

# Cleaning of extremely sensitive optical surfaces

Jean Louis Lizon\*<sup>a</sup>, Sebastian Deiries<sup>a</sup>

<sup>a</sup>European Organisation for Astronomical Research in the Southern Hemisphere, Karl-Schwarzschild Str. 2, D-85748 Garching b. München, Germany

## ABSTRACT

Most of the optical surfaces are sensitive; the cleaning should be done with great cares and using well characterized technique and equipment. In this paper we are reporting about cleaning of some of the most critical optical surfaces, surfaces which are generally known as not allowing any cleaning. The first section reports about the cleaning of the silver coating on an echelle grating. Silver becomes oxidized, or tarnished, from exposure to sulphates in the air. With time this can lead to dramatic loss of the efficiency of the grating. The second section reports about the cleaning of a CCD chip which has been contaminated with grease. A special “contactless” cleaning procedure has been developed and used successfully on real components. In both cases the full procedure is described and a set of measurements document the results and shows how the original performance have been recovered.

**Keywords:** Cleaning, detectors, optical surfaces, sensitive surfaces, vapor cleaning, contamination

## 1. INTRODUCTION

Contamination is often a problem for optical surfaces. Any type of contamination leads to a direct loss of performance. On the other hand these surfaces are sensitive and cannot be treated by most of the cleaning methods and especially all the techniques involving contact. For this reason it was absolutely necessary to explore other possibilities excluding any even extremely soft contact-methods with these delicate optical surfaces. For this very sensitive cleaning we are using the technique which is used as end phase in most of the cleaning facility: the vapor cleaning.

## 2. TYPICAL CONTAMINATION

This section shows a few examples of contaminations affecting various optical surfaces. All of them lead to the same and similar result: a clear degradation and a significant loss in performance. The loss is especially high in the UV spectral range. Some contaminations in addition are unstable, which means, that the performance can vary over time, which is very unwanted by scientists and astronomers. The most common source of contamination for optical surfaces is dust.

Figure 1 shows a glass plate (optical filter) which is heavily contaminated with dust but also with grease (unavoidable in most of optical instruments) and also some accidental trace of finger print. Figures 2 and 3 show a very common type of contamination for sensitive surfaces of optical detectors. These components are generally operated at cryogenic temperatures inside a vacuum chamber. The detector which is one of the coldest points of the system tends to cryo-trap most of the residual gas of the chamber. Some of this contamination could be water vapor and will for a large part disappear during the next warming up. This happens, if the “working point” of the detector is inappropriate (too much water vapour in the vacuum) in the water phase diagram at the border of vapour and solid state at 0.01 Pa and -100°C.

Unfortunately this contamination might be more serious and leave stains on the surface also other source like vacuum grease could contributed to this contamination and a dedicated cleaning of the surface would be required in order to restore the full performance of the detector. Figure 4 shows also on the left side a normal contamination with dust of the surface of an echelle grating while the right side of the photograph show a silver coated grating which has been tarnished due to contact with air.

\*jlizon@eso.org; phone +49 89 32006-780; fax +49 89 3202362, [www.eso.org](http://www.eso.org)

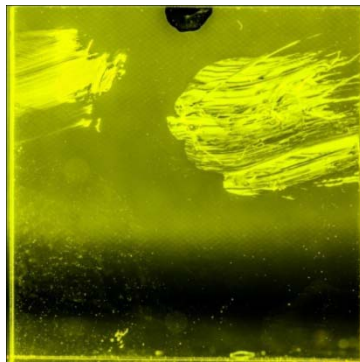


Figure 1. Optical glass contaminated with 4 different contaminants (thermal grease, vacuum grease, finger-print and dust)



Figure 2. Contamination of 2x2k Tektronix backside thinned CCD detector with grease shows crocodile pattern

