TITLE: **RSS COLLIMATOR REPAIR: STATUS REPORT MAY 2014**

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1 Project Status Summary

We are currently at the detailed design phase of the development of the new lens cells and barrels for the new optics. These comprise the doublet and the triplet. The only other collimator optic involving fluid is the field lens. It was originally decided NOT to include this in the scope of work because its measured throughput was not very badly reduced at the time the project got the go-ahead (about 2 years ago). Since the previous Board meeting work has proceeded fairly smoothly albeit slower than anticipated. The project has passed several critical milestones on the development path for the new doublet and triplet groups. Below is a list of the work completed to date:

- Concept Evaluation Review (CER) passed for Triplet Opto-Mechanical Design.
- PDR, CDR and Industrialisation phases passed for the Rotation Stage Assembly.
- Specification Review for Triplet, Doublet and Main Group Tolerancing.
- Development of an interferometric test for the alignment of the Triplet with remaining lenses in the Main Group. **(This test will allow compensation of errors in triplet alignment)**
- Completion of the Alignment Telescope characterisation and integration with a camera.
- CDR Throughput Measurement System optical design
- PDR Throughput Measurement System mechanical design
- CDR Alignment Frame Modifications
- CDR Alignment Telescope Focus adjuster.

The following milestone are in advanced stages of completion work.

- CER of the Doublet Opto-Mechanical design.
- Review and Approval of Lens Alignment Procedure.
- Triplet cells and barrel manufacturing process qualification.

In March, we requested Lisa to repeat the throughput measurements on RSS to determine whether the degradation of the throughput is stable. This was done as a sanity check to confirm our understanding of the failure i.e. that droplets bubbles arising from the immiscibility of the old and new fluids is leading to scattering of the light and the concomitant loss of throughput.

The results were not good and indicated a major drop in the field lens throughput as can be seen in Table 1. Lisa's measurement was a shock and forced us to reconsider the explanation for the second round of throughput failure (i.e. over the last 2 to 3 years), and what other factors might be at work. Therefore we currently cannot claim to understand the throughput failure and might build new optics, based on the original design, which will pass throughput measurements when completed, but

decline steadily but slowly thereafter so we end up in the same place in 2 years. Thus work on the main packages has currently halted. Lisa and Éric Depagne (new RSS Scientist) also found a bubble in the collimator doublet and degradation of the Sylgard bond surrounding the element. This bubble was not present at the previous inspection of the instrument in December 2013 and no sign could be seen of leaking fluid. We think that the Sylgard bond, surrounding the lens, might have failed and allowing air to be drawn into the system. However we cannot say with certainty till we have inspected the Doublet on the ground.

Table 1: RSS Throughput by laser measurement.

Group	Wavelength	Transmission 2012 [%]	Transmission 2014 [%]	Delta [%]
Field lens	Blue	79	60	**-19**
	Red	92	79	**-13**
Main Group	Blue	69	70	+1
	Red	65	61	-4
Doublet	Blue	68	69	+1
	Red	100	100	0
Camera	Blue	78	80	+2
	Red	78	80	+2
Tests by Lisa Crause and Eric Depagne.				

Please see Lisa and Eric's report for more details and pictures. Thank you Éric and Lisa for making these measurement under difficult circumstances and for repeating the measurements.

2 Analysis

The figure below summarises the status of each of the fluid filled groups in the spectrograph. LL5610 is the original fluid used in all the groups. LL3421 was introduced into the field lens and triplet during the previous repair to improve the performance in the NIR since calculations had shown that the original LL5610 liquid has almost 100 times the emissivity of LL3421 at 1.7 µm.

Sylgard 184 is a silicone adhesive used to bond each of the elements into their cells. Each of the bonds are between 2 mm to 4 mm thick. Sylgard was chosen because of its very low viscosity before cure. This makes it easy to cast into liquid tight seal around the lenses. It is also one of the very few adhesives listed by the fluid manufacturer as *"compatible"* with LL5610 and LL3421. Compatible in this case means that the fluid does not degrade the material based on 10 month immersion tests and make no comment regarding the effects of the material on the fluid properties.

