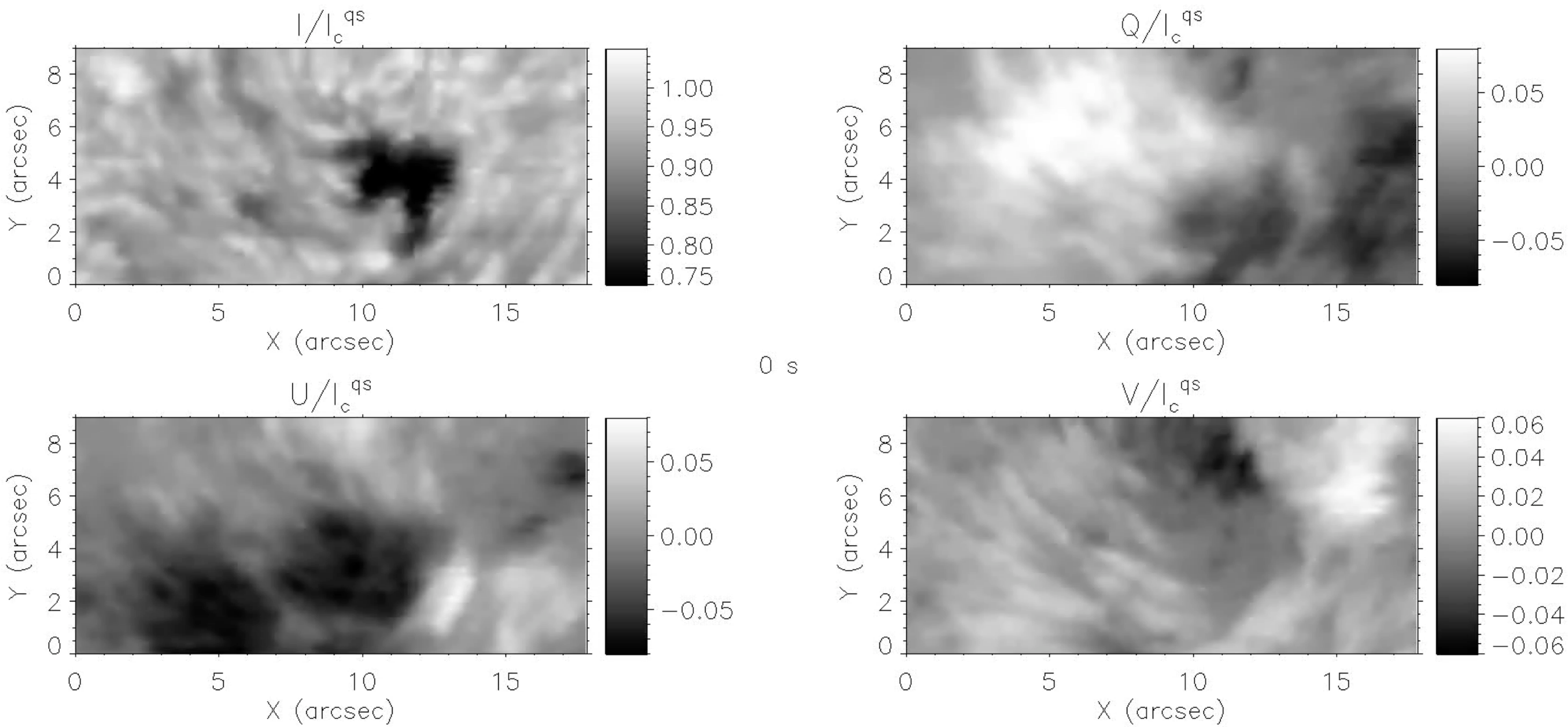
Image slicer IFU prototype @ GREGOR



Instrument open to all observers since 2019

Image slicer IFU prototype @ GREGOR



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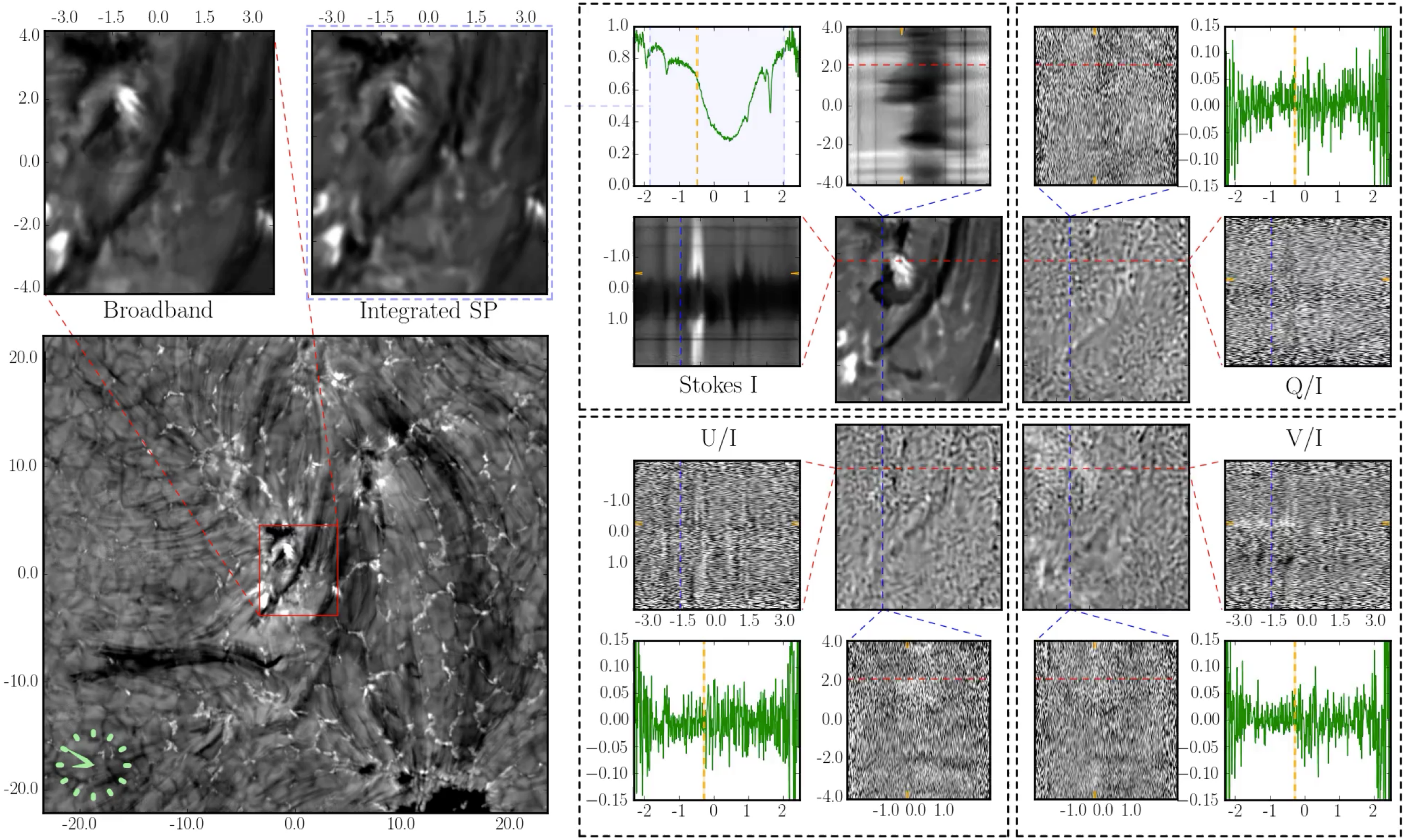
Microlens-based IFU prototype @ SST