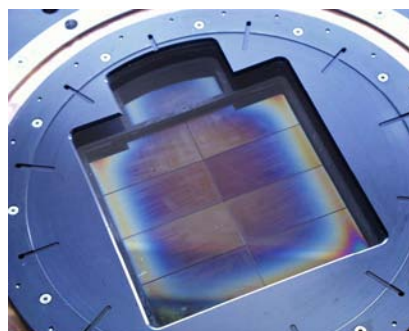


Figure 3. WFOV optical CCD mosaic with typical cryostat contamination (water vapor monomolecular layer and maybe some hydrocarbons)

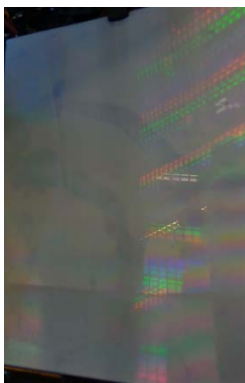


Figure 4. Contaminated ECHELLE grating

### 3. VAPOUR CLEANING METHOD

A method was developed using alcohol or acetone, which is heated until boiling. This method is also used in the last phases of most of the professional cleaning chains. The amount of boiling has to give sufficient vapor without over-boiling.

**CAUTION:** This can be used only in a fume-cupboard with automated fire-extinction system, because the concentration of the vapors used of solvents like alcohol and acetone can easily reach the critical inflammable values/concentrations.

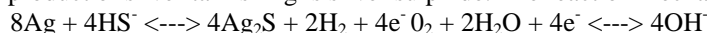
Then the surface to be cleaned is held, slightly tilted, over the bath until the condensation of the vapor is rinsing the surface for some minutes. Using vapor allows, per definition, the use of extremely pure solvent which then will not leave any stain on the surface. At the end of the process the condensation has to evaporate quickly from the surface or has to be blown off with the help of very clean press-air in order not to have stains of residuals on the surface. In general there is no danger of over-heating the sensor or optical element to be cleaned, if this process is limited to some minutes.

### 4. CLEANING OF OPTICAL GRATINGS

The cleaning of grating will address a more complex case than a simple cleaning after grease or dust contamination. Of course the last phase of this method can be applied in a normal cleaning procedure. We will concentrate on a very specific case encountered on several grating at the ESO observatory: the refreshing of silver coating after natural ageing and tarnishing.

A freshly coated Al layer quickly oxidizes when exposed to air. This happens within the first few minutes and hours after exposure to air. The process stops when the  $\text{Al}_2\text{O}_3$  oxide layer has become sufficiently thick and results in the loss of some reflectivity, mainly in the UV. In contrary, Silver reacts with atmospheric hydrogen sulphide in the presence of water on the surface. The result is silver sulphide which is black and reduces reflectivity.

The main product of silver tarnishing is silver sulphide. The reaction mechanisms are:



The first reaction is believed to occur in a thin film of water on the silver surface. In dry air, tarnishing does not take place. In the second reaction, oxygen acts as a cathodic species and consumes electrons as indicated in the equation. Higher concentrations of hydrogen sulphide increase tarnishing. Although the rate of tarnishing gradually declines with increased tarnish layer thickness, the reaction proceeds even on a heavily tarnished surface, since, owing to its coarse structure, the silver sulphide does not form a protective layer against surface corrosion. When relative humidity (RH) is between 5 and 50%, the amount of absorbed water on the surface is approximately constant and the reaction rate is steady. However, between 70 and 80% RH, surface moisture increases and accelerates the reaction rapidly. Considering the danger of capillary condensation of water, a low RH is preferable to reduce the tarnishing reaction level. Experience with several Ag/MgF<sub>2</sub> coated gratings in operation at ESO shows that the Ag/MgF<sub>2</sub> coating will tarnish noticeably when exposed to air by more than a few months. The decrease of reflectivity is fastest in the UV.