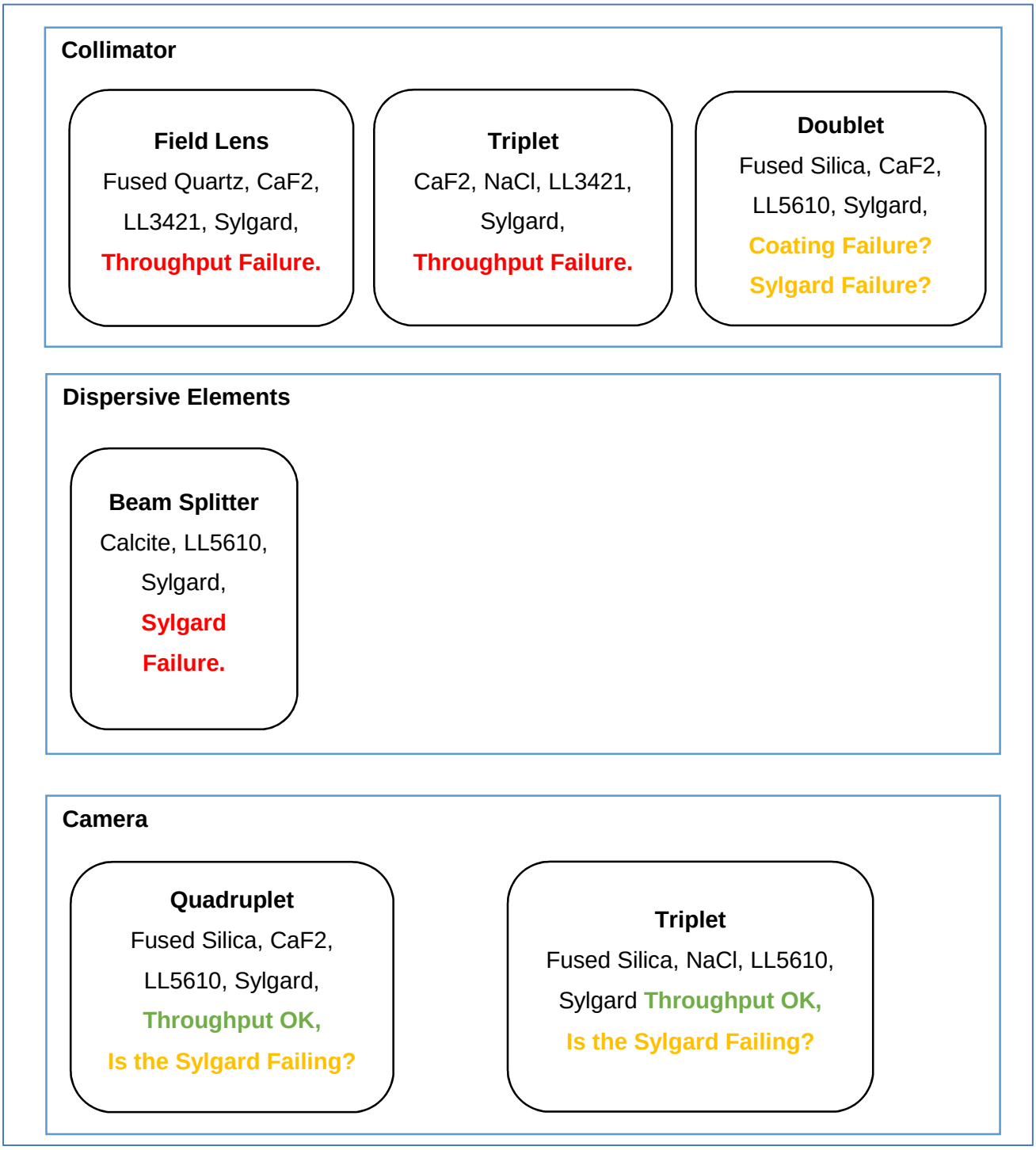

Figure 1: Fluid Filled Group Status Summary

We suspect that there are two failure modes at play.

1. Throughput failure of the groups coupled with LL3421.
2. Sylgard bond failure of groups coupled with LL5610.

2.1 The Throughput Issue

Both the groups filled with LL3421 have suffered throughput issues. The only other group with throughput failure is the Doublet in which the throughput deterioration can be linked to a coating failure. The throughput failure can either be attributed to deterioration of the optical properties of the coupling fluid or by the damage caused to the optical surfaces by the coupling fluid. The only way to discriminate is to replace the fluid in the field lens and the triplet with new fluid and test their throughput before and after. If the failure is linked to fluid degradation the replacing the fluid should **lead to immediate improvement in instrument throughput but only temporarily.** If the lens surfaces were attacked or clouded then replacing the fluid will have little effect. A CRUCIAL AND CERTAIN OUTCOME OF THIS IS TO TIE DOWN WHETHER THE THROUGHPUT LOSSES ARE IN THE FLUID OR THE LENS SURFACES.

