

**Reflectivity measurements on WHT Primary mirror on 19-20th August 2015,
taken before and after CO2 cleaning and again after water washing. Report by Neil O'Mahony.**

Only 3-4 measurements with CT7 were taken on M1 before and after CO2, at AP3.
 These suggest CO2 improved %R only marginally (<0.6%). SMS registers no %R increase.
 However washing improved %R by > 3% measured across all wavebands (and in SMS)
 Scattering reduced by CO2 by factors 1.2-1.4 and by washing by factors 2.7 to 4.4
 Surface roughness measurement reduced by 27%
 Resultant average reflectivity across all CT7 wavebands: 89.2%, 2% lower than fresh Alum.

CT measurements				waveband of measurement (nm)							
		place		365	404	464	522	624	760	970	
503	19/08/2015 12:06:58	0 AP3t	19.4	85.3	84.2	84.6	84.4	83.9	81.8	86.6	
504	19/08/2015 12:07:55	0 AP3t	19.4	87.4	86.1	86.0	86.4	85.6	83.1	88.8	
505	19/08/2015 12:08:47	0 AP3r	19.6	87.4	86.0	86.0	86.5	85.3	83.1	88.7	
506	19/08/2015 12:09:40	0 AP3L	19.8	88.1	86.8	86.6	86.8	86.1	83.5	88.9	
Averages				87.1	85.8	85.8	86.0	85.2	82.9	88.3	

After CO2											
507	19/08/2015 12:42:42	0 AP3t	17.4	85.9	84.9	85.2	84.8	84.5	82.1	87.1	
508	19/08/2015 12:43:45	0 AP3r	17.5	88.4	87.3	87.5	87.7	87.1	84.6	90.5	
509	19/08/2015 12:44:45	0 AP3L	17.7	87.1	86	85.7	86.6	85.6	83.2	89.1	
Averages				87.1	86.1	86.1	86.4	85.7	83.3	88.9	
Improvement from CO2:				0.1	0.3	0.3	0.3	0.5	0.4	0.6	

After Water Wash: minimum values highlighted in yellow, maximum in green.

511	20/08/2015 13:18:09	0 Q2c	22.1	90.0	88.7	88.7	89.3	88.6	86.1	92.3
512	20/08/2015 13:20:07	0 Q2c	21.9	90.0	88.9	89.1	89.5	88.6	86.3	92.2
513	20/08/2015 13:21:28	0 Q2c	22	90.0	88.6	88.6	89.1	88.4	86.0	91.9
Averages				90.0	88.7	88.8	89.3	88.5	86.1	92.1
514	20/08/2015 13:24:28	0 Q3	22.1	90.5	89.1	89.1	89.4	88.8	86.3	92.2
515	20/08/2015 13:27:04	0 Q3	22.2	90.6	89.2	89.2	89.4	88.8	86.3	92.2
516	20/08/2015 13:29:25	0 Q3	22.3	89.8	88.5	88.6	89.1	88.4	86.0	92.1
Averages				90.3	88.9	89.0	89.3	88.7	86.2	92.2
517	20/08/2015 13:30:42	0 Q4	22.4	90.9	89.0	89.2	89.2	89.0	86.0	92.0
518	20/08/2015 13:32:22	0 Q4	22.6	91.0	89.7	89.6	89.9	89.1	86.6	92.4
519	20/08/2015 13:33:30	0 Q4	22.7	90.5	89.2	89.1	89.4	88.8	86.2	92.1
Averages				90.8	89.3	89.3	89.5	89.0	86.3	92.2
520	20/08/2015 13:34:56	0 Q1	22.8	89.9	88.6	88.8	89.4	88.8	86.3	92.4
521	20/08/2015 13:35:53	0 Q1	23	90.4	89.2	89.1	89.5	88.8	86.2	92.1
522	20/08/2015 13:37:44	0 Q1	23.2	90.3	88.9	88.8	89.2	88.7	86.0	92.0
Averages				90.2	88.9	88.9	89.4	88.8	86.2	92.2

Global Average	M1	90.3	89.0	89.0	89.4	88.7	86.2	92.2
Range of averages (max-min. values)	M1	0.8	0.6	0.5	0.2	0.5	0.2	0.1
Global Range		1.2	1.2	1.0	0.8	0.7	0.6	0.5
Std.Deviation	M1	0.4	0.3	0.3	0.2	0.2	0.2	0.2
Std Error	M1	0.11	0.10	0.09	0.06	0.06	0.05	0.05

Average Q4	5.5	5.3	4.9	3.7	3.3	2.5	2.2
	6.1	5.5	4.8	3.1	2.8	2	1.6
	6.8	5.9	6	3.7	4	2.9	2.3
	6.7	6.4	6.3	4.2	4.1	3.2	2.5
Average Q4	6.5	5.9	5.7	3.7	3.6	2.7	2.1
Reference mirror	2.4	3.1	2.7	1.6	1.1	0.9	1.1
	2.7	3.3	2.9	1.7	1.3	1	1.3

SMS micro-Scan reflectometer measurements before CO2 cleaning of WHT M1, immediately after CO2 and again after water washing.

