SPICA-FT

Commissioning #1 Report

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CHANGE RECORD

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1	21/01/2020	All	Creation – DM, PB, JBLB

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1 Scope

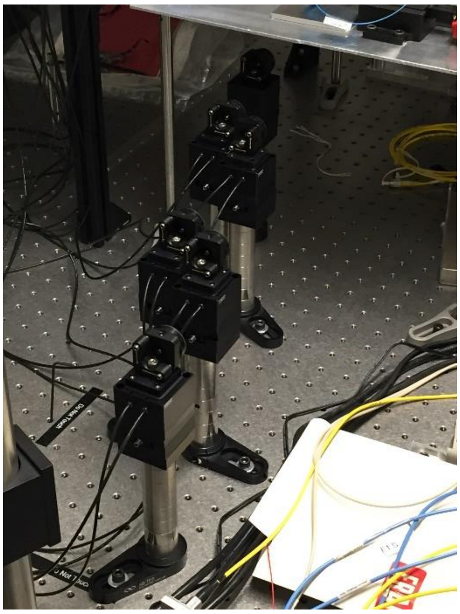
The scope of this document is to report the first commissioning run of the SPICA-FT project which occurred at CHARA from 13 Jan to 23 Jan and involved N. Anugu, P. Bério, J.B. Le Bouquin, D. Lecron, D. Mourard and S. Rousseau + the CHARA team on the Mountain.

2 General Overview

The goal of the project SPICA-FT is to develop a 6T fringe tracker for the CHARA interferometric array. Even if FT-SPICA will be available for all CHARA instruments, it has been designed/specified as the fringe tracker of the future 6T visible instrument SPICA-VIS (D. Mourard, 2017). At the end of 2018, it was decided to integrate SPICA-FT into the MIRCx instrument developed by the Michigan and Exter Universities. SPICA-FT will use several existing modules of MIRCx: birefringence correction, internal delay lines, injection module, the fast and low noise CRedOne detector. SPICA-FT will use the new fast link to the CHARA delay lines to close the loop. Moreover SPICA-FT software will be fully integrated inside the MIRCx software.

3 Modification of the STS

To permit the calibration of the P2VM matrix enabling the decoding of the new images generated by the 6T-ABCD integrated optics chip on the CRedOne detector, it is necessary to use a precise OPD modulation on a 6 beam internal source. As the internal DL of MIRCx do not meet the specifications, it has been decided to implement new PZT translation stages on 5 of the 6 OPD mirrors of the recently commissioned STS. These PZT are on beams 2,3,4,5,6 and have a mechanical stroke of 0-30µm. An UPS and a connected plug racket have been installed under the metrology table to protect these new equipments.



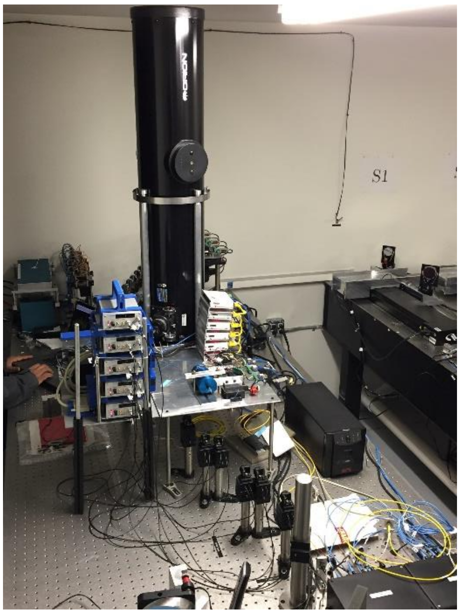


Figure 1: Left: The 6 new mounts supporting the OPD mirrors of the STS. Mirrors are the same as the previous ones. Right: General view of the STS, including the new electronics for the PZT (PZT controllers, DNA system). A new CHARA server (mircx_piezo_server) is in place and in charge of managing the communication with the hardware. Some commissioning GUIs have been used, their integrations into the STS GUI should be considered for the future use of these devices.

