Optical Contacting

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ABSTRACT

Optical contacting is a very interesting technology to realise stable assemblies.
We will describe the latest results that were achieved thanks to optical contacting with different unusual materials as Silicon, Silicon Carbide and present some examples of complex assembly:

1. Double Fabry-Perot qualified for space application
2. Stabilised bench for ultra stables wavelength lock-up system.

Keywords: Optical, Contacting, Stability

1. INTRODUCTION

Optical contacting has been used by optical manufacturer for a long time and is based on the fact that if two flat polished surfaces of good flatness and polishing quality are put in contact they will become a unique piece, due to the molecular attraction between the two surfaces. The only way to destroy this adhesion is by using thermal stress: heating one of the piece and cooling the other one can release the contact due to the effect of thermal expansion.

Repeatability and reliability of this type of contact are not experimentally well known. We will describe in this paper the results, which were achieved, particularly on materials like Silicon and Silicon Carbide.

Our level of repeatability and reliability in this field has allowed SESO to be qualified as a supplier of this technology for Space Programs.

Another improvement to this technology is to create an irreversible adhesion by creating real links between the two surfaces. We will present in the conclusion some of the results of this improvement.

2. SILICON AND SILICON CARBIDE CONTACTING

The main difficulty with these two materials is that they are not transparent and it is very difficult to observe the contact defects between the two pieces (mainly due to small residues of cleaning or dust).

We have developed two different technologies to control it:

2.1. Optical measurements

We measure the variation of transmission of the beam through the optical contacted joint.

We present, in figure 1, a device including 3 pieces, 2 prisms P1 and P2 and a window. P2 is a small prism, which is contacted against half of P1. If the contact between P1 and P2 is good, then a ray beam entering the prism as shown in P1, it will be transmitted in P2. If optical contacting is not well done, there is an internal reflection and the beam is reflected into P1.

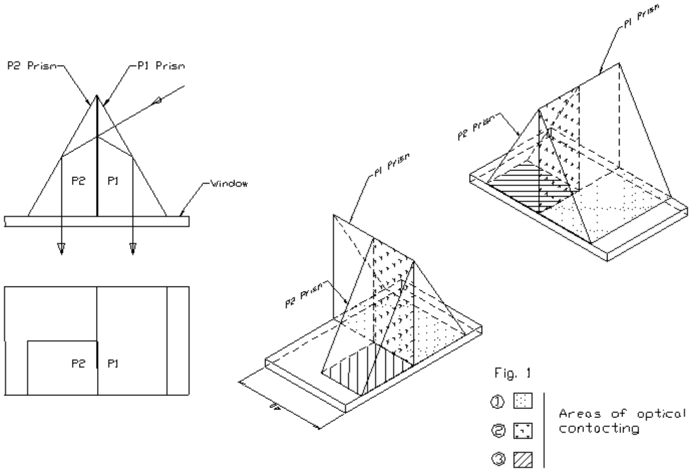

Figure 1: Device scheme

In order to check the optical contact, we have used the method of control, described in figure 2, using a He Ne laser at 3.39 µm, which is transmitted through the silicon.

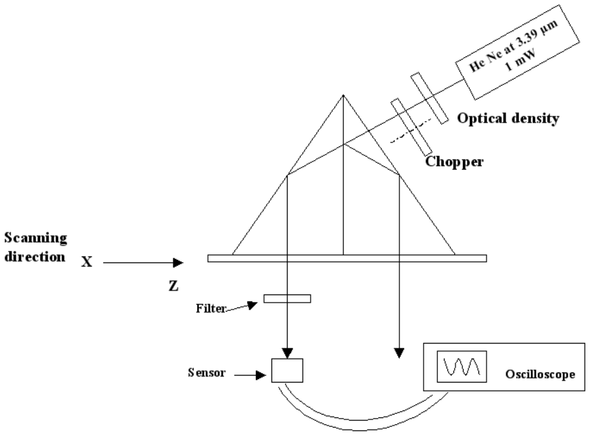

Figure 2: Control method

In case of complete non-contact on the entire beam diameter, the transmitted beam has about 50% of the transmission of the same area if adhesion is correct. So, if one is able to measure this transmission with an accuracy of 5 %, defects that are 10 time smaller that your beam can be detected.

The diameter of the beam, in our case, is 1 mm, which means that we can detect defects of the order of magnitude of 0.3 mm.

Results achieved: scanning the beam through the different areas did not allow seeing variation greater than the accuracy of measurement, which means than there were no defects greater than 0. 2 mm

The final validation test has been to plunge the assembly in liquid nitrogen to create a thermal shock.