Measurements usually in pairs at same location, to check 0.05% repeat. Others marked "solo". Measurement marked "not rep" is outside this range and omitted from statistics. There are more of these than usual. Also many low readings on reference mirror. Instrument clock is approx. 15 minutes ahead

SMS Summary characteristics	Lambda	0.67 micron	
	Incident Angle	25 deg	
	BW Limits	1	0.01

Measurements before cleaning - at AP3

datum #	Scattering at angles Θ, Φ			Reflect-ivity	user comment	Rough-ness RMS(\AA)	TIME	DATE
	$\Theta_s \rightarrow$	0	50					
56	location 1	3.27E-03	2.76E-03	0.894	not rep	40.2	12:02:22	08-19-2015
57		1.22E-02	4.29E-03	0.834		83.5	12:30:39	08-19-2015
58		1.22E-02	4.29E-03	0.833		83.7	12:30:44	08-19-2015
59	loc 2	1.11E-02	4.20E-03	0.837	not rep	78.9	12:30:59	08-19-2015
60		1.11E-02	4.20E-03	0.829		79.4	12:31:04	08-19-2015
61		1.12E-02	4.20E-03	0.821		79.9	12:31:10	08-19-2015
62	loc 3	1.28E-02	5.55E-03	0.79		86	12:31:22	08-19-2015
63		1.35E-02	5.15E-03	0.799		89	12:31:31	08-19-2015
64		1.35E-02	5.15E-03	0.803		88.7	12:31:37	08-19-2015
65	loc 4	1.42E-02	5.03E-03	0.808	solo	91.4	12:31:53	08-19-2015
averages		1.26E-02	4.73E-03	0.815		85.2		

Reference mirror

66 4.41E-03 2.15E-03 0.929 46.3 12:37:11 08-19-2015

Value is acceptably close to typical maximum 93%

Measurements immediately following CO2 cleaning

67	loc 1	9.38E-03	2.41E-03	0.843		76.4	13:05:46	08-19-2015
68		9.38E-03	2.39E-03	0.847		76.3	13:05:52	08-19-2015
69	loc 2	1.08E-02	3.10E-03	0.836		80.5	13:05:58	08-19-2015
70	loc 3	9.31E-03	2.67E-03	0.834	skip	75.1	13:06:18	08-19-2015
71		9.34E-03	2.64E-03	0.816		76.2	13:06:23	08-19-2015
72		9.32E-03	2.64E-03	0.807		76.4	13:06:28	08-19-2015
73	loc 4	9.28E-03	2.45E-03	0.815		76.9	13:06:37	08-19-2015
74		9.38E-03	2.48E-03	0.812		77.4	13:06:42	08-19-2015
75	loc 5	1.13E-02	4.15E-03	0.817		80.7	13:06:54	08-19-2015
76		1.13E-02	4.14E-03	0.813		81	13:06:58	08-19-2015
77	loc 6	1.56E-02	5.93E-03	0.789		96.3	13:07:14	08-19-2015
78		1.57E-02	5.93E-03	0.793		96.2	13:07:19	08-19-2015
79	loc 7	9.28E-03	2.64E-03	0.822		75.6	13:07:26	08-19-2015
80		9.30E-03	2.64E-03	0.822		75.7	13:07:32	08-19-2015
81	loc 8	1.13E-02	3.80E-03	0.795		82.6	13:07:46	08-19-2015
82		1.13E-02	3.80E-03	0.81		81.9	13:07:52	08-19-2015
83		1.22E-02	4.45E-03	0.8		85.1	13:07:59	08-19-2015
84	loc 9	4.35E-03	8.89E-04	0.827		55.5	13:08:06	08-19-2015

averages 1.05E-02 3.32E-03 0.816 79.5

Reference mirror

85	1.69E-03	1.30E-03	0.926	28.3	13:39:49	08-19-2015
86	1.68E-03	1.29E-03	0.925	28.3	13:39:56	08-19-2015
87	2.28E-03	1.56E-03	0.926	33	13:40:06	08-19-2015
88	5.59E-03	1.92E-03	0.917	54.1	13:40:14	08-19-2015
89	2.38E-03	1.34E-03	0.925	33.9	13:40:21	08-19-2015

Readings ~ 0.5% low

Improvements in Scattering by factors of 1.2 (at 0,0) to 1.4 (at 50,180)

These improvement factors are comparable to those obtained using CO2 previously.
 However no improvement measured in reflectivity. Improvement obtained has been decreasing.
 Some %R readings following CO2 are lower than expected, even from low reference values.
 CT7 measurements confirm that the improvement in reflectivity was indeed very small.