A mircx_piezo_server has been developed and is running as part of the MIRCx servers. At init of the hardware controller and of the server, the PZT are setup to 16µm, which is the mid-course. A first version of a GUI has been developed, in parallel to the commissioning tools (client for direct communication to the DNA and piezos). The MIRCx server connect to the piezo_server as client, so that the modulation parameters are saved in the FITS file. It should be noted that the OPD controller is not using the server channel for communicating with the pzt. The communication with the DNA does not permit for the moment to monitor the positions of the PZT. The clients can just reconstruct the position with respect to the history of the motions (start time, amplitude, step time, nb step).

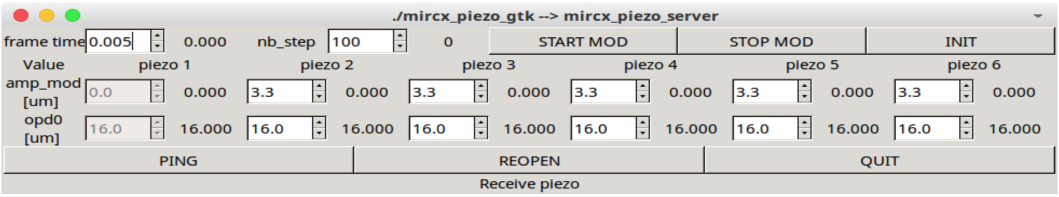


Figure 2: The mircx_piezo_gtk allows to start modulation on the PZT of the STS. The modulation are triangular. At the end of the modulation, the PZT return back to the reference position of 16µm.

During the 10 days of the run, we noted the remarkable stability of the STS alignment and internal OPD. From day to day it was not necessary to realign the fibers with the fiber explorer and fringes were always present within a few microns.

4 Installation of the SPICA-FT chip in front of the MIRCx spectrograph

During the development phases of SPICA-FT on one side and of MIRCx and MYSTIC on the other side, it has been decided to install the SPICA-FT IO chip on a temporary support, to permit a rapid switch back to MIRCx. This supports is already compatible with the future evolutions of the ALL-IN-ONE combiner and spectrograph.

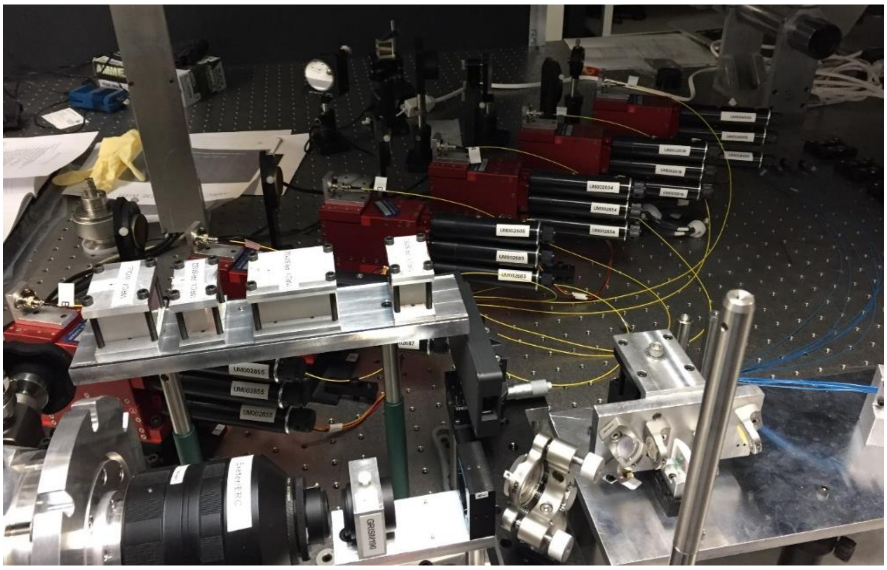


Figure 3: Installation of the SPICA-FT IO Chip in front of the MIRCx spectrograph. The 6 SPICA-FT fibers (yellow jacket) are connected to the MIRCx OAP injection modules. The IO Chip is installed inside a grey box supported by a goniometric mount. A tip/tilt flat mirror permits to align the outputs of the chip on the detector. The focus is made by manually moving the whole plate in the direction of the spectrograph.