WP6: JRA

Common-use permanent instrument under development

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sWP6.1

Improvements of techniques of image slicers for 2D spectroscopy

sWP leader: Carlos Domínguez-Tagle

Goal: increase the spatial resolution, which can only be achieved by having thinner slicers (100 → 30-70 microns)

Two strategies will be followed to that aim:

- glass slicers (to be produced by WO)
- metallic slicers (to be produced by NINS)

The two alternatives are pursued and compared in order to decide the best option for EST.

They will be tested at the lab and the best slicer will be demonstrated at GREGOR.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP 6.1

Improvements of techniques of image slicers for 2D spectroscopy

There are no pending deliverables to date:

Deliverable Number	Deliverable Title	Lead beneficiary	Type	**Delivery Date**
D6.1	Image slicer design	IAC	Report	13 **(delivered)**
D6.2	Ability to manufacture thin glass slices	WO	Report	14 **(delivered)**
D6.3	Ability to manufacture thin metallic slices	NINS	Report	14 **(delivered)**
D6.4	Glass image slicer	WO	Demonstrator	37
D6.5	Metallic image slicer	NINS	Demonstrator	37
D6.6	Tests (at laboratory and at telescope)	IAC	Report	48

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP 6.1

Improvements of techniques of image slicers for 2D spectroscopy

This sWP is on schedule, according to the planned milestones:

Milestone Number	Milestone Title	Lead beneficiary	**Delivery Date**
MS10	Validation of the ability to manufacture thin metallic and glass slices	IAC	13 **(achieved)**
MS11	Manufacture thin glass slices	WO	36
MS12	Manufacture thin metallic slices	NINS	36 **(achieved)**
MS13	Integration with the reimagination optics	WO	39

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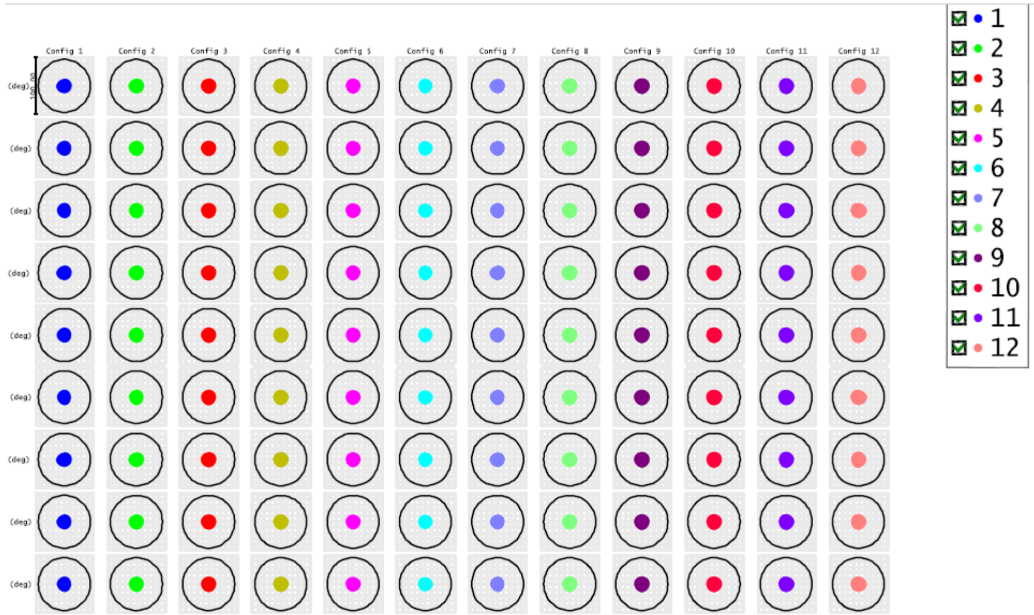
sWP 6.1

Glass slicers (being produced by Winlight Systems)

Winlight Systems (WS, formerly WO) dedicated additional manpower to update the optical design to reduce the diffraction effects. They are now in the manufacturing process: already received the blanks and started the polishing.

Specification	*Value*
Aperture	**F/40.6**
Field	**3.15"x4.9"**
Wavelength range	**1083-1565 nm**
Slice numbers	**12**
Slices dimensions	**70 µm x 1.3 mm**
Slices radius	**∞ - Flat**



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sWP 6.1

Glass slicers (being produced by Winlight Systems)

WS is now in the manufacturing process: already received the blanks and started the polishing.