Reference mirror measurements prior to washed mirror measurements:

datum #	Scattering at angles Θ, Φ		Reflect-ivity	user comm-ent	Rough-ness RMS(\AA)	TIME	DATE
	Θ s->	Φ s->					
	0	50					
	0	180					
90	Ref	2.15E-02	5.33E-03	0.905	112.4	13:18:32	08-20-2015
91		2.08E-02	5.27E-03	0.879	111.9	13:18:38	08-20-2015
92		8.04E-03	2.75E-03	0.924	64.6	13:18:47	08-20-2015
93		8.04E-03	2.75E-03	0.924	64.6	13:18:52	08-20-2015
94		6.22E-03	2.88E-03	0.928	55.2	13:18:59	08-20-2015
95		5.54E-03	1.73E-03	0.921	54.4	13:19:08	08-20-2015

Some low values but similar maximum value to before, just 0.2% below "threshold"

M1 after wash:

96	loc 1	3.86E-03	5.50E-04	0.85		58.9	13:39:36	08-20-2015
97		3.86E-03	5.50E-04	0.85		58.9	13:39:41	08-20-2015
98		4.47E-03	6.60E-04	0.85	solo?	62.4	13:39:49	08-20-2015
99	loc 2	3.88E-03	5.69E-04	0.859		57.9	13:40:56	08-20-2015
100		3.90E-03	5.71E-04	0.871	not rep	57.7	13:41:01	08-20-2015
101		2.70E-03	3.29E-04	0.856	solo	53.3	13:41:17	08-20-2015
102	loc 3	3.54E-03	5.62E-04	0.844		54	13:48:55	08-20-2015
103		3.54E-03	5.62E-04	0.859	not rep	53.6	13:49:01	08-20-2015
104		3.54E-03	5.61E-04	0.852	not rep	53.7	13:49:07	08-20-2015
105	loc 4	5.03E-03	7.20E-04	0.843		67.4	13:49:15	08-20-2015
106		5.02E-03	7.20E-04	0.833	not rep	67.6	13:49:20	08-20-2015
107	loc 5	7.25E-03	4.17E-03	0.823		62.6	13:50:09	08-20-2015
108		7.25E-03	4.16E-03	0.822		62.6	13:50:15	08-20-2015
109	loc 6	3.21E-03	4.87E-04	0.855		52	13:50:32	08-20-2015
110		3.21E-03	4.87E-04	0.855		52.1	13:50:37	08-20-2015
111	loc 7	1.53E-03	1.26E-04	0.856		53	13:51:42	08-20-2015
112		1.53E-03	1.26E-04	0.857		52.9	13:51:47	08-20-2015
113	loc 8	1.70E-03	1.26E-04	0.857		61.6	13:52:10	08-20-2015
114		1.70E-03	1.27E-04	0.853		61.3	13:52:14	08-20-2015
115	loc 9	1.59E-03	1.54E-04	0.856		47.5	13:52:53	08-20-2015
116		1.59E-03	1.54E-04	0.857		47.5	13:52:58	08-20-2015
117	loc 10	5.02E-03	9.25E-04	0.846		60.8	13:54:26	08-20-2015
118		5.02E-03	9.26E-04	0.845		60.8	13:54:31	08-20-2015
119	loc 11	2.53E-03	3.88E-04	0.846		46.2	13:55:07	08-20-2015

120		1.84E-03	3.45E-04	0.853	not rep	36.5	13:55:15	08-20-2015
121	loc 12	5.58E-03	8.13E-04	0.843		70.4	13:55:25	08-20-2015
122		5.54E-03	8.08E-04	0.842		70.1	13:55:31	08-20-2015
123	loc 13	3.82E-03	6.57E-04	0.848		54.3	13:55:39	08-20-2015
124		3.17E-03	6.12E-04	0.835	not rep	47.9	13:55:47	08-20-2015
125	loc 14	3.01E-03	4.49E-04	0.848		50.9	13:55:56	08-20-2015
126		3.01E-03	4.48E-04	0.848		51	13:56:03	08-20-2015
127	loc 15	7.30E-03	9.94E-04	0.836		83.4	13:56:13	08-20-2015
128		7.33E-03	9.93E-04	0.84		83.6	13:56:18	08-20-2015
averages		3.85E-03	7.52E-04	0.848		58.0		
average				0.849	omitting non-repeated values			
std.deviation		1.76E-03	9.16E-04	0.011		9.9		
std.error		4.55E-04	2.37E-04	0.003		2.5		

final Reference mirror measurements

129		2.82E-03	1.90E-03	0.914		36.9	14:05:56	08-20-2015
130		1.85E-03	1.17E-03	0.926		29.8	14:06:03	08-20-2015
131		2.59E-03	1.40E-03	0.927		35.3	14:06:12	08-20-2015
132		1.31E-02	3.31E-03	0.916		86.8	14:06:19	08-20-2015
133		4.19E-03	1.49E-03	0.913		46.7	14:06:27	08-20-2015
134		3.78E-03	1.85E-03	0.916		43.1	14:06:35	08-20-2015

Reference values remain about 0.5% lower than normal but consistent throughout these tests.

Improvement in Reflectivity

Change due to CO2 could not be measured

Improvement in scattering by factors of

Improvement in surface roughness of

3.3 % due to washing only

2.7 (at 0,0) to 4.4 (at 50,180) and

27% due to washing only