The chip that has been installed (VLC04-2) is not the definitive one, as it presents one output that has a low transmission, a general unbalance between the 5 channels issued from one input, and very large (~12µm) internal closure phase because of issues in the design. These issues have been identified during the tests in Nice a few months ago and a new fabrication run is ongoing. We will receive a new chip by the end of March. As a consequence of this, the chip has been removed at the end of the run, also for permitting the re-installation of the MIRCx cover. The expected evolution of the disperser wheel for MIRCx will in any case introduce a modification of this cover.

The alignment procedure using the mircx_rtd_gtk tool permitted to check the correct spacing of 5 pixels between the outputs of the chip. We do not detect any vignetting on extreme beams (A-B12 or D-B56). The focalisation permits to put ~90% of the flux in one pixel. From day to day, and excepted the situation where we have changed the disperser, it is noted that the stability of the 60 outputs on the CRedOne detector is excellent and in any case much less than one pixel.

5 Software architecture

MIRCx is using a Shared Memory between the image grabber and the data acquisition system. An adaptation of the real-time analysis of the images has been realized, using the P2VM matrix, and is now producing in a new Shared Memory (Phase Sensor Shared Memory) the information (fluxes, coherent fluxes and variances) required by the OPD controller. The real-time use of the P2VM matrix permits the use of all the standard MIRCx tools (Fiber Explorer, Polarization Controller, Group Delay Tracker…). The new OPD controller processes the information of the PSSM and send commands to the actuators (PZT if the STS is the source, OPLE if the sky is the source). The OPD Controller is also filling a third Shared Memory that is used by the commissioning real-time display GUI (not based on CHARA socket). This OPD controller is built on the principles of the GRAVITY fringe tracker (Lacour, 2019). The OPD controller also implements a prototype of CHARA server, accepting basic messages and sending status. This is used to display information in a CHARA-compatible GUI and in the header of the MIRCx FITS files (only gain for now).

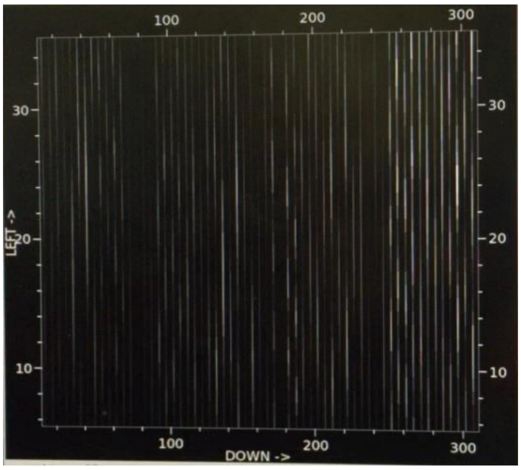


Figure 4: The 60 dispersed outputs of the SPICA-FT chip with GRISM190. Dispersion is vertical and the 60 outputs are separated horizontally by 5 pixels each. These 60 outputs represent the four ABCD signals of the 15 pairs generated by the 6 telescopes. The four outputs on the right of the image corresponds to ABCD of baseline Beam1-Beam2. Fringes appear as the modulation along the spectrum and as the differences of these modulations between the four ABCD signals (phase shifts of $\pi/2$ between the ABCD).

6 Achievements

An example of the new images on the CRedOne detector is presented on Figure 4, with the GRISM190. The configuration of the detector has been defined and saved for the GRISM190, the PRISM22, and the PRISM50. We also recorded a configuration allowing to record J band and H band with PRISM50.

