Mirror cleaning review at NOT
DRAFT

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1 Introduction

This document reviews the mirror cleaning procedures at NOT and at other observatories. The idea is to give an overview of what has been done here and how, and summarise the results. Also there is a brief overview of the mirror cleaning procedures and results at some other telescopes, based on the google search results. Finally, some suggestions are given concerning the mirror cleaning in the near future at NOT.

2 Why bother cleaning the mirror and how to do it

In order to keep the performance of the telescope at its optimum, one needs to remove dust and dirt from the mirrors. Dust reduces the reflectivity of the mirror, increases the IR background emissivity and the PSF is expected to be wider due to diffusion.

There are at least three different methods of cleaning the mirror; CO_2-cleaning, wet-cleaning and cleaning using UV-lasers. For freshly deposited dust, CO_2 cleaning is a sufficient method to recover the reflectivity. Several users believe that frequent CO_2 cleaning is necessary with a minimum interval of two weeks and even more often if it is dusty time. It is believed that less frequent cleaning than every two weeks with CO_2 will not give so good results (Kimura et al. PASP 107, 888 (1995)). However, eventually other methods i.e. wet-cleaning are needed to improve the reflectivity of a dirty and dusty mirror. This document has a short summary of the CO_2- and wet-cleaning methods. The UV-lasers based method is relatively expensive, hence it is not reviewed here.

- CO_2-cleaning
  This method is based on CO_2-snow which is blown onto the mirror surface. CO_2 particles trap and drag the dust by gravity out from the mirror surface. This procedure is relatively cheap and fast done and no hazard to the telescope. The main limitation is that the humidity must be low enough (say $> 40 - 60\%$) to avoid condensation on the mirror surface. Typically reflectivity improves one to two per cent and also the amount of scattered light is reduced, but only slightly. The CO_2-cleaning interval is typically from some weeks to month(s). Frequent CO_2-cleaning is favoured, because

in a shorter time the dust does not have any time to "sink in to" the mirror and is easier to remove.

- Wet-cleaning
  Wet-cleaning means cleaning the mirror surface with distilled water, soap and a sponge. Wet cleaning decreases the scattered light a lot and recovers the mirror reflectivity better than CO_2-cleaning. However more manpower is needed than with the CO_2-cleaning, and it is somewhat risky to the telescope itself due of the physical contact to the mirror and water near electronics. Wet-cleaning is performed typically once a year or more seldom.

2.1 Procedures

CO_2-cleaning procedures are similar at all telescopes, but wet-cleaning has some minor differences from site to site.

- CO_2-cleaning
  The CO_2-cleaning procedure is simply to spray CO_2 all over the mirror using a wand. In order to ensure no residues are left on the mirror surface CFHT and IRTF use 99.99% pure CO_2. However, other users (Keck and MMT) have found that 99% - 99.5% purity works satisfactorily (Kimura et al. 1995).
  The main safety issue is static charge, hence it is important to ground the wand.

- Wet-cleaning
  At some telescopes before spraying water on the mirror surface, the loose particles are removed using CO_2. Then the mirror is rinsed with distilled water. The washing itself has some variations, e.g at KPNO and CTIO they spray soapy water and use natural sponge, at TNG baby shampoo, at CFHT water with sponge and finally at NOT cotton wool without any soap. After washing and rinsing the mirror is dried. At CTIO nitrogen gas is used and at KPNO the mirror is patted dry and after that CO_2 cleaned to remove any traces of lint. At NOT dry mirror cooling air is used to dry the mirror surface after washing.