2.2 The Sylgard Issue

There are four fluid coupled groups in RSS containing the LL5610 fluid:

- Beam splitter
- Collimator Doublet
- Camera Quadruplet
- Camera Triplet

Two of the four groups, Beam splitter and Doublet has suffered leaks, bubbles or deterioration of the Sylgard bonds holding the elements in their cells and coupling fluid in place. It is impossible to visibly inspect the bonds on the remaining two groups, the Camera Quadruplet and Camera Triplet, to tell if the bonds are degrading. So how do we determine whether the Camera bonds are being degraded? The only way to confirm the problem in the Camera is to chemically compare coupling fluid extracted from the Collimator Doublet and the Camera Quadruplet with new fluid to see if degradation of the Sylgard leaves traces in the coupling fluid.

3 Project Going Forward

These findings impact the project significantly which was reviewed by the project team and Ted, Darragh and David. The team agreed that to complete the tasks above we need to remove RSS from the telescope for a period of not more than four weeks. The 4 week time scale is driven by the need to remove all the collimator optics, measure throughput both with existing fluid, and no fluid, and replacement fluid, and put back on the telescope correctly aligned. None of this can happen for several weeks as preparatory work is needed to develop a removal plan sooner than we anticipated, including preserving the alignment of the existing optics, and complete the new throughput system which will provide measurements at multiple wavelengths, and not just 2 as is the case for the on-telescope system. We had never planned to touch the field lens and so this is also new territory.

The benefits of taking the instrument off the telescope are:

- We can get samples of the lens coupling fluid from all collimator multiplets to determine it's properties.
- We can get samples of lens fluid from the camera quadruplet to compare with the collimator doublet to possibly establish whether the Sylgard is degrading.
- We can change the lens coupling fluid and if the throughput loss is due to contamination of the fluid, we would:
    - Confirm this.
    - **Improve the throughput of the instrument dramatically (but on a temporary basis).**
- We can check whether the lens fluid is degrading the lens surfaces (this might be the cause of loss of throughput).
- Confirm the CAD modeling of the attachment of the optics to the instrument framework.
- Practice alignment of the optics (for when the new optics appears).

All round, instrument removal is essential to reduce risk to acceptable levels of failure of this project

Should the Board agree we will plan to do this around the beginning of July. This will allow enough time to prepare hardware and procedures. We also need to assemble and commission a throughput measurement system to enable us to measure the throughput at more than the current two wavelengths. This system is generic and will enable us to evaluate throughput for general optics and test optical transmission of materials.

The continued degradation of the field lens throughput raises significant questions about the current opto-mechanical design which we first have to answer before proceeding with the repair to the triplet. The bubble and possible failure of the Sylgard raises even more questions about the long term chemical compatibility of Sylgard and LL5610 as used in the doublet. Hence all work on the design of the new triplet and doublet has been stopped. We are proceeding with the coating of the lenses and manufacture of the rotation stage, a long lead time item which would be required in any case. The solutions will significantly influence the scope and cost of the project going forward. We do not have the information available at this point to determine the cost and will re-scope the project once we have more information. However performing an oil change on the field lens and triplet should improve the throughput of the instrument and buy us some time to develop the solution.

Let us also offer some comments on possible ways forward, which we have been debating ever since we received Lisa's results

- It could be that the existing plan (i.e. what we were pursuing before Lisa's results) can still go ahead. This proposal to remove the instrument will then result in a 2 month schedule slip on the existing plan.
- It could be that bonding the lenses with Sylgard 184 is indicated. This is what is used in SALTICAM - This is new territory for RSS which has much bigger optics.
- Replace fluid with air. This is a guarantee of no more failures. The downside is 8 more air-glass surfaces which, if coated with MgF2, would lead to 16 per cent loss. Might not be a bad compromise, considering the history of the instrument's optics. A big question mark over this is "Would the MgF2 on the NaCl element in the triplet protect it from moisture?". Only the triplet has NaCl, so this could be an option for doublet and field lens, if not the triplet. Darragh have explored, briefly, the sensitivity of the optical design to changing fluid to air. The existing optics and the new optics seem to be insensitive to such changes and all that is required are modest changes in spacings. But this is only a preliminary assessment.

So there are a number of possibilities for the way forward, though none of them is, at the moment, obvious and/or problem/risk free. The correct choice must be made.

4 Conclusion

To summarise then:

- Since the last Board meeting a large amount of work has been completed on the agreed scope of work.
- A measurement of the collimator throughput has caused a halt to the original plan due to substantial decline in the field lens throughput. Originally the field lens throughput had been considered acceptable and improving it was outside the scope of work.

- Extrusion of bonding agent and development of an air bubble in the collimator throughput has been found.

- We need to remove the instrument for 4 weeks and seek Board approval for this. Removal of the instrument would enable investigations to ascertain the causes of the problems discussed above.