The optical design fits in a 150x40x30 mm box

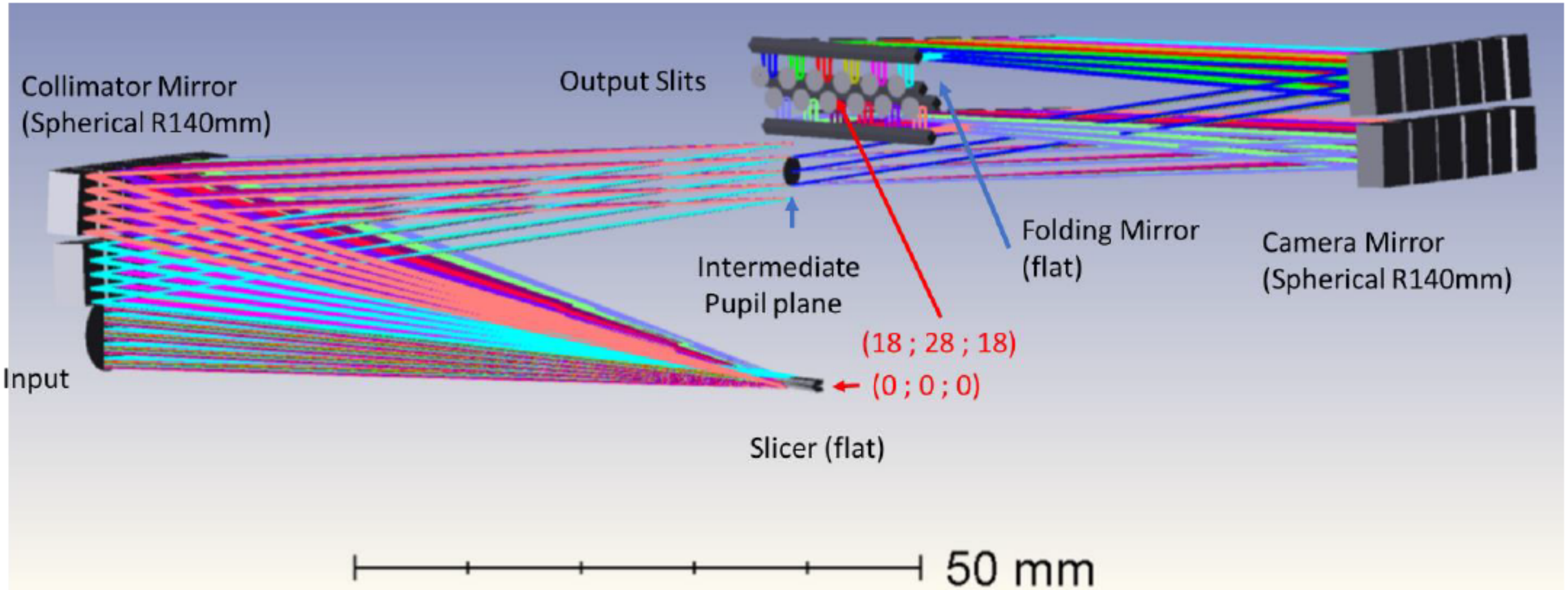

Figure 1 : Optical slicer overview

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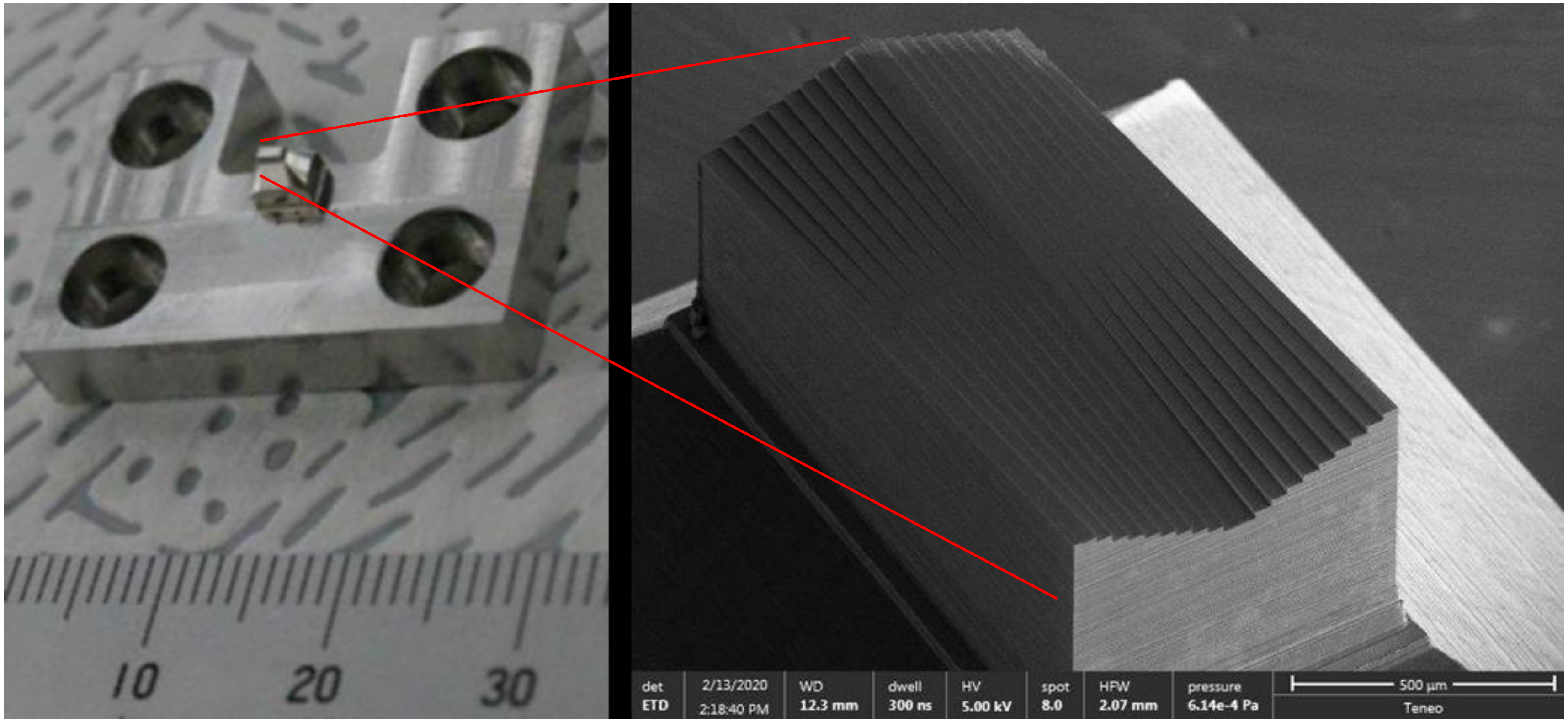
sWP 6.1

Metallic slicers (produced by NINS)

NINS has already manufactured the image slicer in collaboration with CANON, Inc. IAC is currently working on the IFU design to reduce the effect of diffraction in the subsequent optics.