6.1 Fluxes of the ABCD chip

After the correct estimation of the P2VM we used the fiber explorer to get an estimation of the flux measured through the chip and we compared them with the measurements made on MIRCx before the change:

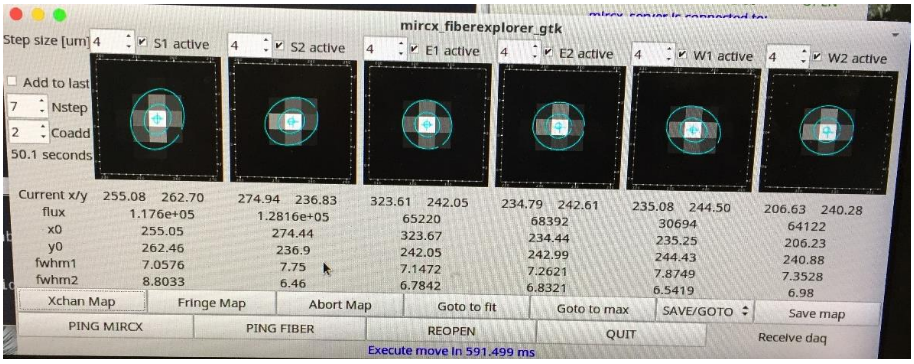


Figure 5: Result of the Fiber Explorer on the ABCD Chip

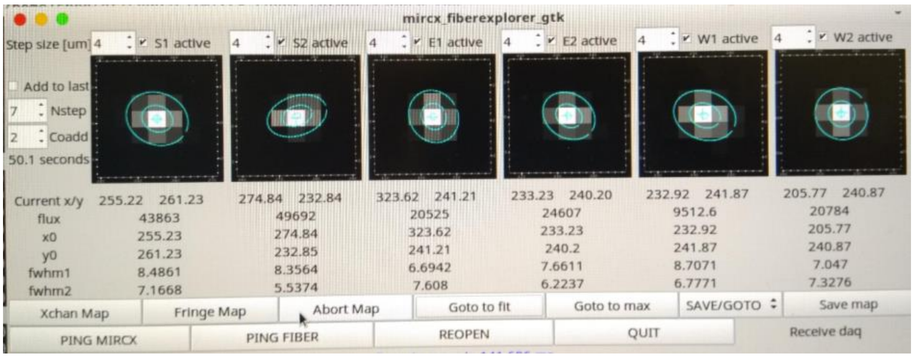


Figure 6: Measurements made on MIRCx before changing the fibers

MIRCx is using 20% of the light for the photometric channels (Kraus+2018). From these numbers we can compare the flux in SPICA and in the total flux of MIRCx. We obtain a mean value of 0.58 which is coherent with the estimated transmission of the chip.

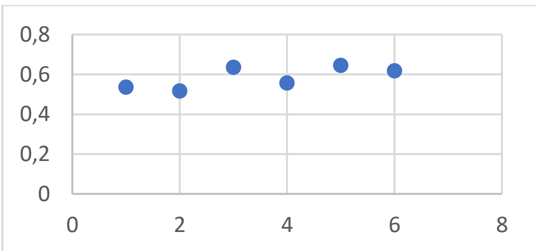


Figure 7: flux ratio between SPICA and MIRCx-total for the 6 beams

6.2 Correction of the birefringence of the SPICA-FT fibers

We were also able to optimize the contrast with the polarization compensators, beam4 being taken as reference beam. This measure has been made with the GRISM190.

	Beam1	Beam2	Beam3	*Beam4*	Beam5	Beam6
MIRCx	257899	240520	243088	*247075*	235647	248419
SPICA-FT	262899	245520	246088	*247075*	240647	245419

Figure 8: Position of the birefringence plates

The two positions are therefore very close. They typically correspond to $\lambda/10$ in the sinusoidal pattern of contrast. This is interesting to know with respect to the length equalization of the fibers.

6.3 Estimation of the P2VM matrix

Thanks to the python code developed by PB, we have been able to correctly estimate a P2VM matrix for the Grism190 and the Prism22. The second one has a little bit more contamination than the first one. The procedure is now well established with the PZT modulation.