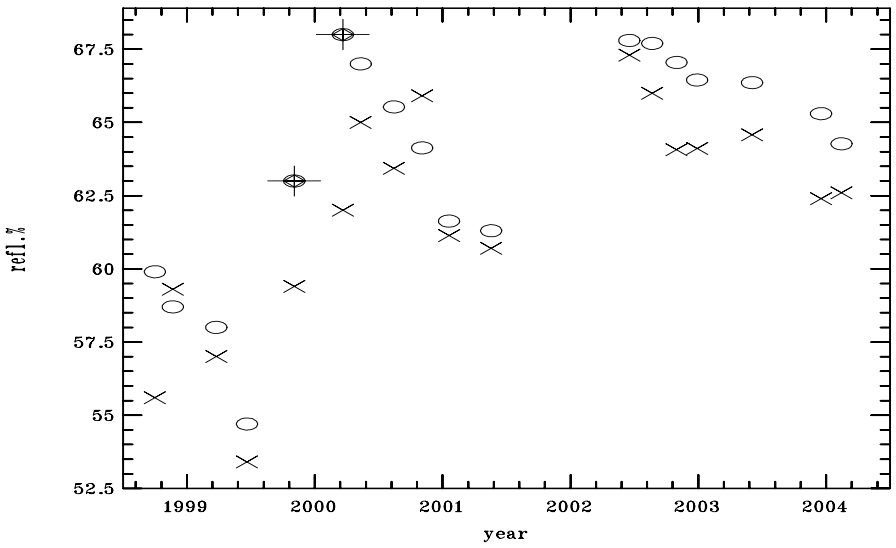

Figure 1: Reflectivity (at λ=4500 Å) of the telescope mirrors (combination of M1 and M2) measured before (crosses) and after (circles) CO_2 cleaning. In addition, two measurements after wet-cleaning are indicated with crosses. Note that the reflectometer was re-calibrated in May 2002 after realuminising the mirrors.

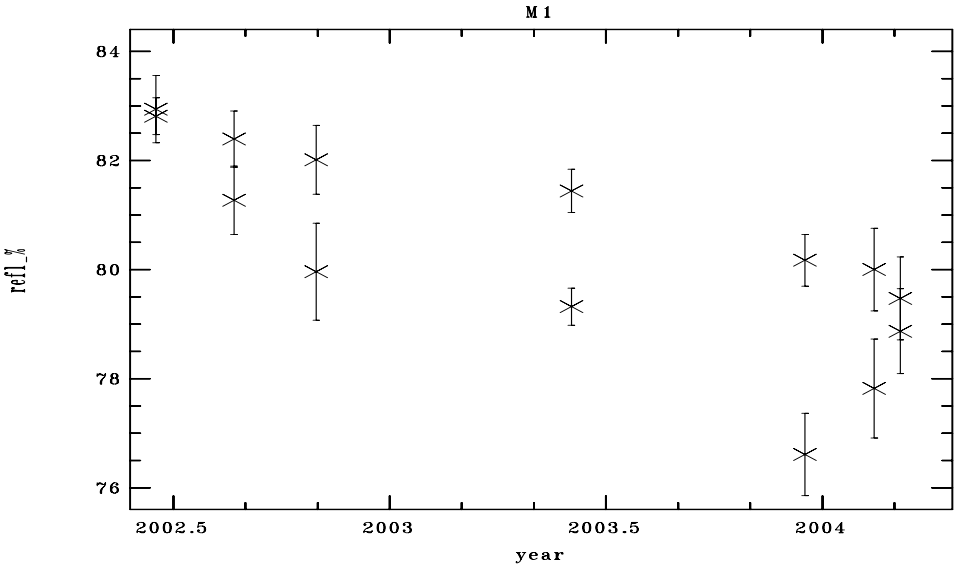

Figure 2: Reflectivity (at λ=4500 Å) of M1 measured before and after CO_2 cleaning since the last aluminising of M1 and M2. The error bars are the standard deviation of ten reflectivity measurements.

3 Mirror cleaning at NOT

The first experiments on CO_2 and wet -cleaning at NOT were done in 1997. The conclusions were that both types of cleaning can improve the performance of a dirty mirror (see Report on Aluminization of Primary 1997, Hugo E. Schwarz http://www.not.iac.es/telescope/alu97.ps.gz).

3.1 How often?

The cleaning records go back to the end of 1998. Since then the telescope mirrors have been cleaned 20 times (until 31.3.2004) of which two times have been "wet" cleanings (10.5.2000 and 5.10.1999) and the rest CO_2-cleanings. There are a couple of long gaps between the cleaning, but on average the time between the cleanings is about two to three months. Occasionally the CO_2-cleaning has been terminated, because of running out of CO_2. In more detail, since the last aluminising of the mirrors (May 2002) they have been CO_2-cleaned eight times.