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sWP 6.1

Metallic slicers (produced by NINS)

CANON's metallic-image-slicer technology is now under study for a future DKIST instrument:

13 December 2020

The mechanical design of the machined image slicer integral field units for the diffraction-limited near-IR spectropolarimeter

Morgan B. Bonnet, Haosheng Lin, Takashi Sukegawa, Yukinobu Okura, Tomonao Nakayasu, Yukimasa Suyama

Author Affiliations -

Morgan B. Bonnet,[1] Haosheng Lin,[1] Takashi Sukegawa,[2] Yukinobu Okura,[2] Tomonao Nakayasu,[2] Yukimasa Suyama[2]

[1]Institute for Astronomy (United States)
[2]Canon Inc. (Japan)

Proceedings Volume 11451, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation IV; 114512C (2020) https://doi.org/10.1117/12.2560809
Event: SPIE Astronomical Telescopes + Instrumentation, 2020, Online Only

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP 6.2

Microlens-fed spectrograph

sWP leader: Michiel van Noort

Goal: increase the field of view

Requirements

- Larger number and smaller microlenses are needed
- 30k × 30 k detector would be needed → FoV splitting + sensor mosaic
- Challenge: data handling, reduction and restoration

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP 6.2

Microlens-fed spectrograph

Deliverables

Deliverable Number	Deliverable Title	Lead beneficiary	Type	**Delivery Date**
D6.7	Field splitter design and MLA specs	MPG	Report	14 **(delivered)**
D6.8	Data reduction tools for single field data	MPG	Other	24 **(delivered)**
D6.9	Field splitter and MLA lab tests	MPG	Report	36
D6.10	Data reduction tools for multi field data	MPG	Other	36
D6.11	Final report on microlens-fed spectrograph	MPG	Report	48

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP 6.2

Microlens-fed spectrograph

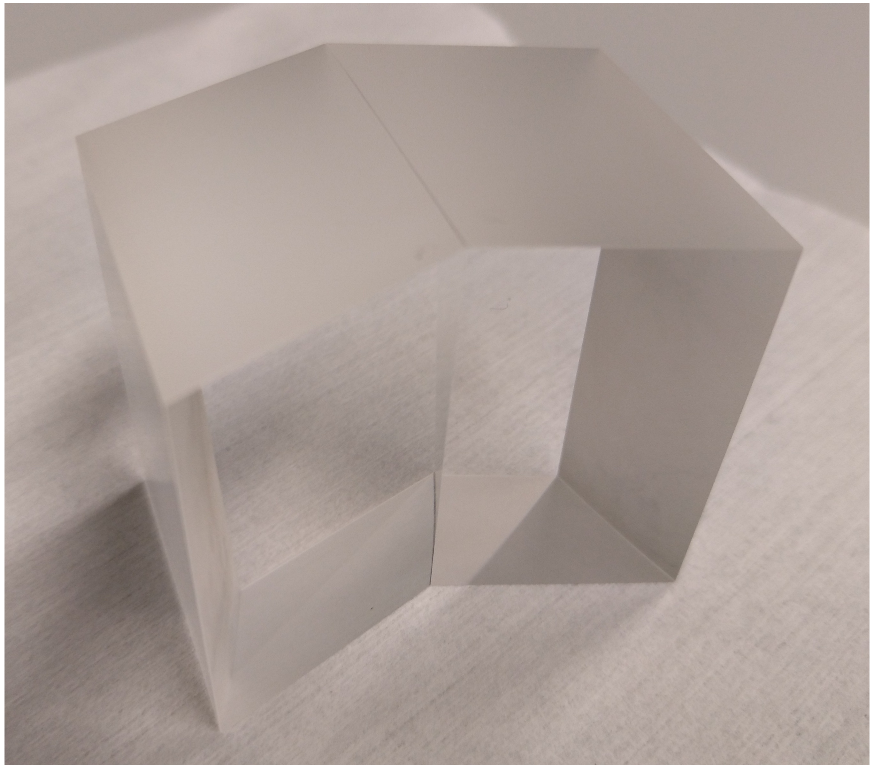
Milestones

Milestone Number	Milestone Title	Lead beneficiary	**Delivery Date**
MS14	Field splitter optics complete	MPG	24 **(achieved)**
MS15	Large format MLA delivery	MPG	30

