Cleaning of Contaminated Gratings by UV Light

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Report on Efforts to Clean Contaminated Gratings

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Background Gratings mounted in vacuum, for example in the vacuum compressor in A103, are subject to contamination, probably due to deposition of carbon atoms on the surface [1]. In fact, every piece of vacuum mounted optics having metal coating are being contaminated when subjected to the high irradiance of the terawatt laser pulses.

At the synchrotron facility BESSY in Germany, a cleaning device has been developed for such contamination, employing a plasma of oxygen that supposedly reacts with the deposited carbon, thereby removing it.

At the synchrotron facility Maxlab here in Lund, an alternative method has been utilized. In contrast to the involved setup at BESSY, a Mercury lamp is put in the vicinity of the contaminated surface, effectively removing the contamination.

Objectives The aim of this study was to implement at least one of the cleaning methods; an oxygen plasma excited by a powerful radiofrequency transmitter or a Mercury lamp. The proximity of Maxlab and the simpleness of that method made it the obvious first candidate. Only if that method was unable to clean a test candidate; an old contaminated grating, Spectrogon PC1200.120.140.20Nie, the plasma cleaning would be tried.

It would be of great advantage if the cleaning could be done inside the evacuated chambers with the optics kept mounted in their pre-aligned positions. The BESSY method can be employed without breaking the vacuum after the equipment is installed. However, it is not easy to move around this setup to the various optics that require cleaning. The Maxlab method requires that the evacuated chambers are vented, but the setup can easily be moved around. Considering the short time required to evacuate the chambers, the venting is not considered a problem.

Achievements Ralf Nyholm at Maxlab provided a contact at Maxlab from which a Mercury lamp, Pen-Ray® Lamp (probably with part number 90-0004-01) and power supply PS-4 (99-0004-02 PS-4) by Ultra-violet Products (UVP), could be borrowed. The illuminated part of the lamp has a length of 23 cm and a diameter of 9.5 mm. The spectrum of this lamp is indicated in Figure 1. The lamp burns at a relatively low temperature because of its low pressure, reducing the risk of damaging nearlying optics.

The contaminated grating were put face up with the Mercury lamp a few millimetres above. The setup was held in a fume cupboard to protect people from ozone. The contamination was a five centimetre in diameter large spot from the spatial mode of the terawatt laser. The lamp was placed above the spot centered in one direction, but since the grating is smaller than the lamp is long, the lamp illuminated the grating primarily along a line that crossed the whole grating surface. The lamp was turned on and left for a few days. Subsequently the dark spot on the grating had disappeared. However, the spot is still visible at som inspection angles and there is a question if the grating surface appears more "foggy" than usual. Furthermore, after treatment a spot of dirt was found on the grating.

Evaluation of the cleaning procedure was performed by measuring the reflectance of the grating (the -1 order reflection) at several different points on and off the contaminated spot as indicated by Table 1 and Figure 2. A laser

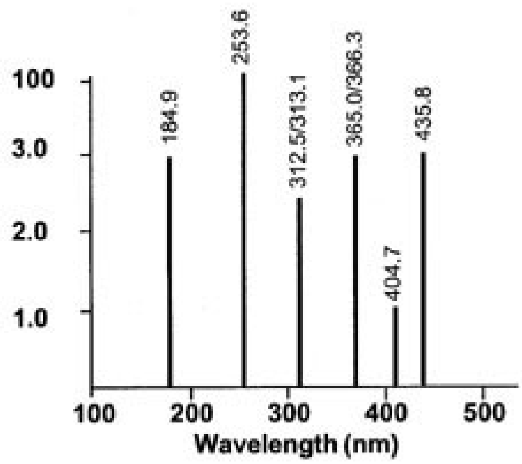

Figure 1: Spectrum of the UVP Pen-Ray Lamp. The line at 185 nm generates ozone.

Table 1: Reflectance measurements of the treated grating. A monochromatic laser diode with a few millimetres beam diameter was employed. Position (3) was measured on twice, independently of each other, in order estimate the non-systematic errors.

