SALT Edge Sensor (SAMS) Project

– SALT Board Meeting #35 Report –

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Executive Summary

Developments since the Oct 2013 SALT Board meeting (#34) have been included in reports for BEC meetings #52(Jan), #53 (March) and #54(May) and can be summarized as follows:

- Phase 1 sensors (24 pairs) and hardware has been delivered after first phase of FAT held at Fogale
- Full hardware and environmental characterisation of sensors currently underway
- Initial test results show sensors to be within specification
- Some further software development needed on both control and embedded s/w
- Installation and commissioning on telescope is imminent

Progress Reports

We summarize the progress on SAMS in this report as follows:

1. Status update since Board meeting #34 (25 October 2013), reported at BEC #52 (January 2014)
2. Status update at BEC #53 (March 2014)
3. Status update at BEC#54 (May 2014)
4. Status update since BEC#54

1. Progress reported at BEC #52 (January 2014)

Following on from the report at the Nov Board meeting, intensive testing has continued both at FOGALE and SALT, particularly long term (5-13 day) continuous sensitivity tests. Our investigations have highlighted some issues relating to the FOGALE testing, mostly a consequence of the somewhat inferior test setup (compared to ours at SALT). This has meant that some hysteresis/repeatability effects have been seen in FOGALE's testing, albeit at a low level, which is likely to be due to their test set up rather than the sensor itself. That said, the sensor test results indicate that the sensors are performing within specification and the long term sensitivity tests are very encouraging. However, we desire to know as much as we can about the sensor's performance during Phase I (culminating in the delivery of the first batch of 24 sensor for the 7 segment sub-array test), so we are doing as much testing as we can at this stage to mitigate any technical risks.

To ensure success and reduce technical risk, the Factory Acceptance Test (FAT) has now been divided into a provisional FAT, to be held at FOGALE, followed shortly thereafter by a final FAT at SALT. This was jointly decided given the inconsistencies mentioned above in the environmental results collected at FOGALE, where their experimental setup is thought to be responsible. All 3 sensor pairs intensively tested at SALT have not shown the same issues and are all comfortably within the overall error specification.

Progress with SAMS since the Board meeting in November 2013 can be summarised as follows:

1. Work has been ongoing on the characterisation and validation of the 3 sensor pairs sent to SALT.
2. We've independently shown the temperature sensitivity to be linear and repeatable over all temperature regimes including sub-zero temperatures. There is no long-term change in the behaviour of the sensor.
3. The relative humidity (RH) response has been reduced and made very repeatable after some improvements to the connector and cabling. We've tracked down two exposed joints introduced during the assembly of the sensor. After some experimentation sealing them with conformal coating and epoxy, we have eliminated the sensitivity completely on 1 sensor pair and reduced the residual error to 5nm on the other 2 pairs.
4. All 3 pairs we've validated and characterised comfortably meet specification under all environmental conditions.
5. The remaining sensors (21) required for phase 1 are being validated at FOGALE's facility in preparation for the FAT. An ongoing problem has, however, been the inconsistency of their results. We are certain that their experimental setup is largely responsible for this. To accelerate the completion of the FAT, a decision has been jointly made that we validate the sensors at SALT using our test facilities over which we have better control.

6. FOGALE will continue to validate other aspects of the specification requirements, including EMI sensitivity, dynamic response, metrology and temperature sensitivity. This provisional FAT will take place in mid-February as a precursor to the final environmental validation at SALT, which will conclude the FAT portion of phase 1.

Key future milestones:

a. Delivery of all the hardware (sensors, electronics, cabling) is scheduled to take place end-Feb.
b. The final portion of the environmental testing at SALT for FAT is expected to take approx 3-4 weeks.
c. Installation of hardware on the telescope, commissioning and testing early April.

2. Progress reported at BEC #53 (March 2014)

1. Factory Acceptance Testing

The Factory Acceptance Test (FAT) for SAMS Phase 1 (7 segment sub-array) was held at Fogale from the 12 – 15 March, at their facility in Nimes, France. By agreement with Fogale, this is considered to be a preliminary test and final acceptance depends on the outcome of further tests to be conducted at SALT with the final hardware during April.