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP 6.2

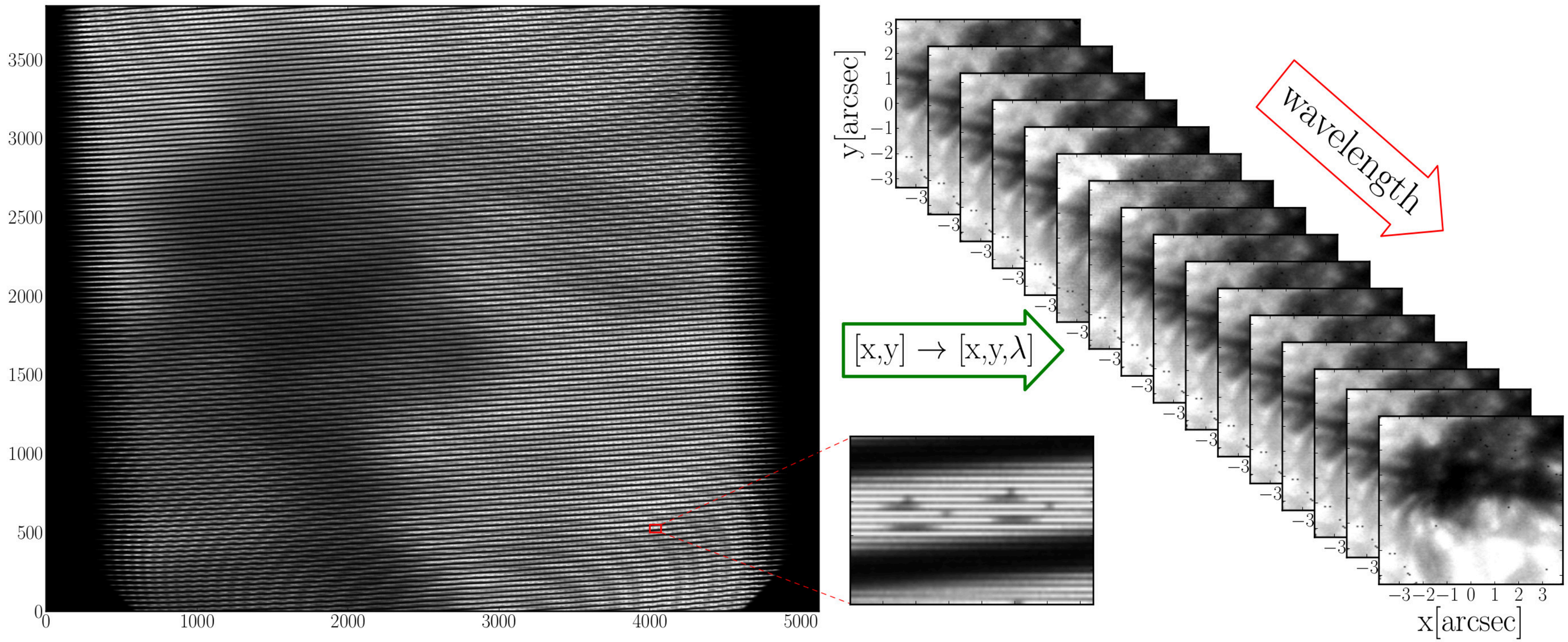
Microlens-fed spectrograph



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

D6.8: part 1: Data extraction

- Model instrument properties
- Fit mapping function to flatfield data
- Use inverse map to extract data
- Incomplete: To be delivered as part of D6.10



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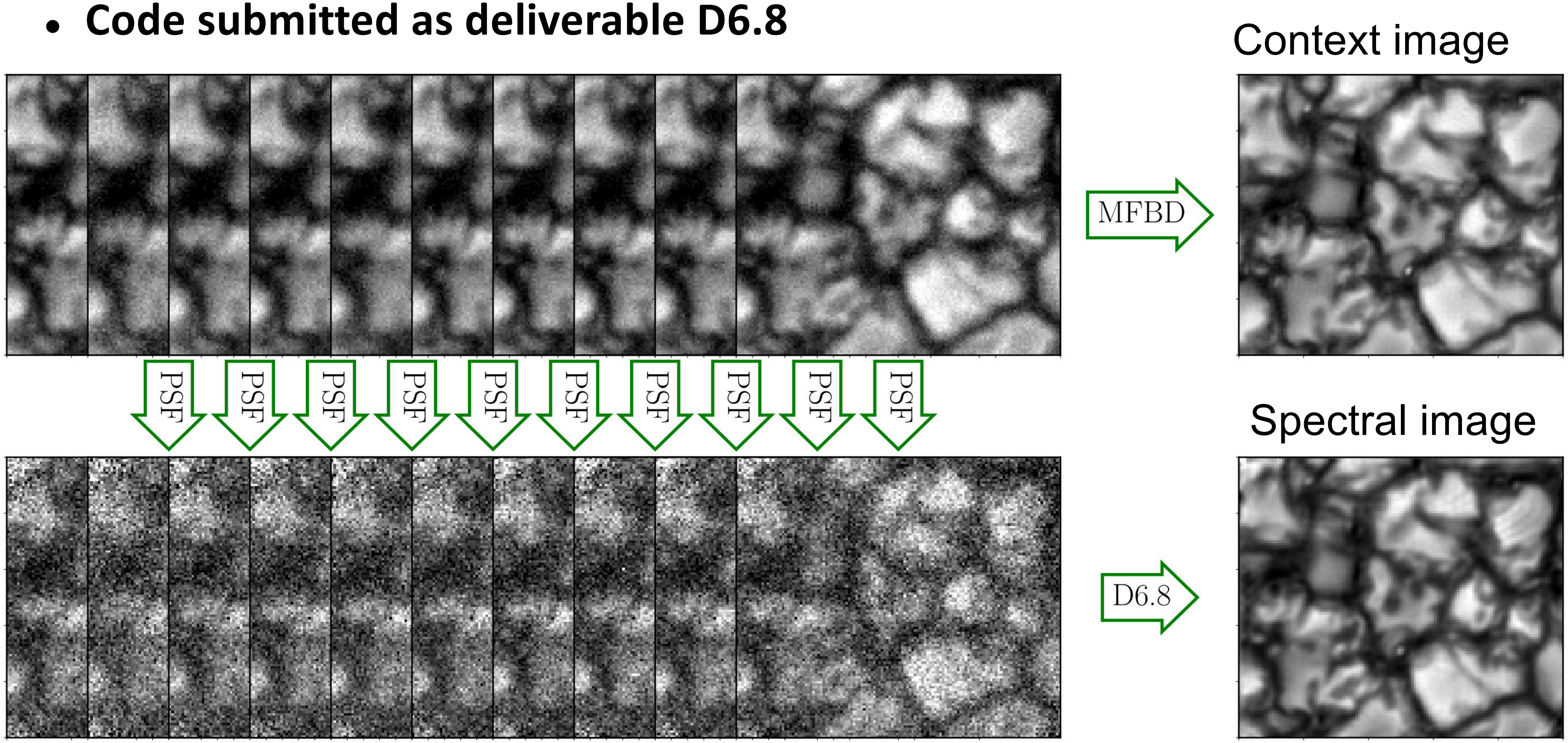
D6.8 part 2: Image restoration