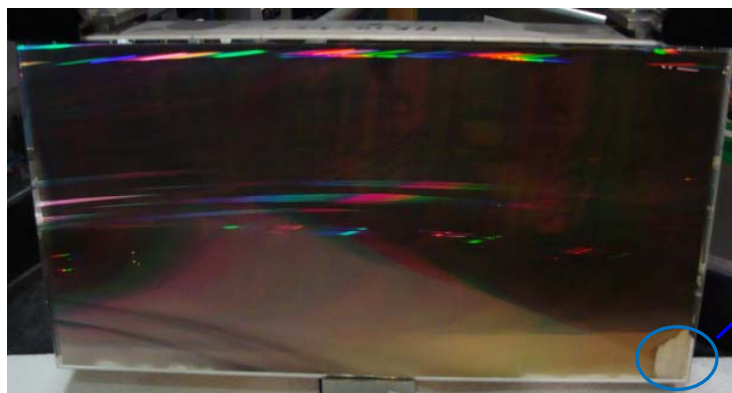


Figure 5. Grating after a local cleaning test

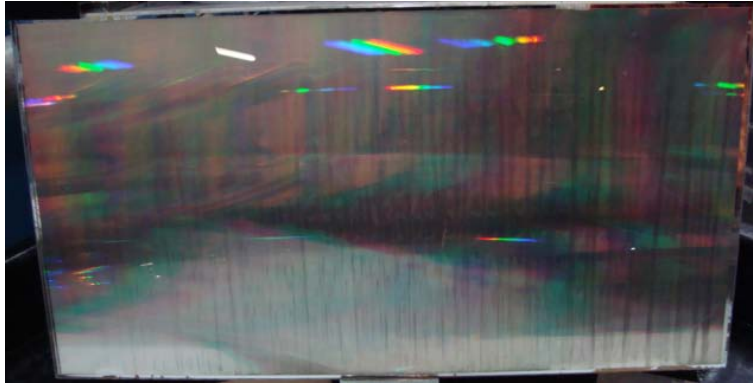


Figure 6. Grating after full cleaning

This effect has been followed out and analyzed on the grating of one of our spectrograph (Giraffe). Figure 7 shows the evolution of the Giraffe system efficiency in HR mode, measured on standard stars measured for two different wavelengths at 447 nm (left side) and 652 nm (right side). Between MJD 54000 and 55700, the system efficiency (top of the atmosphere to detected photoelectrons) decreased from an average 0.045 to 0.018 at 447 nm, a factor 0.4 over 1700 days. The decrease with time is fully attributable to tarnishing of the HR grating.

The cleaning was carried out with a diluted solution used by numismatic collectors for cleaning of silver coins. This cleaning which allows a very efficient recovering of the original shining of the silver has the disadvantage to leave very damageable trace and stain of salt on the surface if it is not removed extremely rapidly. For this reason the silver cleaning method has been applied in combination with an acetone vapor cleaning. The grating has been sprayed with the silver cleaning solution and with a few minutes vapor cleaned. For the vapor cleaning the grating was kept with the optical surface facing the acetone container and slightly tilted (~15 degrees) around the perpendicular to the groove. This orientation guarantees an efficient and continuous cleaning of the groove.

