LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

LIGO Laboratory / LIGO Scientific Collaboration

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LIGO Vacuum Qualification of First Contact™

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1 Regular (clear) First Contact™

The allowable flag hydrocarbon outgassing rate, for any First Contact™ which is (unintentionally) left in the vacuum system,[1] is ~10^{-12} torr-liter/sec. Given the measured flag hydrocarbon outgassing rate of 10^{-13} torr-liter/sec/cm^2 (an instrument background limit result) the total accumulated amount of First Contact™ which can (unintentionally) remain in the vacuum system is 10 cm^2. In the H2 interferometer, corner station vacuum volume, there are ~56 optics with HR surfaces in optical cavities[2]. Each of these optics might be cleaned by First Contact™. This implies that the RGA derived limit of residual First Contact™ is 0.2 cm^2 per optic.

The limits on contamination induced loss are defined in the COC Requirements Document[3] (and repeated in the UHV Materials List[4]) as < 1 ppm/yr absorption and < 4 ppm/yr scatter loss for any test mass (TM), high reflectance (HR), surface. Since these limits are from all sources, here we allocate 1/10th of this limit[5] for First Contact™, i.e. < 0.1 ppm/yr absorption and < 0.4 ppm/yr scatter. Using the pump scaling factor (between the optical contamination cavity test and the LIGO vacuum system), the resulting limits on residual First Contact™ (unintentionally) remaining in the vacuum system is < 150 cm^2, based on the scatter loss limit.

Consequently, the most restrictive limit is set by the hydrocarbon outgassing rate to 0.2 cm^2 per optic. Note that this limit is a result of the mass spectrometer noise floor in the measurement and could be less restrictive if a larger sample is measured.

The amount of residual First Contact™ left on an individual optic is expected to be less than 0.2 cm^2 per optic. As a consequence the use of First Contact™ is approved for use in aLIGO.

2 Red First Contact™

See also the RGA results in E1100584 and the optical contamination cavity results in E1000294.

The measured hydrocarbon outgassing rate is 2.4e-14 torr-liter/sec/cm^2, which corresponds to a total allowable residual amount of red first contact in the vertex vacuum volume of 41.5 cm^2 (see Table below). The residual first contact is most likely to be left along the perimeter. The allowable amounts of residual first contact is given in the following table. The allowable amount of residue,

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[1] D. Coyne, Vacuum Hydrocarbon Outgassing Requirements, LIGO-T040001. Based on this document, the flag hydrocarbon outgassing rate limit per assembly is ~10^{-12} torr-liter/sec. Rai Weiss has argued that the requirements defined in this document are more restrictive than required since it does not take into account the pumping capacity of the beam tubes and it is likely that initial LIGO requirements suffice. If so, then the requirements are ~300 times more lax. In this note, this relaxation of requirements is considered margin in determining the allowable amount of First Contact™ which is permitted (unintentionally) to remain in the vacuum system.

[2] In the H2 vertex vacuum volume there are 14 optics with HR surfaces in cavities: 2 ITMs, 2 FMs, 1 BS, PR3, PR2, PRM, SR3, SR2, SRM, and 3 MCMs.

[3] G. Billingsley et. al., Core Optics Components Design Requirements Document, section 4.2.2.6 of LIGO-T080026-00. The timescale for accumulation (i.e. the time span between in situ re-cleaning of the test mass optics) has been chosen here to be 1 year. It is possible that a somewhat shorter time span could be accommodated.

[4] D. Coyne, LIGO Vacuum Compatible Materials List, LIGO-E960050-v3

[5] Other potential high hydrocarbon outgassing sources (i.e. sources with polymers) include BOSEM assemblies, AOSEM assemblies, cabling, SEI position sensors, SEI actuators, etc.

based on the hydrocarbon outgassing, seems within likely amounts to be inadvertently left on the optic.

Vertex Vacuum Volume Optics:

OPTIC	Qty	Dia. (cm)	Circumference (cm)
ITM	2	34	213.6
BS	1	37	116.2
P/SR3	2	26.5	166.5
P/SR2	2	15	94.2
P/SRM	2	15	94.2
MCn	3	15	141.4
SMn	2	5	31.4
PMMTn	2	5	31.4
Fixed Optics	40	5	628.3
TOTALS	56		1517.4

ALLOWABLE (BASED ONLY ON HYDROCARBON OUTGASSING)

1.00E-12	torr-liter/sec/vertex
41.5	cm^2 of residual red first contact
0.7	cm^2 of residual red first contact per mirror (average)
0.0	cm^2 of residual red first contact per cm of circumference

cm^2 of residual red first contact per optic:

ITM	2.9
BS	3.2
P/SR3	2.3
P/SR2, P/SRM, MCn	1.3
SMn, PMMTn, Fixed	0.4

The measured rates of loss for optics exposed to the first contact at 1064 nm and high irradiance is:

Absorption: 9.1×10^{-4} ppm/yr/cm^2

Scatter: 8.3×10^{-2} ppm/yr/cm^2

It is the scatter loss which dominates over absorption loss. The allowable total amount of residual red first contact in the vertex vacuum volume, based on scatter loss, is 275 cm^2, which is greater than that allowed on the basis of hydrocarbon outgassing. So, just as is the case for regular (clear) first contact, hydrocarbon outgassing measurements dictate the maximum allowed residual material.

Sample Test:

Material under test:			Photonic Cleaning Technologies Red First Contact		
units			112.5	cm^2	6 glass slides (25 mm x 75mm) with red first contact on one side
absorption	-0.11773	±	0.11012148	ppm/yr	1 sigma
scatter	3.283258	±	3.01135829	ppm/yr	1 sigma
max. normalized absorption			9.11E-04	ppm/yr/unit	2 sigma
max. normalized scatter			8.27E-02	ppm/yr/unit	2 sigma
test turbopump speed (liter/s)			24.391574	torr/liter/sec	

Scaled to LIGO:

LIGO Vacuum Volume	Vertex	LHO Diagonal	End	Comments
Quantity (units)	275	670	165	Allowable amount of material area (cm^2)
LIGO ion pumping speed (liter/s)	2800	6800	1700	see E0900398 or PSI V049-1-078 for pump rates
pumping speed ratio (test/LIGO)	0.0087	0.0036	0.0143	does not include cryo-pump and effective pumping from the Beam Tube
max. absorption (ppm/yr)	0.002	0.002	0.002	* Limit is < 0.02 ppm/yr for a single source
max. scatter (ppm/yr)	0.198	0.199	0.196	* Limit is < 0.2 ppm/yr for a single source

* The overall limit on contamination loss on optics for AdL is < 0.5 ppm/yr absorption and < 4 ppm/yr scatter from all sources, per Table 4 of the COC Design Requirements Document (T000127-v1). It is assumed that ~20 sources could contribute.