The following items were addressed over the 4 days:

i. Review of environmental test results against specification (understanding the disparity with test results obtained at SALT)
ii. Assessing the test equipment and their uncertainties
iii. Investigating the apparent difference in performance achieved at Fogale vs. SALT
iv. Sensor bonding training; sensor bonding accuracy
v. Testing and reviewing the dynamic metrology tests
vi. Software integration of the new MARS software with the recently completed rack containing the 8 x 3-channel modules (to support 24 edge sensor pairs).
vii. Investigating the linearization algorithms and their implementation in the software
viii. Review the reports and test results on other aspects of the system eg. EMI, sensor bonding accuracy
ix. Software training on the programming software required by the modules and the rack

2. Review of Test Results (Items I, II and III)

Tests were conducted each day using Fogale’s environmental setup, aimed at establishing cable and electronic module dependence and repeatability of sensor sensitivity to temperature variation.

The tests generally showed that the performance of the sensors was independent of the 3 channel cables and electronic modules. These tests revealed that the single channel electronics used at SALT were largely responsible for the difference in apparent behaviour between Fogale’s and SALT’s test results.

The 3 channel cable setup required by the new 3 channel amplifier modules uses an additional DB25 metal connecter. It was found by experiment that it was sensitive to mechanical shock and steps are being taken by Fogale to mitigate this effect on the delivered system by better isolating the receiver and transmitter sections.

The 3 channel cable includes 3 twisted pairs for the receivers, each of which has a stray capacitance. Automated testing of the cables using the instrument illustrated in Fig. 1 revealed that, for all the cables in the batch being used by Fogale, 1 channel has a different capacitance from the other 2, not unexpectedly given the manufacturers stated tolerances. This has a very small, but perceptible, effect on the measured temperature sensitivity of a sensor which Fogale are taking steps to remove by making a simple modification to the cable connector (mounting small surface capacitors).

Any remaining uncertainties about the quality of their experimental test setup should be removed during the characterisations to be performed at SALT.

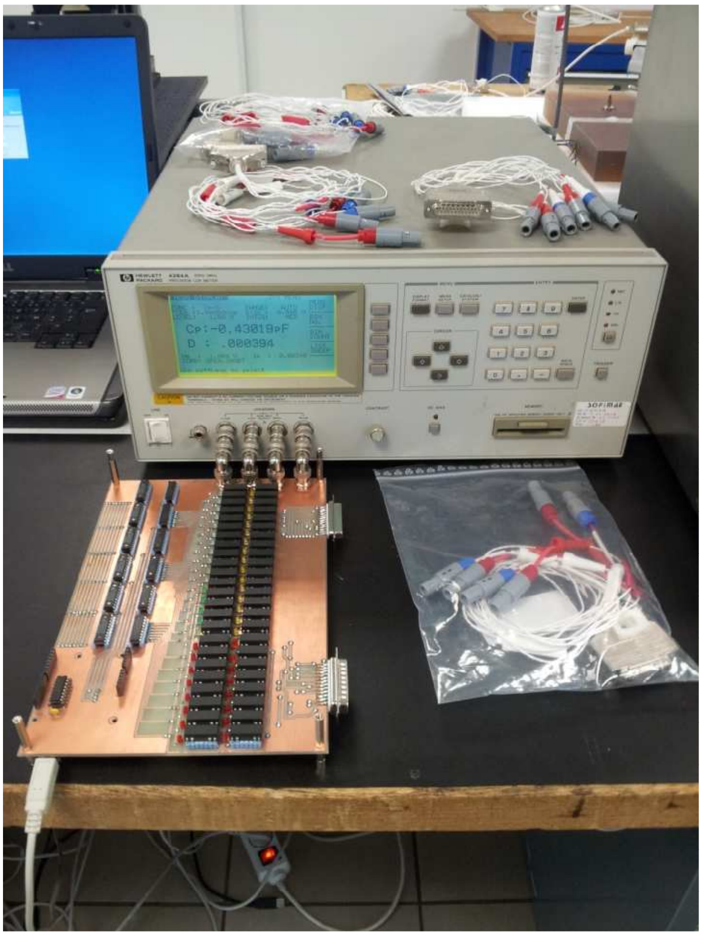


Figure 1: Cable characterization instrumentation

3. Sensor Positioning and Bonding (Item IV)

The sensor bonding process using the developed tool was reviewed and HG was trained in the use of the bonding jigs and optical alignment tools required by the process.