- **Spectral data very noisy**
- **MFBD on simultaneous context images**
- **Use PSF to restore spectral data**
- **Code submitted as deliverable D6.8**



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sWP 6.2

Microlens-fed spectrograph

Relevant issues :

- Negotiations for microlens array manufacture behind schedule (optical design behind, manufacturing capabilities have changed)
- Significant delay in MLA delivery (MS15) expected
- Limited version of D6.9 and D6.10 will be attempted with existing MLA, complemented with final MLA when delivered.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP6.3

Design concept of a Narrow-Band Tunable-Filter Imager for EST

(UNITOV lead, IAC, INAF, KIS, SU, BDP E&M)

sWP leader: Francesco Berrilli

Goal: define the optimum configuration of the EST Narrow-Band Tunable-Filter Imagers

1. Configuration trade-offs
    - telecentric or classical mount
    - lens, mirrors or catadioptric system
    - plane or 3D set-up
2. Optical design
    - optical performance
    - stray light analysis

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP6.3

Relevant issues:

1. Close coordination with PRE-EST groups for instrument definition: SAG, Review Panel and Instruments Groups
    - the light distribution has been modified
    - the requirements for the instruments have been revisited

2. A technical position at UNITOV started on January, 2020.

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sWP6.3

Design concept of a Narrow-Band Tunable-Filter Imager for EST

Deliverables

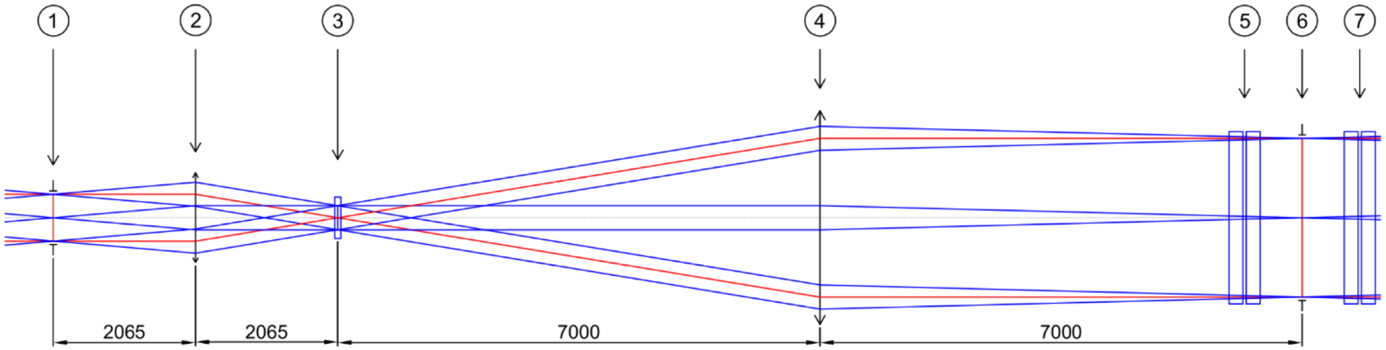
Deliverable Number	Deliverable Title	Lead beneficiary	Type	**Delivery Date**
D6.12	**Review of the scientific requirements of Narrow Band Imager**	**UNITOV**	**Report**	12 **(delivered)**
D6.13	**NBI Trade-off analysis**	**UNITOV**	**Report**	18 –> 23 **(delivered)**
D6.14	NBI Optical design	BPD E&M	Report	36
D6.15	NBI Review and Analysis of tolerances	UNITOV	Report	48

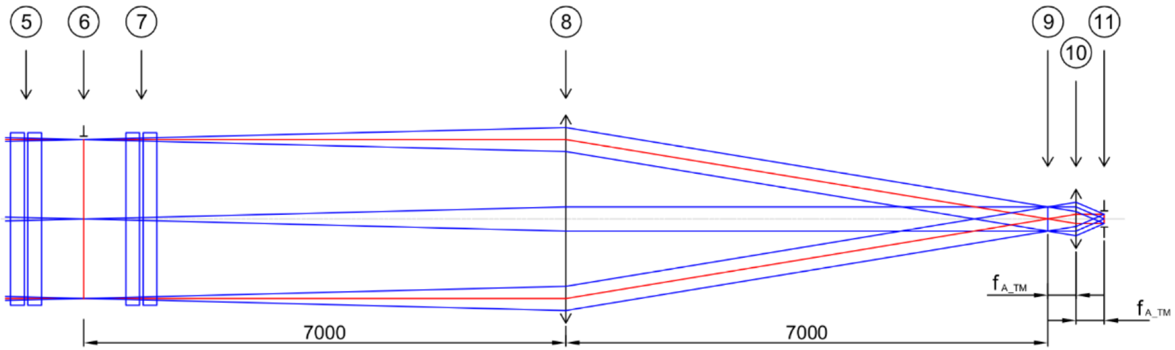
No milestones

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP6.3

D6.13 trade-off analysis: 4 configurations (telecentric/collimated, dioptric design) for each of the 3 bands (TB1, TB2, TB3)





Telecentric Mount design

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

sWP6.3

Conclusions of the D6.13 trade-off analysis: recommendations for the D6.14 (optical design)

- Two FPIs, one high-resolution high-reflective FPI plus one low-resolution low-reflective FPI (tilted for ghost suppression).
- Telecentric configuration.
- The f-number should be f#150.
- The foreseen FPI diameter is 220 mm (180 mm clear aperture) with 2 nm RMS cavity errors.
- The optical design should prefer lenses and optical elements as small as possible to deal with inhomogeneities.