There are still some problems with some spectral channels on some P2VMs. This generate significant cross-talk between the beams. We may need some quality criteria to assess if a P2VM is acceptable to be used for operation. A useful check is to apply the P2VM to the background file and checking the resulting telescope fluxes are all 0.

The use of the P2VM in the MIRCx code will have to be clarified/simplified for operation.

6.4 First estimation of performance of the new OPD controller

The main development made for this run was the new OPD Controller based on the model developed for Gravity. Thanks to the STS and the new piezo stages we have had the possibility of testing it. The parameters of the OPC_controller loop are:

- the gain of the loop (on the error). After iteration it looks like we are able to reach a gain of 0.15-0.2 without introducing oscillations. This gain permitted to record close-loop and open-loop measurements for the estimation of the transfer function. This work permitted us to catch all the potential hardware and software issues and ended with an estimation of the transfer function well modeled by a pure integrator and a delay of 3 frames. For this purpose, we used an exposure time of 2.7ms and a coherent integration of 3 frames (see Figure 9). It should be noted that, by experience, the PZT of the STS are not able to run faster than 200Hz. The delay of 3 frames comes probably from the communication with the PZT. The computing time of the PhaseSensor/OPDC is small (less than 3ms). Additional tests will be done in order to fully characterize the timing of the control loop.
- the threshold on the variance of the phase delay, defining the level at which the state of one specific baseline is switching from tracking to searching. Searching is not yet implemented.

With the low resolution (PRISM22) we noticed some difficulties related to the use of the reference vector in the computation of the GD. This reference vector intends to take into account any instrument or astrophysical non zero closure phase perturbing the tracking. With the current chip and its large internal non-0 closure phase, the reference vector is evolving rapidly depending on the number of open shutters. The behavior of the tracking could also be erratic if beam1 is lost, as beam 1 is playing a particular role in the reference vector. This will have to be fixed for the future.

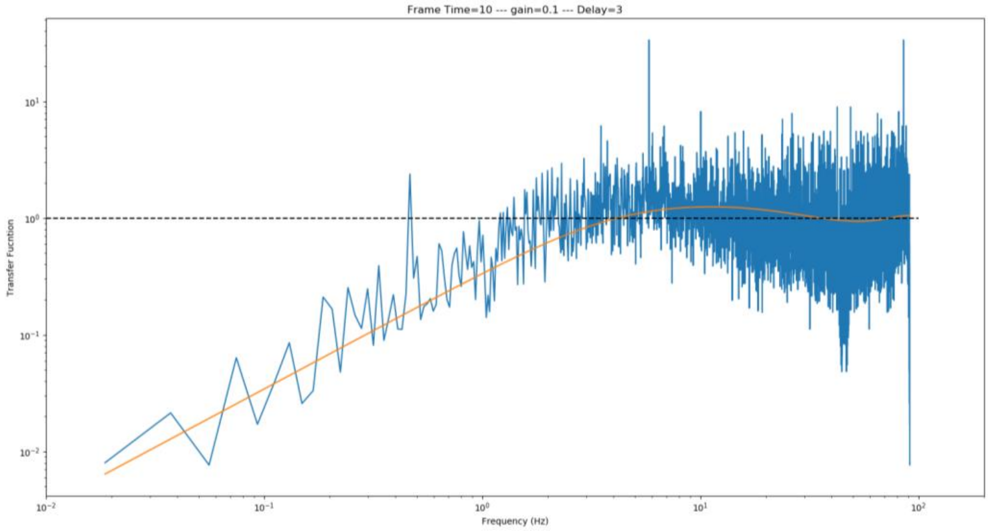


Figure 9: Transfer Function of the control loop with STS - Comparison with the transfer function of a pure integrator with a delay of 3 frames and a gain of 0.1

On the STS, closed loop on all 6 beams have been realized in the different spectral configurations (GRISM190, PRISM50, PRISM22) of the H band.

6.5 J band measurements

With the PRISM50, we have been able to record simultaneously the J and H bands. A raw image and a spectrum are presented below. A fine tuning of the focalisation will probably necessary. Fringes in J and H bands seem very close in phase, the data processing will help in quantifying this effect.