Measurements were made after this immersion without any change on the cartography defects.

2.2. Ultrasonic measurements

This has been applied to SiC samples. These samples are flat samples of 30 mm x 30 mm in sintered SiC. They have been coated with a CVD SiC and polished down to a roughness better than 5 Å RMS.

After optical contacting they have been checked with an acoustic microscope. Here below (figure 3) we present results of such a test on two samples, one has a good contact, and the other has some defects.

We submitted these samples to the following test:
- Thermal cycles: -20°C to 60°C, gradient 30°C/h
- Thermal humidity 50°C/48 hours, Hr 95%.

Before test

Sample with good contacting

Sample with local contacting defects

After test

Figure 3: Evolution of contacting after thermal tests

An inspection was done after these tests and we have not seen any deterioration (figure 3). We then set up a shearing test. The results were very successful and with the bench we used it has not been possible to break the samples.

Forces applied on the samples described above were much higher than 1500 N and were maintained. The results achieved were very repeatable: on a batch of 10 samples the equivalent stress, which has been applied without breakage was greater than 4.0 MPa, with a root mean square at 1 σ of 0.4 MPa.

We have not been able to break the parts due to the limitation of our shearing machine.

3. SILICA AND ZERODUR

For these materials, we have tested 3 different kinds of samples, based on the combination:

- Silica-silica,
- Zerodur-zerodur,
- Silica-zerodur.

In that case, the optical contacting surface was 15x15 mm. Samples were polished down to a mean value of $\lambda/8$ PTV and a roughness of 5 Å.

Shearing test results are presented in figure 4, corresponding with tests results in table 1:

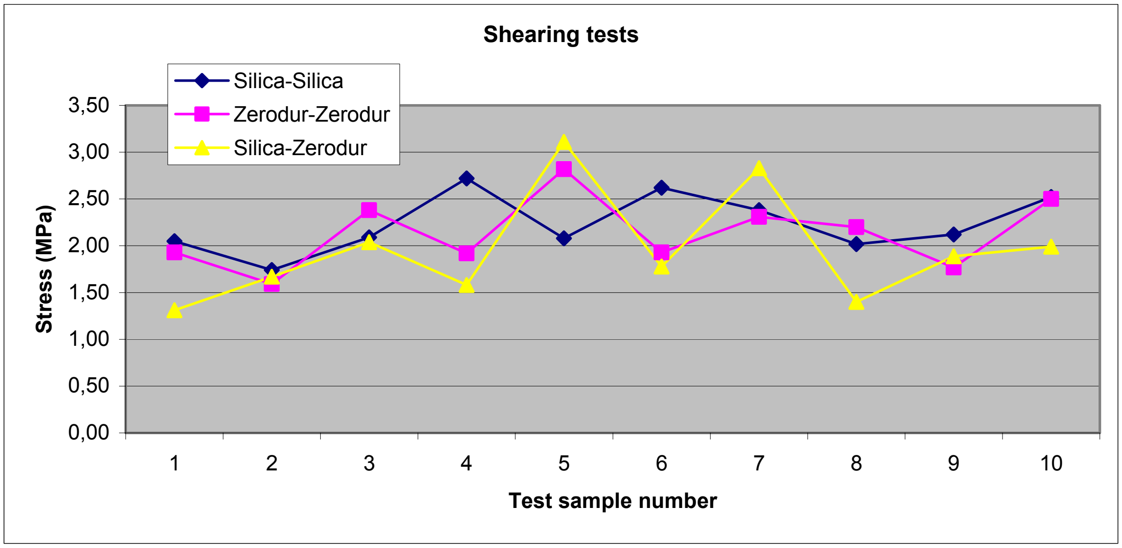

Figure 4: shearing test results

	Silica-silica	Zerodur-zerodur	Silica-zerodur
Mean value MPa	2.23	2.15	1.96
σ (RMS) MPa	0.3	0.37	0.59

Table 1 : Test results

3.1. Comparing these results to those obtained on SiC, we think that the difference is linked to the shape of the pieces. As we are applying the shear force near the optical contacting joint and due to the reduced section of the test samples, we think that the stress induced locally by the shearing machine is much higher in the area of contact between the knife of the machine and the test piece and this induce a local defect of the optical contact.

3.2. Adhesion is generally better for similar materials.

3.3 In all cases, test pieces have been able to pass successfully a shearing test corresponding to a stress greater than 1 MPa.