Reflection Position Number	On/Off Contaminated Spot	Reflectance
0	off	0.42
1	off	0.60
2	on	0.61
3	on	0.57 (0.56)
4	off	0.48

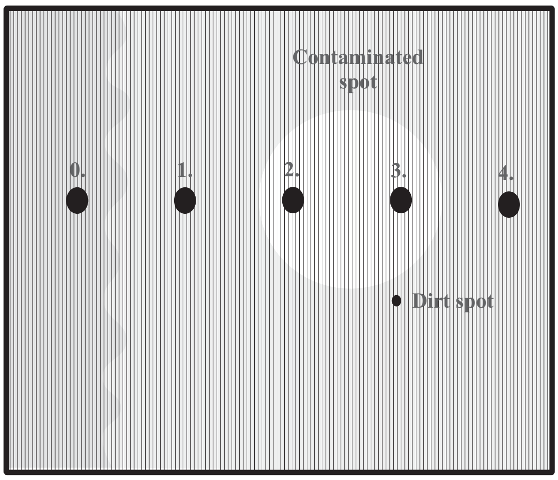

Figure 2: The positions on the grating probed in the reflectance measurements.

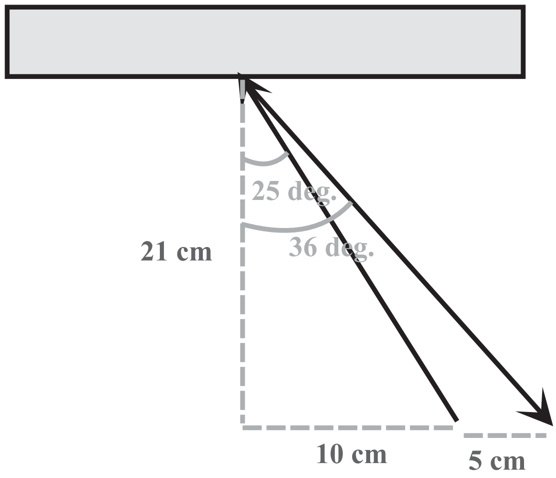

Figure 3: The geometry of the measurements. The diode laser and the power meter were moved to sample the different positions on the grating.

diode operating at 780 nm was used in the reflectance measurements. The laser diode beam size is a few millimetres, i.e. much smaller than the previously contaminated area.

The results in Table 1 imply that the grating reflectivity is varying over the grating surface, the highest reflectivity being at the previously contaminated area. The reflectance is lower than the 0.90 that is usually expected because the incidence angle was not chosen optimally in this measurement. The "foggier" area, indicated by darker grey in Figure 3, reflects the least. It seems, however, that the previously contaminated area is restored to a good condition.

To verify that the fogginess does not come from the Mercury lamp treatment, the grating is again setup as in the first treatment, with the addition of a ground-connecting cable from the gold surface to the wall socket. After three hours no change can be found of the foggy areas.

Conclusion and Suggestions for Further Work The Maxlab method employing a Mercury lamp is successful in cleaning the test grating, effectively restoring the reflectivity of the grating. Mercury lamps can be manufactured in almost any form, for example as a two-dimensionally folded so-called grid lamp covering large surfaces. Whichever lamp is bought, the irradiance should be as high as possible; $\gtrsim 1$ mW/cm^2 is a reasonable guess. UVP, the manufacturer of Pen-Ray®, also sell an ozone generator. Perhaps this could do the job? It generates a flow of ozone that can be directed at the optics.

Regarding the foggyness of the grating, a discussion with Åke Ogeryd from Spectrogon reveals that they clean gratings by gently spraying the surface with cyclohexan, thereafter blowing air (or nitrogen) on the surface to dry it. This could be tested after a good spraying device has been bought/borrowed. Cyclohexan is stored in the chemistry lab A310.

Bibliography

[1] F. Eggenstein, F. Senf, T. Zeschke, and W. Gudat. Cleaning of contaminated XUV-optics at BESSY II. *Nucl. Instrum. and Meth. A*, 467-468:325–328, 2001.