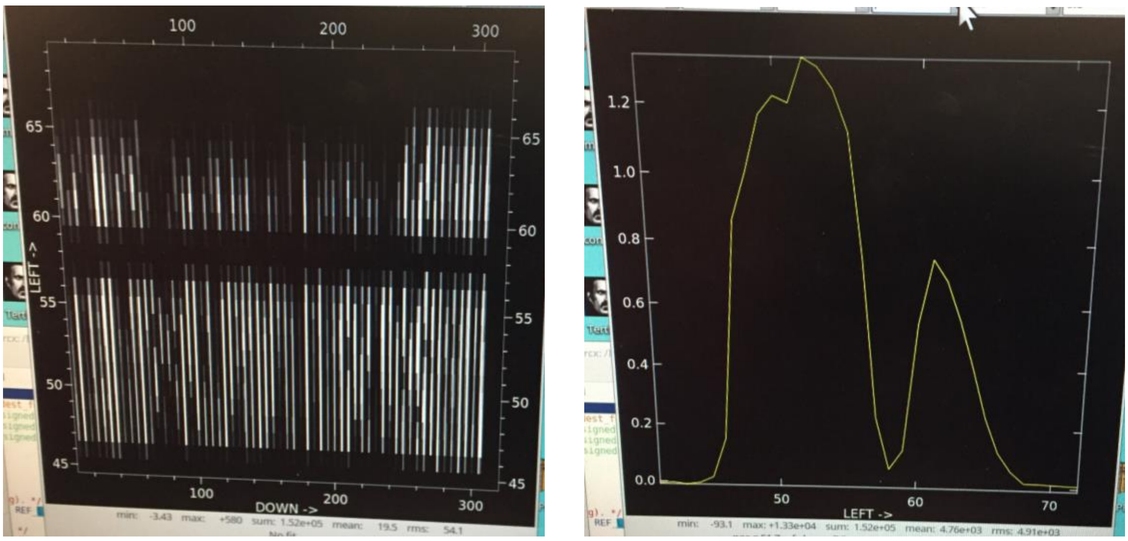


Figure 9: Raw image and spectrum with PRISM50. J band is on top (left figure) and on right (right figure)

7 On sky tests (UT 22 Jan 2020)

During the last night of the run, we observed two stars (H=3 and 4.5) for a few hours using E1W1W2S1E2 on beams 12356, S2 being unavailable. Despite the difference of alignment between the STS and the sky beams, we had no problems to find the beams with the fiber explorer. We had some difficulties with some beams (E2, S1 mainly but also E1) presenting very low flux, clearly related to the misalignment (poor centring of the beacon on the LABAO) or poor behaviour of the beams with the TELAO (S1E1E2). Fringes have been found almost at their expected offset, except for W1, the reason being that the LDC was let in the beam on this line….

Unfortunately the link between the new OPD controller and OPLE was not tested enough in the previous days and we were unable to close the group delay loop with the new controller. We used the classical MIRCx GD tracker and used the OPD controller and its real time display to analyse the behaviour of the system.

The chip encoding, the P2VM decoding and the whole software architecture work very well and faster than the MIRCx GD. The time frame was set to 2.8ms and a coherent integration of 2 frames was used. The OPD controller is able to follow this rate. We will of course have to characterize the behaviour of the new OPLE controller to correctly characterize the control loop.

One of the main lessons learned during the night is the importance of a correct evaluation of the variance of the phase delay to feed the state machine deciding if fringes are locked or if they should be searched again, including a necessary temporization before the decision. It is also understood that the group delay loop should not try to control the OPD at a fraction of lambda.

The OPDC GUI should be developed with the possibility of closing and opening the loop, modifying the gain and the threshold (done), but also with the required parameters to temporally filter the computation of the variance, of the group delay. With this tool in hands and the link between the OPD controller and the delay lines, it will be possible to characterize correctly the transfer function and to optimize the control loop.