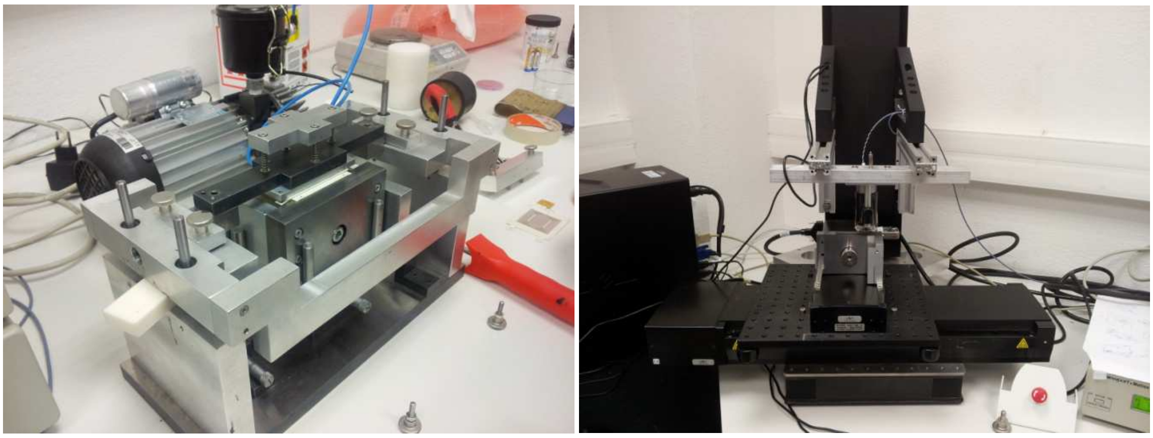
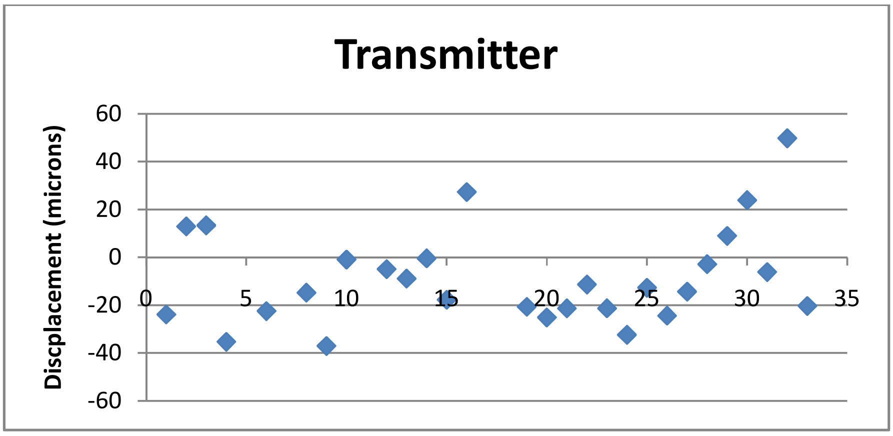


Figure 2: Sensor bonding tool (left) and Optical validation test (Right)

The validation tests of the position of the flexible sensor with respect to the L-bracket were performed with the tool shown on the right in Fig.2, namely an accurate XYZ stage with a microscope camera.

We are confident that the sensors for subsequent Phases of the project can be bonded to within the required tolerances at SALT by a technician, after a short training period. The critical positioning parameter is static twist, which adds a measurable dynamic offset to piston when combined with shear. The error budget places a limit of ~30μm on the twist position of the sensor. All of the 24 sensors destined for Phase 1 were shown to be within specification with respect to shear, piston and twist. The twist displacements measured for the receivers and transmitters are shown in Fig. 3.



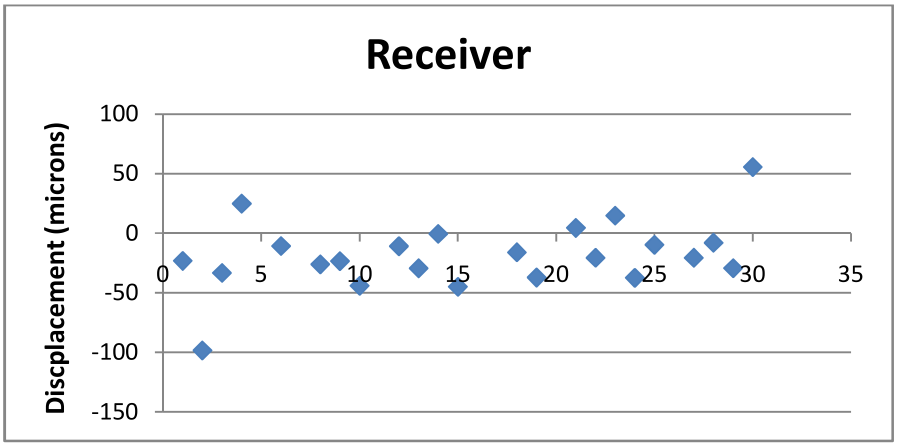


Figure 3. Measured twist displacement

4. Metrology Data (Item V)

The Piston dynamic response was verified using a translation stage (Fig. 4) over the specified working range of 1.6mm.