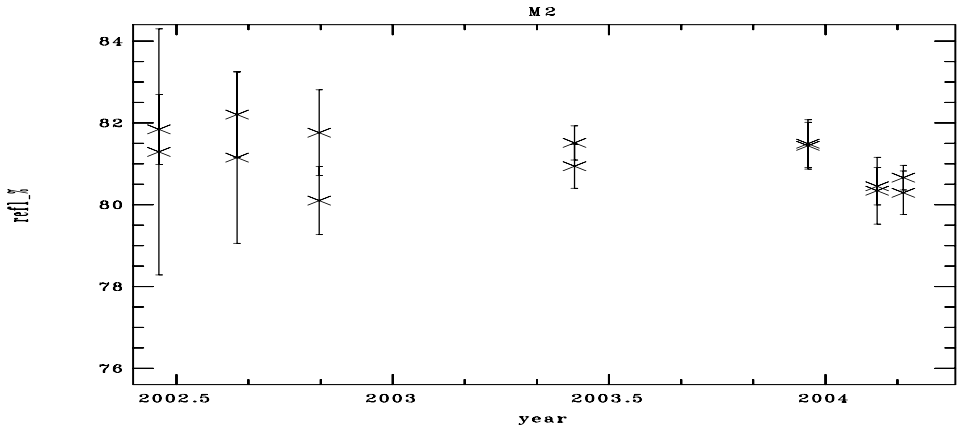

Figure 3: Same as Fig. 2 but for M2.

3.2 Needed man power and "special" tools

CO_2-cleaning is a relatively short and cheap operation. Including all the preparations before hand, such as bringing the CO_2-hoses to the observing floor, power-on the telescope, pointing the telescope almost to the horizon and power-off the telescope and tidying after one cleaning takes about an hour and a half. This includes measuring the reflectivity before and after the cleaning. For safety and convenience reasons usually two people are needed, especially when measuring the reflectivity. One bottle of CO_2, which cost about 90 euros, is enough for four to five cleanings.

Wet-cleaning is a slightly more time consuming operation than CO_2-cleaning, but the cleaning materials -distilled water and cotton- are cheap. Cleaning takes about half a day for two persons. Preparations include tiliting the telescope and attaching plastic around the mirror in order to lead the water away from the electronics.

3.3 Results

Figure 2 indicates that the upper envelope of the reflectivity have little or no relation to the frequency of the CO_2-cleaning. The slope of the degradation of the M1 is steeper then M2 is. Using the first measurement after the aluminisation and the most recent reflectivity measurement, the difference is 3.4% for M1 and 1.2% for M2. Similarly, the biggest reflectivity gain after CO_2-cleaning is about

Table 1: Log of CO_2-cleanings at NOT since May 2000, showing reflectivity of M1 and M2 before and after cleaning.

date	M1 before	M1 after	M2 before	M2 after	Comment
08.03.2004	78.87	79.47	80.29	80.63:	M2 partially cleaned
13.02.2004	77.82	80.0	80.45	80.34	
16.12.2003	76.6	80.2	81.5	81.4	
02.06.2003	79.32	81.42	80.94	81.51	
31.12.2002	80.52	81.62	79.62	81.41	
28.10.2002	79.99	82.01	80.1	81.76	
19.08.2002	81.34	82.4	81.2	82.2	
18.06.2002	82.81	82.9	81.2	81.8	reflm recalib.
18.05.2001	78.12	79.43	77.64	77.20	
18.01.2001	78.55	78.95	77.83	78.06	
15.01.2001	78.86	XX	77.46	XX	CO_2 bottle empty
31.10.2000	82.21	81.56	80.18	78.63	
18.08.2000	79.59	82.19	79.7	79.74	
10.05.2000	82.0	83.4	79.6	80.3	

3.6% for M1 and only 1.9% for M2 and the greatest drop from cleaning to the time just before the next cleaning is 4.8% for M1 and 2.1% for M2. The differences between M1 and M2 is not surprising, because the M2 is much better shielded against dust than M1. These results suggest that if the CO_2-cleaning interval is about one month or less the reflectivity can be kept constant within a couple of percent or better. Unfortunately there are no scattering measurements available.