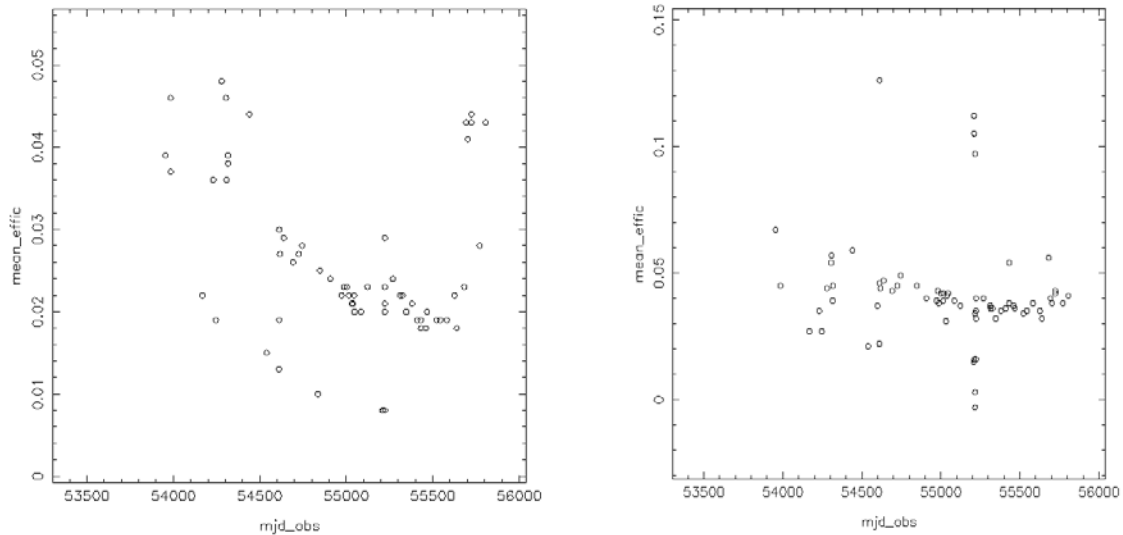


Figure 7. evolution of Giraffe system efficiency in HR mode, measured on standard stars (at 447 nm left and 652 nm right). The decrease with time is fully attributable to tarnishing of the HR grating. The grating was washed with a silver-cleaning solution around MJD 55750.

Figure 7 shows how the efficiency of the complete instrument in the blue could be almost completely recovered after the cleaning of the grating.

## 5. VAPOR CLEANING USED AT OPTICAL CCDS

Installing a CCD detector on its mount and then inside its housing and or inside the cryostat is known and recognized as a very critical operation. Despite all care taken for such operation accidental contamination might happen. This was the case for which we report specifically in this section. While integrating the series of CCD for MUSE (24 x e2v 4kx4k optical CCD231-84) an incident with vacuum grease happened one of them resulting in an area with lower efficiency. Two alternatives offered to us either a dismounting of the detector element or a cleaning in situ using our vapor technique.

The following photographs show the sequence use for the cleaning of the detector using the alcohol vapor. The alcohol contained in a small container has been brought to boiling using a small heater. Then the complete detector assembly has been kept on top of the bath with the detector oriented such that the bond wires are vertical in order not to apply to much stress to these, which could disconnect them, making the detector inoperable.

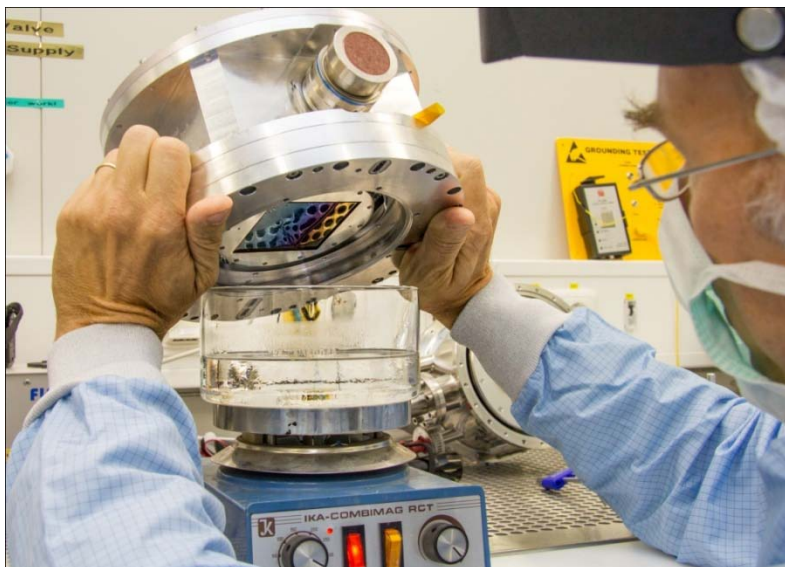


Figure 8. Complete cryogenic vessels can be placed into alcohol or acetone vapors