4. IRREVERSIBLE ADHESION

The results obtained previously can be reversible, which means that the breakage can occur on the optical contacting joint. This is particularly true if a thermal shock is applied on one of the two pieces and if the expansion coefficient is not the same. This can in some case be unacceptable, so we have developed an irreversible process for which the results are the following (figure 5):

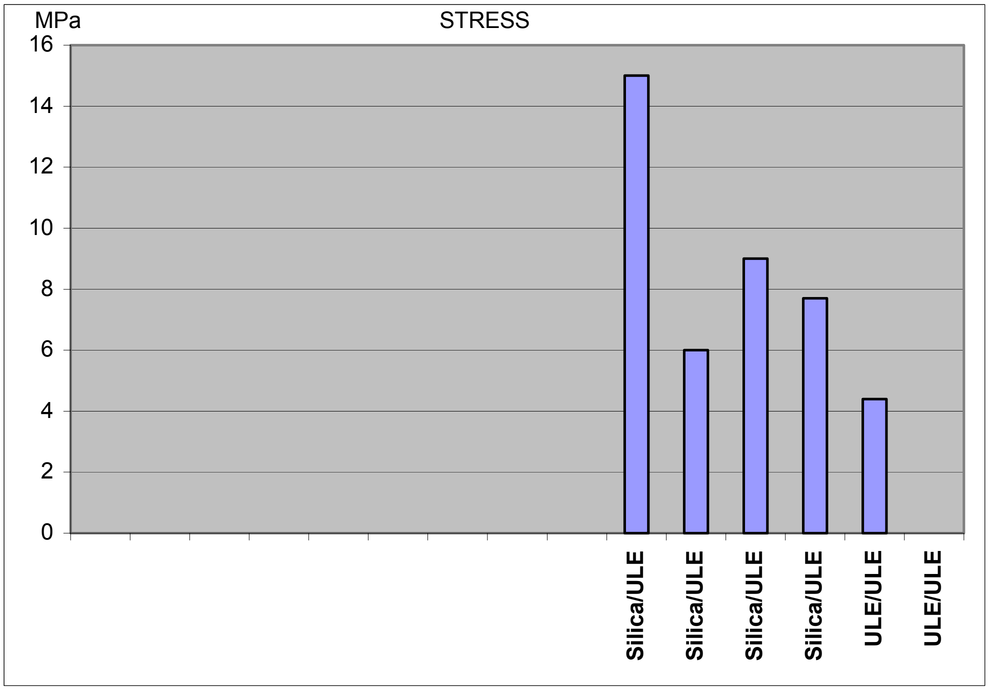

Figure 5: results obtained with an irreversible process

Those results are directly comparable to the results shown in the previous paragraph, so we can conclude that the shearing stress has been greatly improved up to 4 MPa (instead of a mean value of 2 MPa) and this is linked to the irreversibility of the process: each time the sample was broken in the glass and not in the optical contact joint.

5. EXAMPLE OF OPTICAL SYSTEMS MANUFACTURED:

Based on this technology, we have developed two systems: the first one has been made for ESA and ASTRIUM SPACE to qualify optical contacting for space application (Aladin Program, which has the goal to manufacture a space lidar to measure windspeed); the second one has been developed with ILGA Laboratory in OCA (Observatoire de la Côte d'Azur) with CNES support and would be part of the LISA program (figure 6), which is an interferometer between 3 satellites.