Data and a dump of the OPDC Share Memory have been recorded for further analysis.

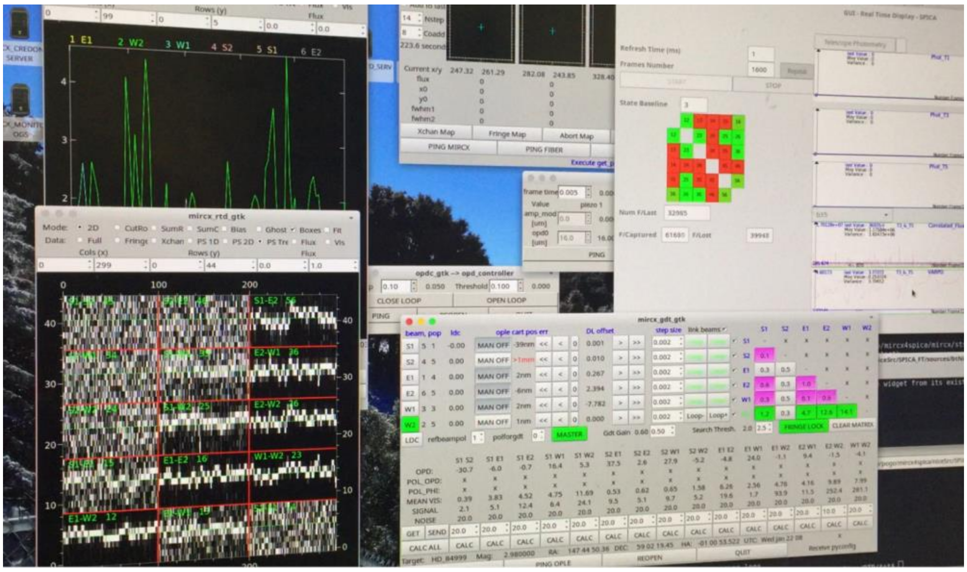


Figure 10: Left and bottom: MIRCx-RTD (15 waterfalls of Power Spectrum): 10 fringes are seen in this part of the figure. Bottom Right: the MIRCx GDT allowing to control the servo loop on the delay line: again 10 fringes are either green or pink (depending on instantaneous SNR). Upper-right: the RTD of the OPDC as developed for the integration and the tests and presenting detailed plots of the photometry, the variance of the phase, the group delay… and the status matrix.

As a conclusion, the system behaves very well with potentially nice performance. Transmission, internal contrast of the chip are very good and the power of the OPDC is really impressive. The system is ready for operation, although additional developments are of course necessary. They are presented in the last section.

8 Next steps

1. Merge the software of btNice/ and mircx/ repository so that one can deploy sources easily. For now, the/ location of btNice with respect to mircx/ is hardcoded in Makefile. And it cannot compile as pogo but it is ok if one compiles as spooler and install as pogo.
2. More sky tests for a full characterization of the transfer function of the system with the delay lines and their new control system currently under implementation.
3. Continuation of the tests with the STS (or the Nice testbed) for the characterization of the timing in the control loop (exposure - frame grabber – Phase Sensor – OPD Controller – Command sent – Command received - Command executed). For this we plan to different kind of remote tests:
    a. Use of the STS remotely from Nice to continue the characterization of the different delays in the loop and to validate the operation of the OPDC GUI (control and RTD).
    b. If possible, with two beams and the CHARA reference source in AutoCol with the corner cubes, test of the OPDC – OPLE dialog and first performance.
4. New chip will less internal closure phase and better balance.
5. Better management of the reference vector (what to do on this vector, when).
6. Improvement of the Ncoh parameter of MIRCx: why Ncoh=1 is not possible?
7. Search function and state machine Track-Search to be implemented and tested.
8. Phase delay estimation
9. Kalman filtering
10. Preparation of the May run (6 nights MYSTIC followed by 5 nights SPICA, so some overlap is interesting to organize)
11. SPIE paper (Pannetier+)

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