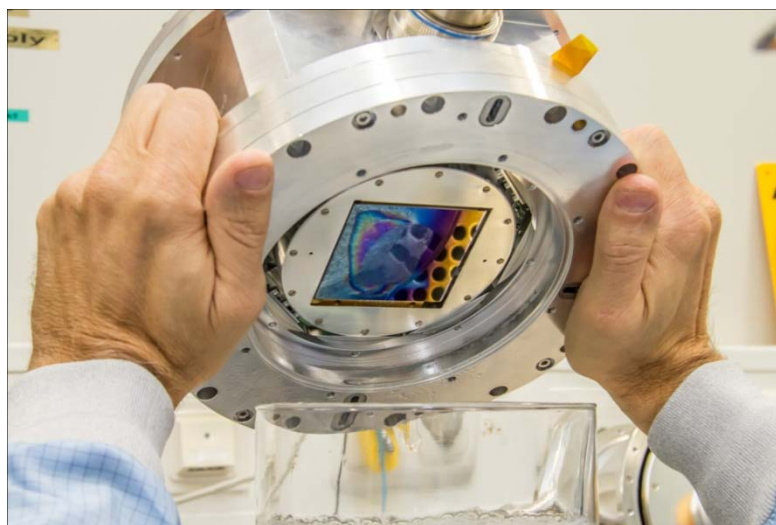


Figure 9. Alcohol vapor is condensing at the detector surfaces

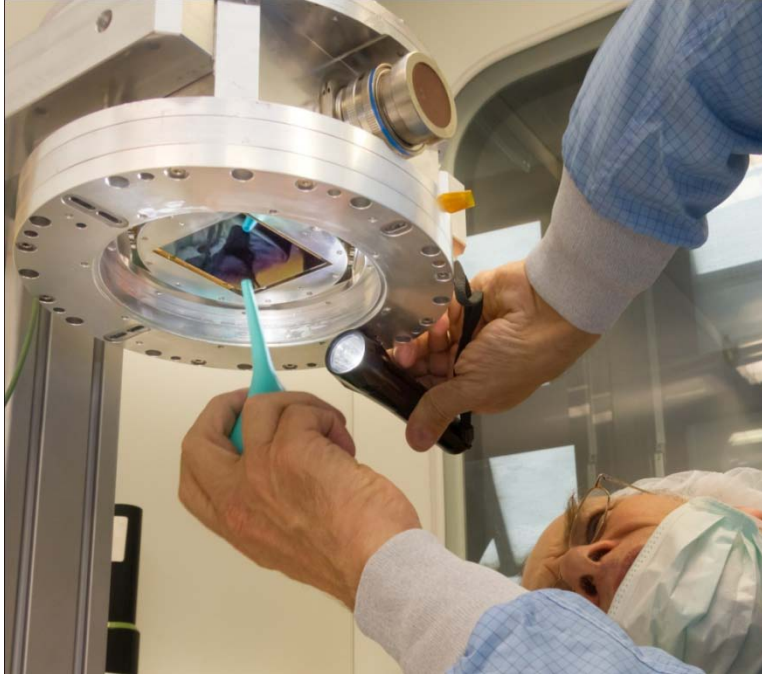


Figure 10. Inspection of the vapor cleaned surface and blowing off of last dust particles

This cleaning technique is very efficient for removing most of the residual traces of grease by direct solving. It also helps to remove some very strongly adhering dust particles. Only a last verification completed with a soft blowing is then required in order to fully restore the original cleanliness of the detector.

Figure 11 shows the is very convincing result: the grease-contamination at the MUSE CCD has completely dis-appearing after vapor cleaning as seen in the taken flat-fields:



Figure 11. Flat-field of detector before (left) and after (right) vapor cleaning

The following figures show another application where this cleaning method has been applied successfully. For our adaptive optics projects we are assembling a series of wave-front sensors where the various focal plane components (CCD detectors, lens-let array and window) are compacted to an extreme. The assembly and alignment of these elements cannot be done in a complete dust-free environment and moreover the pieces delivered are already dust-contaminated. Therefore here the vapour-method was very valuable to get cleaner results.