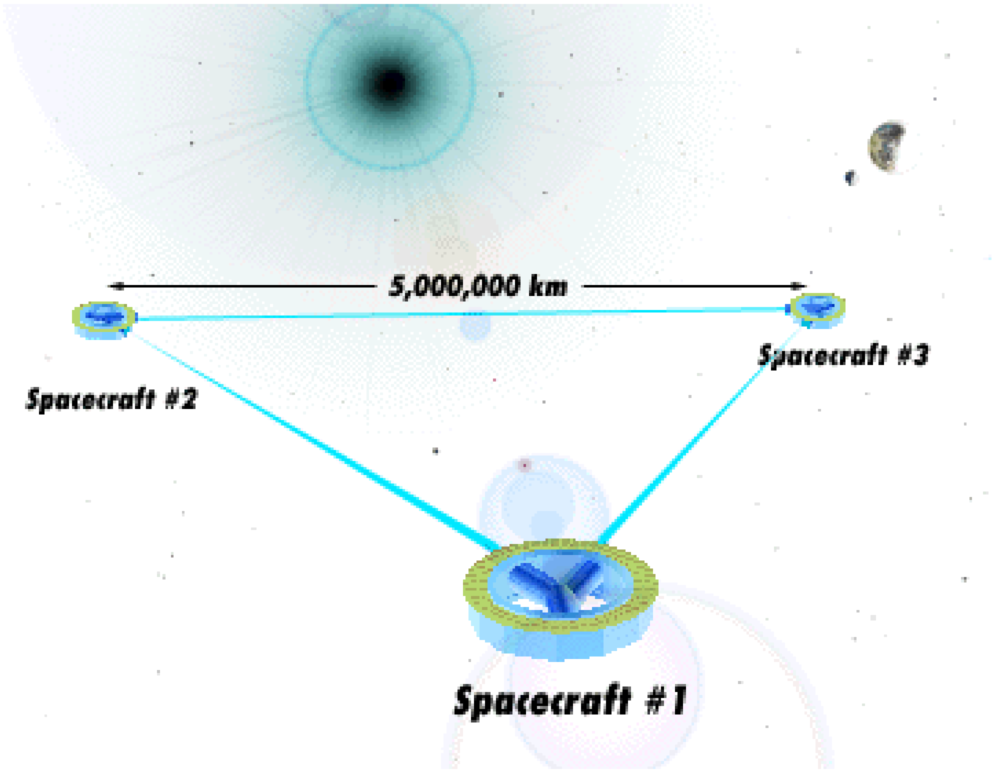

Figure 6: LISA program

The part, which is concerned by a stable assembly, is linked to the frequency stabilisation of the Nd:YAG laser.

5.1. Aladin Program

A scheme of the system is shown in figure 7. This includes:

- Double Fabry Perot with a difference of thickness of 80 nm between each. This Double Fabry Perot has been realised on the same cavity.
- 4 prism, 4 waveplates and one lens.
- A base plate and its fixture. The complete assembly is shown on figure 8.

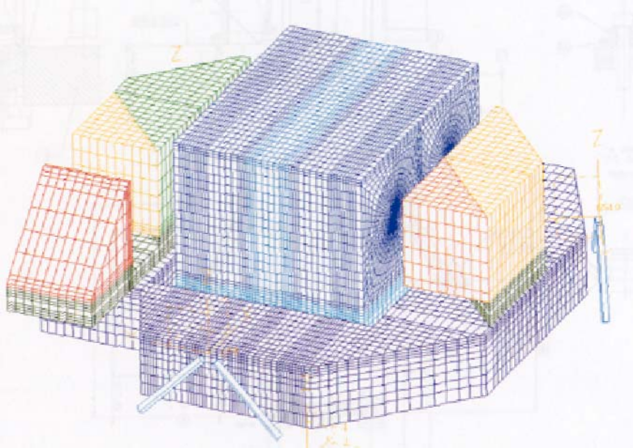

Figure 7: scheme of the system

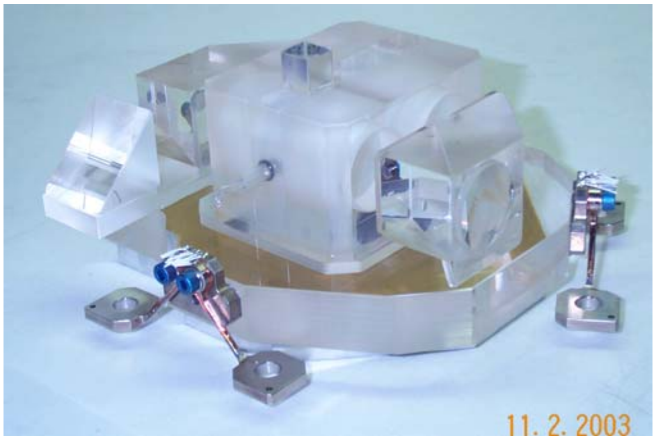

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Figure 8: complete assembly

Main specification, which were achieved, are the following:

- Fabry Perot flatness of 2 areas of 26 mm diameter: 9 nm and 18 nm
- Coating R = 65 ± 1%; absorption < 0.3%
- Finesse 65 at 355 nm
- Assembly is able to pass:

  - Static accelerations > 30 G on all axes
  - Thermal environment –20°C to 50°C.

5.2. Lisa Program

The goal is to realise a cavity made with 3 mirrors (2 pieces ① and ⑦) on figure 9. The stabilisation is based on the Pound Drever Hall or Tilt locking. The main part of this cavity is a cylinder of 138 mm length with a 95 mm diameter. On the 2 flat surfaces of this cylinder ⑥ are optically contacted pieces ⑦ and ②, piece ② is a prism on which the mirrors ① are optically contacted. A socket ⑤ is also contacted and on this support socket are cemented the sensors. With this cavity the goal is to obtain a frequency stability better than 10Hz/sqrt(Hz) for time stretches greater than 10^4s. The Finesse should be comprised between 10000 and 100000.