Figure 4. Dynamic metrology test stage

The large range of piston explored necessitated a large step size to determine the linearity over the entire range. The linearity achieved over the range +/- 500 µm is +0.04%/-0.08% which meets specification of +/- 1% over the gap range 2.5mm to 4.5mm, as shown in Fig. 5.

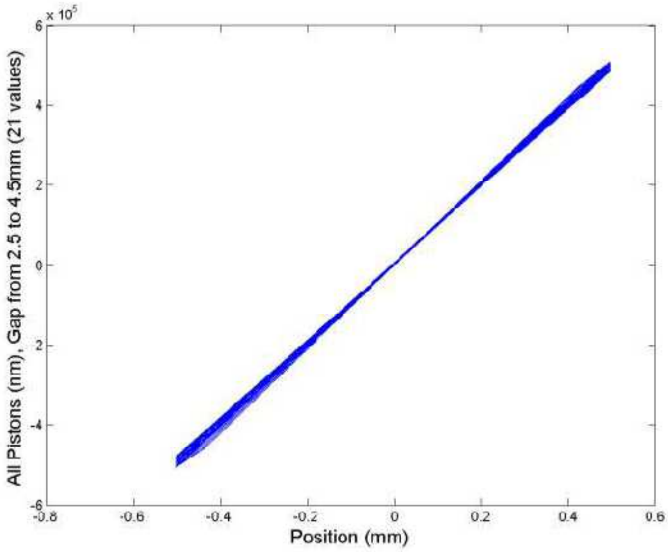


Figure 5. Piston linearity results for various gaps

5. Software Integration (Item VI, VII)

The new SAMS software (now called MARS) was successfully integrated with the rack hardware for the first time (the software was developed using a hardware simulator). During discussions covering the linearization of the sensors, additional aspects of the algorithm came to light that will require implementation in the software.

6. Reports and Manuals (Item VIII)

The following manuals and reports were presented and reviewed at the FAT:

i. Factory Acceptance Test Report

The FAT Test report includes environmental, metrology, long term drift and noise data collected by Fogale for a subset of the Phase 1 sensors. The report shows all sensors to comply with the overall error budget for the sensor. The data presented in this report will be verified for all 24 Phase 1 sensors at SALT during the characterisation process.

ii. Operating Manual of the Racks and Module Systems

The operating manual supplied covers the setup and programming of the individual amplifiers modules (gain, offset etc.) and the rack. A troubleshooting guide will be included.

iii. Bonding Manual

The bonding manual was reviewed during the training bonding process and is being updated following our suggestions.

iv. EMC Test Report

The EMC test report showed that after some small corrective actions to the rack power supply, found to be responsible for a deviation in radiated emissions at a single frequency, that the rack now meets all EMC criteria for both emission and immunity.

7. Fogale: Immediate Future Work

i. The PCB inside the connector will be redesigned to separate the receiver and transmitter connections so as to completely eliminate the possibility of cross-talk inside the connector described earlier.
ii. Provision for surface mount capacitors will be made to balance any difference in capacitance (at the few ten pico (10^{-12}) Farad level) between receiver lines in the same cable, effectively removing any dependence on cables or electronic modules.