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sWP6.4

Absolute high precision polarization measurements

(USI/IRSOL)

sWP leader: Michele Bianda

Goal: Technique to measure absolute (linear and circular) polarisation, with high spatial resolution and applicable to solar telescopes with large aperture

Technique based on combined slow+fast modulation

1. Analytical study of optimum modulation schemes
2. Tests to explore the strengths and limitations of the method
3. Design and construct a prototype system for GREGOR
4. Telescope tests

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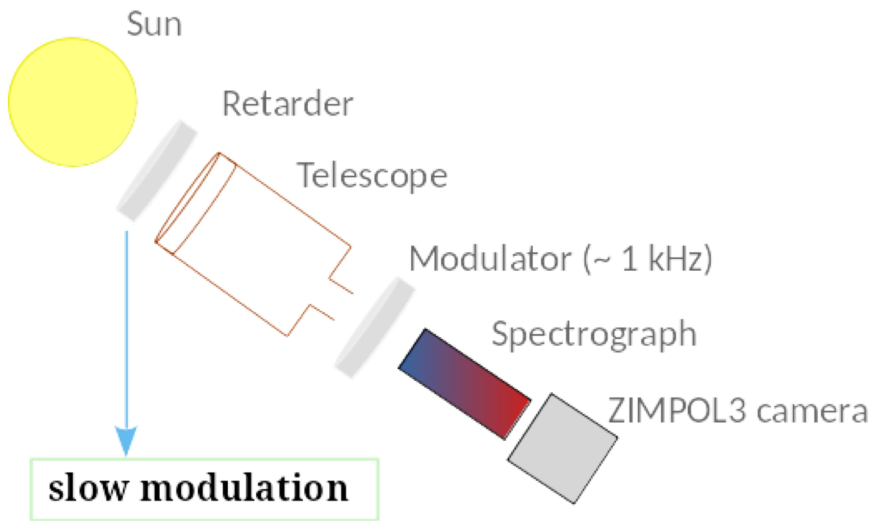
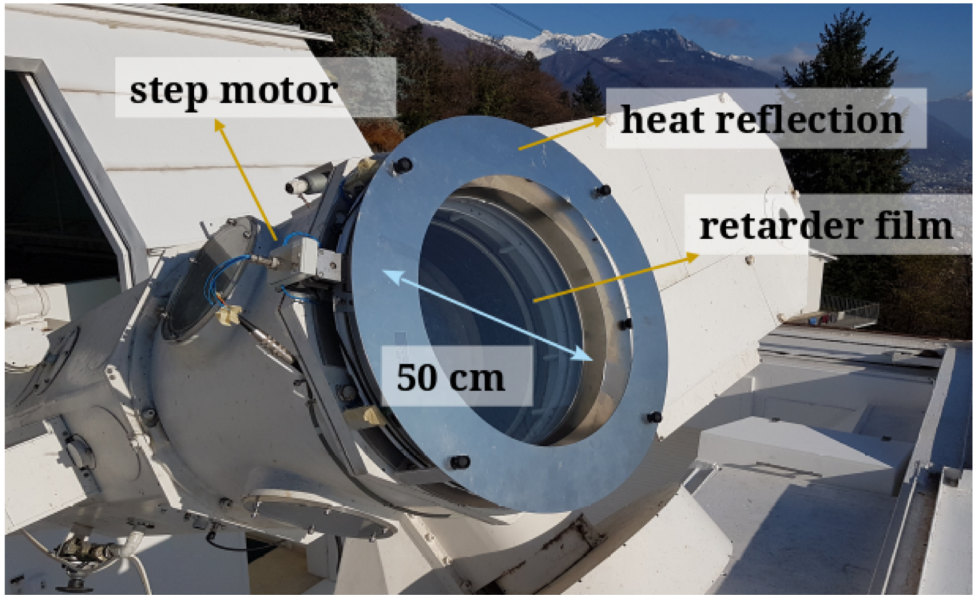
sWP6.4

Absolute high precision polarization measurements

Prototype setup:





Slow modulator placed in front of the Locarno telescope (telescope calibration unit, TCU)

Retarder film: large, low-cost zero order half- or quarter-wave plate

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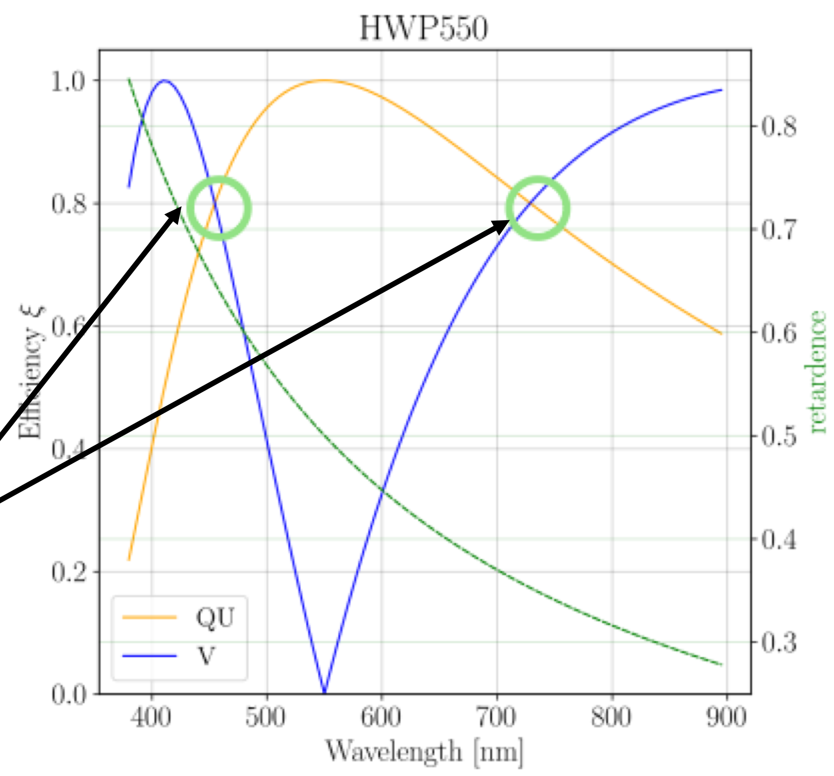
sWP6.4

Analytical study of modulation schemes

- Modulation schemes for linear and circular polarization
- 8 angle positions of retarder film (22.5° per step) → to correct for additional cross-talk induced by zero-order retarder
- Different efficiencies for linear and circular polarization
- For a specific retarder, full Stokes correction are balanced in two wavelength points