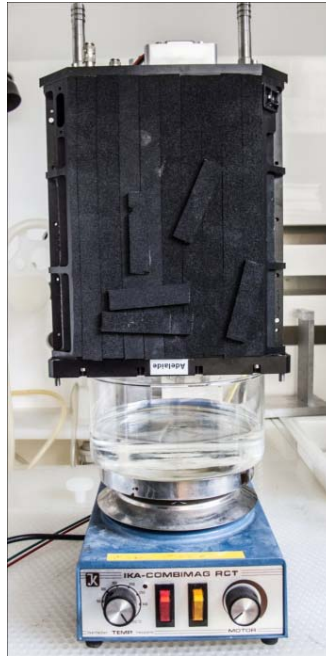


Figure 12. Detector surface inside AO wave-front sensor camera with open window directly above boiling alcohol

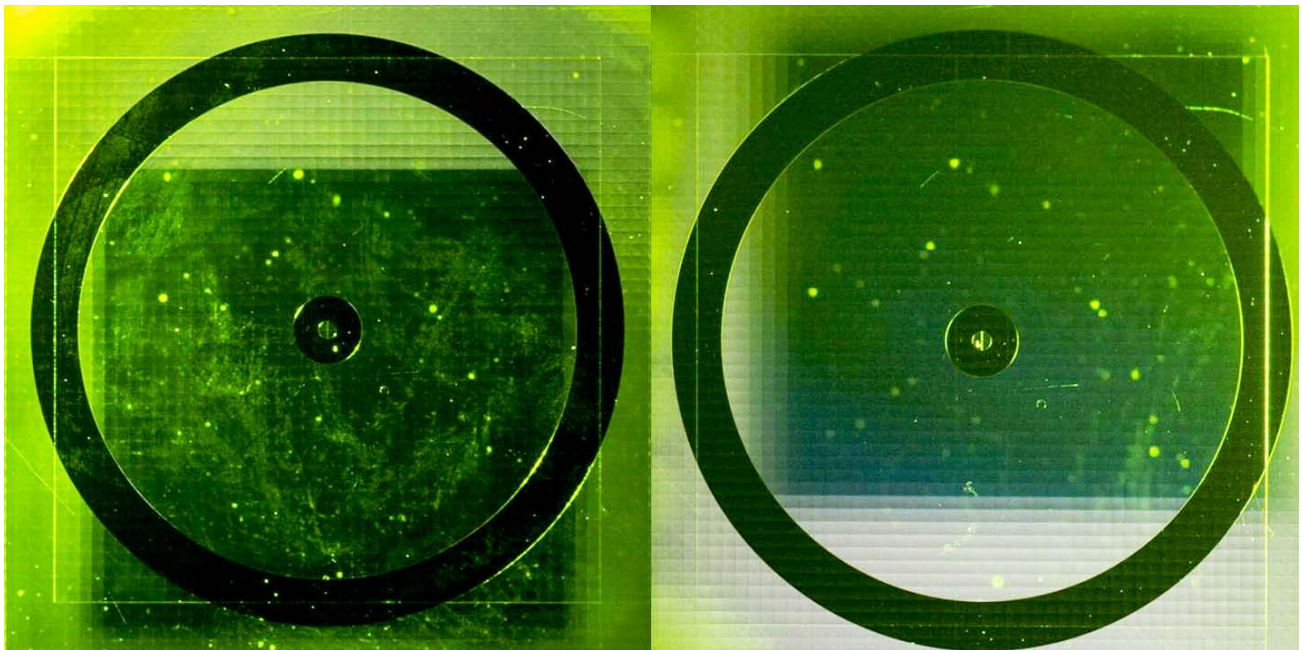


Figure 13. AO lens-let before (left) and after vapor cleaning (right); Note: Some dust and the not accessible backside of the lens-let could not be cleaned

## 6. CONCLUSION AND OUTLOOK

The vapour cleaning method is very powerful at sensitive surfaces, which cannot be cleaned mechanically. Until now alcohol was used in the most cases. With some more aggressive chemicals like acetone more tests and maybe better results could be achieved.

In addition to a non-negligible direct financial saving (a new replication for a grating of the size of the Giraffe grating cost several thousand of Euro) this method also offers a considerable man power saving. Most of the cleaning operations can be executed without dismounting the detectors from their supports. This is very important in many cases and more especially in the case of the MUSE detector, where the chips are individually positioned inside the head with an accuracy of a few microns.

## REFERENCES

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