4 Mirror cleaning at other telescopes

This section gives miscellaneous comments on mirror cleaning from some other telescopes.

- KPNO
  (http://claret.kpno.noao.edu/glaspey/KP/Coatings/Conference2001/MirrorCleaning/sld005.htm)
  The mirrors are CO_2-cleaned when ever it is needed, but the goal is at least

once a month. When there is only dust in the mirrors just CO_2-cleaning is used. They have used industrial grade CO_2, without any problems.

- CFHT
  (http://www.cfht.hawaii.edu/Reference/Bulletin/Bull28/28.html) (1993)
  Their experience is that CO_2-cleaning increases reflectivity by about 1.3% and "wet" cleaning about 3.5%. Scattering shows similar trends, CO_2 improves by a factor of 1.6 and wet-cleaning by a factor of 4.2.

- 3.5m ARC telescope at Apache Point Observatory
  (http://www.apo.nmsu.edu/Telescopes/eng.papers/4010-24_spie.htm)(1999)
  They have monthly CO_2-cleaning apart from major dust events or if a visual inspection suggests increased scattered light. For the justification of a dust event, the site has two Met 1 particle counters, one in the dome and one outside. The APO have found that CO_2-cleaning removes about 35% of the accumulated dust. They have used TMA Microscan scatterometer and have found that the scatterometer must have the same temperature as the measured surface. Errors as large as 8% have been seen with a 20 Deg. C. differential.

- ESO/NTT (Messenger 103, 3/2001)
  They have routine CO_2-cleaning once a week if the weather permits (low enough humidity). The reflectivity is measured on a monthly basis. Wet cleaning has been performed if the reflectivity has dropped below 88% at 6700Å. In reality this means about once a year. The timing of the cleaning has been chosen for the time when the humidity is high, hence the frequency of the CO_2-cleaning is disrupted.

- CTIO 4m telescope
  They wet clean the mirror every six months. The needed man power is 2 persons for the washing and at least 3 assistants. The whole process takes three hours of which first hour is for the preparations. For washing they use Orvus soap (sodium lauryl sulphate??) and nitrogen gas for drying.
  Between August 1998 and August 2000 the average gain per cleaning session was +0.36% and -0.28% in reflectivity and scattering, respectively, in the visible.

- 8.2m Subaru Telescope (Iye et al. astro-ph 0405012)
  The main mirror is routinely CO_2-cleaned every 2-3 weeks. The reflectiv-

ity is kept better than 82-83% and the surface roughness is 70-80 Å as measured using a scatter meter (6700 Å).

- WHT (M.F. Blanken et al. The ING Newsletter No. 7 Dec. 2003)
  (http://www-kpno.kpno.noao.edu/glaspey/KP/Coatings/Conference2001/ING/index.html)
  http://www.ing.iac.es/ eng/mechanical/Group_ stuff/Optics/reflectivity_ results/Reflectivity_ frame.htm
  At the ING the main mirrors are CO_2-cleaned once a month. Mirror measurements are taken before and after the cleaning and every further two weeks to check the state of the mirrors.
  The wet cleaning has only be done on the INT. They get the best result when the mirror is in the mirror cell and vertical. They try to do wet clening every 6 months but it depends on schedules and work loads. They wash with the vapour cleaners, flotter soap and natural sponges. They only use the sponges with a dabbing motion and not wiping them because they give micro scratches.
  They have found that the CO_2-cleaning improves the reflectivity by 1-2 and reduces the scattering very little. The wet washing is a lot better and restores the mirror to nearly fresh aluminum values.

5 Near future plans

Since it is almost two years since the aluminisation of the mirrors, wet cleaning has been scheduled at the end of May. After that the mirrors should be regularly CO_2-cleaned, in order to see if the reflectivity decreases in a similar way as between May 2002 to May 2004. This will hopefully help to find the optimum interval for the CO_2-cleaning. Also, monthly intervals of CO_2-cleaning should keep the reflectivity within a couple of percent excluding the "normal" degradation of the aluminium.

In the near future it should be aimed to have:

- Regular CO_2-cleaning (about one month intervals)

- ING measurements, which include the scattering measuremnts in a 1-2 month interval plus our own "normal" measurements

- Regular standard-star observations