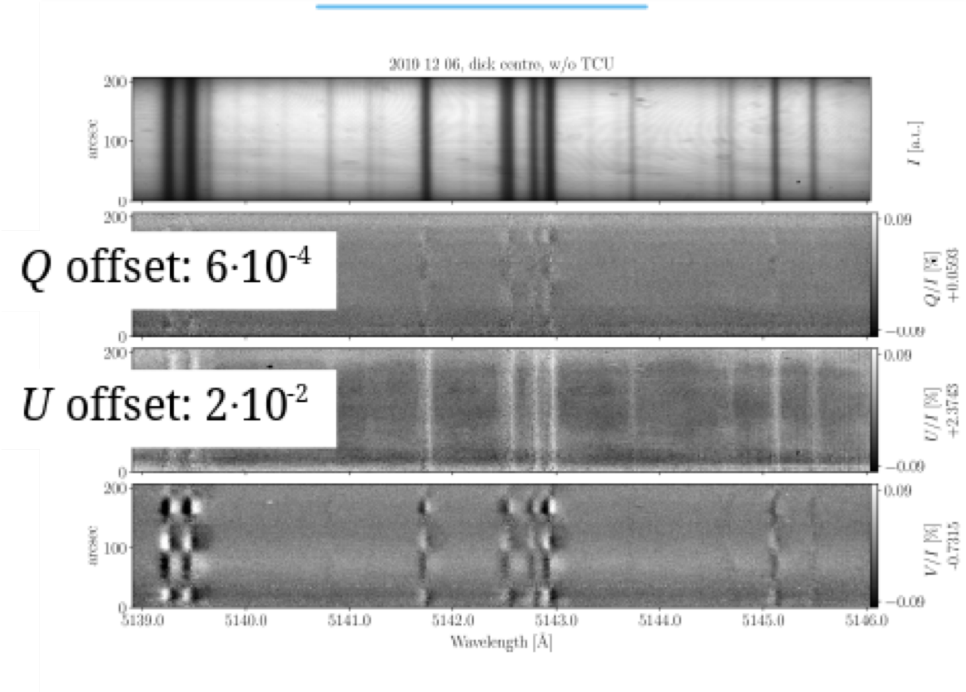
Retardence and efficiency curves for half-wave plate at 550 nm

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824135.

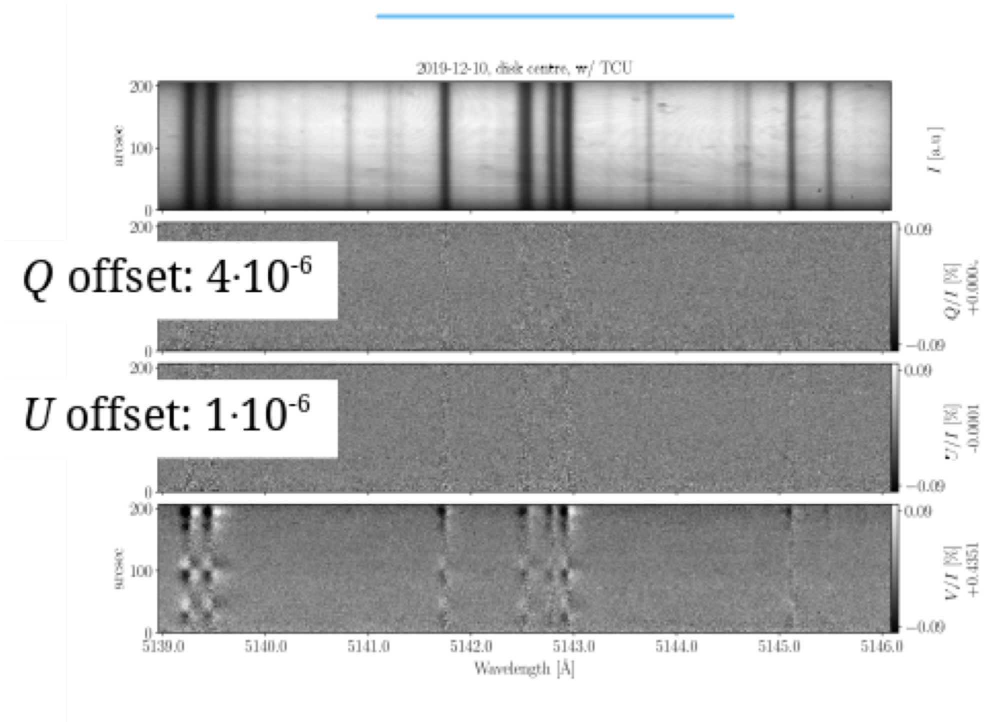
sWP6.4

Example for linear polarization correction:

w/o TCU



w/ TCU



Disk center: left: offsets, cross-talks, rigth: corrected

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sWP6.4

Error of absolute linear polarization level:

Wavelength [Å]	4607		5144		5896		6495	
Stokes /I	Q	U	Q	U	Q	U	Q	U
PEM, w/o TCU	1.0977	0.8600	0.1561	0.05810	0.0704	0.1182	0.4703	0.5862
PEM, w/ TCU	0.0013	0.0012	0.0006	0.0008	0.0006	0.0006	0.0009	0.0009
FLCM, w/o TCU	1.1768	3.3625	1.3592	2.8821	-	-	1.9076	3.5672
FLCM, w/ TCU	0.0022	0.0020	0.0020	0.0016	-	-	0.0037	0.0054

Offsets for different wavelengths and modulators with and without applying the new method. Values are given in %.

Offsets are reduced by 2 orders of magnitude over a wide wavelength range

FLC fringes are significantly reduced

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sWP6.4

Relevant issues:

- Spatial resolution is decreased, needs to be quantified with GREGOR
- Device for GREGOR is in preparation, feasibility will be discussed in the next technical GREGOR meeting
- Tests at the GREGOR telescope possible in the second half of 2021?

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sWP6.4

Absolute high precision polarization measurements

Deliverables

Deliverable Number	Deliverable Title	Lead beneficiary	Type	**Delivery Date**
D6.16	Performance report of the new measurement technique at IRSOL	USI/IRSOL	Report	24 **(delivered)**
D6.17	Performance report of new measurement technique at GREGOR	USI/IRSOL	Report	48

Milestones

Milestone Number	Milestone Title	Lead beneficiary	**Delivery Date**
MS16	Device to be used on GREGOR	USI/IRSOL	34