8. SALT: Immediate Future Work

i. Rack, sensor cables, sensor block and 24 sensor pairs will be shipped to SALT next week (31 Mar).
ii. Environmental characterization of 24 sensor pairs will then commence at SALT, with a conservative estimate of ~6 weeks for completion.
iii. Software changes to incorporate new linearization algorithms.
iv. Place all project documentation under config control (SALT generated doc already are) and establish a relevant project repository
v. Completion of button bonding jigs following modifications of the prototype
vi. Liaise with Tech Ops regarding planning the procedures, manpower and scheduling of the installation of Phase 1 sensors
vii. Bond buttons to segments
viii. Install the Phase 1 sensors (beginning in May)
ix. Commission system on telescope (~June)
x. ATP of Phase 1 system (July)

3. BEC #54 SAMS (May 2014)

- Hardware including all electronics, sensors and sensor blocks arrived.
- 18 of the 24 sensors have undergone initial temperature characterisation testing in preparation for installation on the telescope.
- The balance of the sensors will completed shortly

- Environmental testing shows 16 of the 18 sensors tested thus far to be within temperature sensitivity specification.
- Commissioning the new 3 channel hardware has highlighted some software deficiencies within the Labview interface in the management of data. This will need some additional software development, which is currently underway.
- A few additional issues have also arisen whilst commissioning the new hardware which we're in the process of resolving with Fogale:
  - The new version of the cabling required by the 3 channel hardware includes a PCB which may make the sensor more sensitive to RH when compared to the single channel cable we've used during testing.
  - Aspects of the data being broadcast by the rack are not consistent, fixes to the embedded software are required. We have the equipment needed to apply the code.
  - There is some intermittent measurement noise in the piston measurement
- Completion of all environmental, hardware and software tests is dependent on the outcome of the tests currently underway. Expected completion early June.
- Installation of buttons and sensors on telescope expected mid June.

4. Progress since BEC #54

Sensor testing

All 24 sensors have been characterised for temperature sensitivity. One sensor is unusable due to severe temperature sensitivity; the other 23 sensors are within specification for temperature sensitivity. One of the sensors tested extensively in the past can be substituted for the bad one to make up the 24 required for the first phase.

The remaining cables with the new updated PCB have been manufactured and are due to arrive end May.

The validation of the Phase 1 sensors is thorough in order to validate the new electronics, cabling and sensors completely before installation. The remaining validation tests required are as follows:

i. RH sensitivity tests with the new cabling and PCB
ii. Verification that all modules and cabling are interchangeable and produce consistent results for any given sensor.
iii. Bug fixes to the embedded software to correct data inconsistencies
iv. Track down source of intermittent burst noise in the piston data

Phase 1 Priorities

The following are the priorities towards the completion of phase 1.

i. Complete the environmental characterisation of 24 sensor pairs.
ii. Complete the validation of electronic hardware and software

iii. Remaining jigs required for button bonding are being manufactured; once complete, the process of bonding buttons to segments can begin.
iv. Complete the development of the control software incorporating changes required to correctly interface with the hardware
v. Bond buttons to segments
vi. Draw up official ATP test document
vii. Install the Phase 1 sensors (beginning in June)
viii. Commission system on telescope (July)
ix. Develop scheme for the in-situ calibration of sensors
x. ATP of Phase 1 system (July/Aug)

ATP Testing

The commissioning of phase 1 will compromise the following:

1. Initial calibration of the sensor to determine initial piston offsets and range

2. Fine in-situ calibration of piston over a reasonable temperature range to establish temperature correction term including second order effects (in-plane motions). This will require dedicated engineering time using the CCAS instrument to monitor the primary. A temperature span of at least 5°C is needed.

3. To establish the performance of the sensors over the entire environmental range the system will run in closed-loop sensor control and its performance gauged at regular intervals as part of the normal operational CCAS alignment routine.

A formal test document detailing the tests and pass criteria is in the process of being drawn up.

Risks

- Temperature sensitivity does not remain constant with time (unknown ageing effects) leading to occasional recalibration.
- Sporadic noise visible in the piston data with the new hardware, whose exact source (data, electronics, environment) is still not clear, may affect stability of the system.

Schedule

Key milestones towards the completion of Phases 1, 2 and 3

Task	Expected Completion
Button bonding	Early June'14
Sensor Characterisation/hardware validation	Mid June'14
On-telescope commissioning	July'14
Atp Phase 1	July-August'14
Initiate Phase II	August'14
Manufacture, install and commission 156 sensors	August'14 – Jan'15
ATP Phase II	February '15
Initiate Phase III	February '15
Manufacture, install and commission 300 sensors	February '15-August '15
ATP Phase III	September '15

A contract with Fogale began in July 2012 with envisaged project duration of 22 months ending May 2014. The best estimate predicts a project end in September 2015, this represents a project slip of 16 months.

Every attempt will be made to reduce the manufacturing times within phases 2 and 3 to lessen the overall project schedule slip.