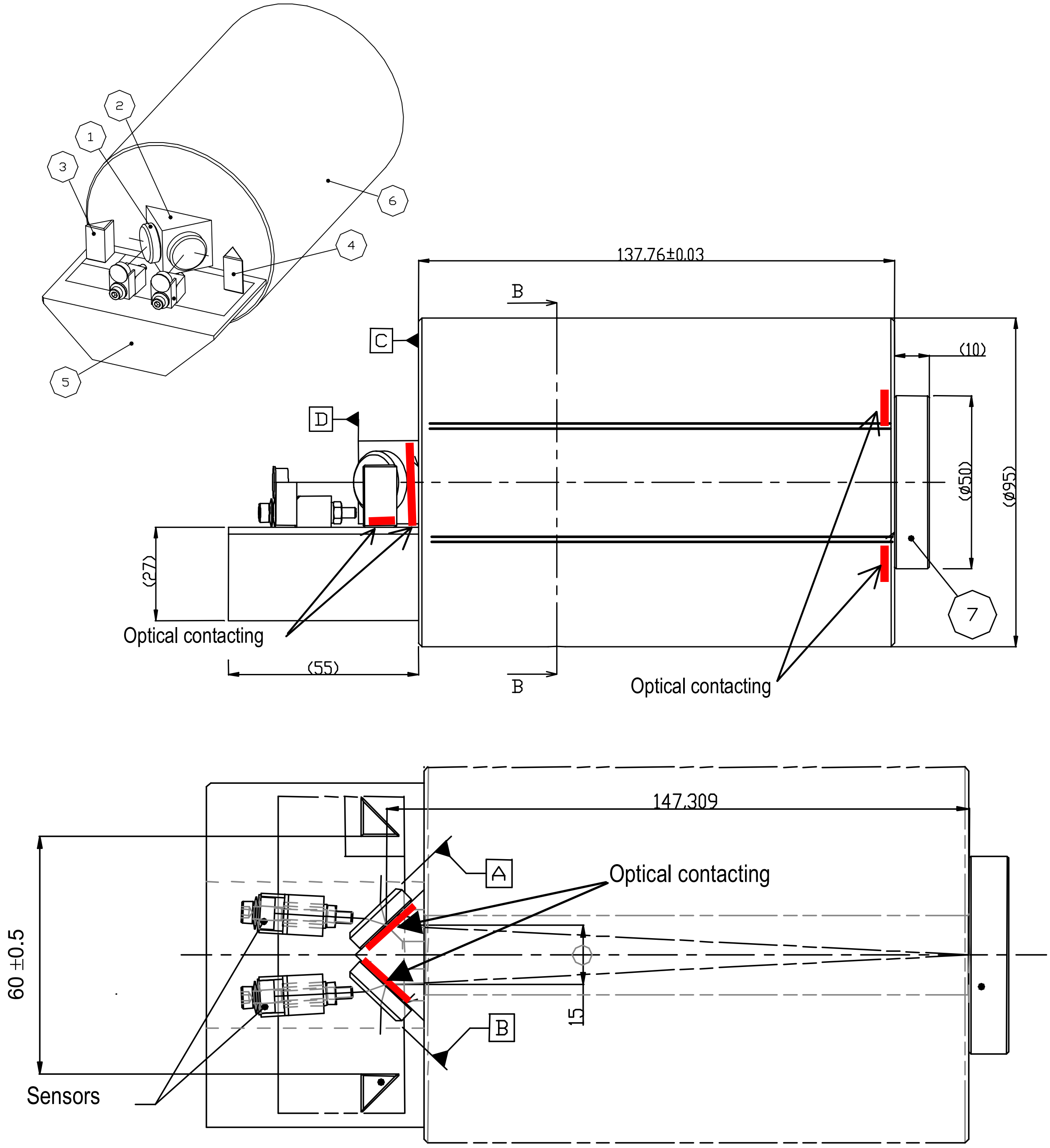

Figure 9: Lisa program cavity

6. CONCLUSION

By developing polishing and cleaning techniques, SESO has been able to improve the technology of optical contacting and to present reliable numbers for the stress limit, which can be achieved.

We would like to thank all partners, which have been mentioned in our paper for their support.

ALADIN Program

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ASTRIUM SPACE, Observation de la Terre & Science, 31 av. des Cosmonautes, 31402 Toulouse Cedex 4, France

LISA Program

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