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Inputs to Beam Tube Scattering and Optical Surface Roughness Requirement Analysis for Advanced LIGO		
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1. INTRODUCTION

This document captures the inputs required for an Advanced LIGO analysis on Core Optics Component surface roughness specifications for their fabrication. Surface roughness in the spatial frequency regime 1 $cm^{-1} < \nu < 100\ cm^{-1}$ contributes to scattering that illuminates the beam tube baffles and can consequently lead to increased phase noise at the detection port due to light scattering. The light scattering mechanism was documented and analyzed extensively for the LIGO I construction of the Beam Tube subsystem. This document is intended to gather in one place the inputs required to repeat this analysis for Advanced LIGO. The goal for this analysis is to determine whether LIGO I quality for Advanced LIGO is sufficient, and at the same time to determine the maximum amount of de-centering that can be tolerated for a given BRDF.

The inputs to that analysis include the following:

- Beam tube surface optical properties: reflectance and the bi-directional reflectance distribution function (BRDF);
- Beam tube baffle optical properties: reflectance and BRDF;
- LIGO I optical substrate roughness properties: spatial PSD of surface errors and consequently calculated BRDF;
- Beam tube (and hence Beam Tube baffle) wall motion.

These will be discussed below. These inputs have been measured in the past and this note is intended to document these inputs in one place for the Advanced LIGO analysis.

2. BEAM TUBE SURFACE OPTICAL PROPERTIES

The beam tube wall properties were measured during beam tube and baffle construction.

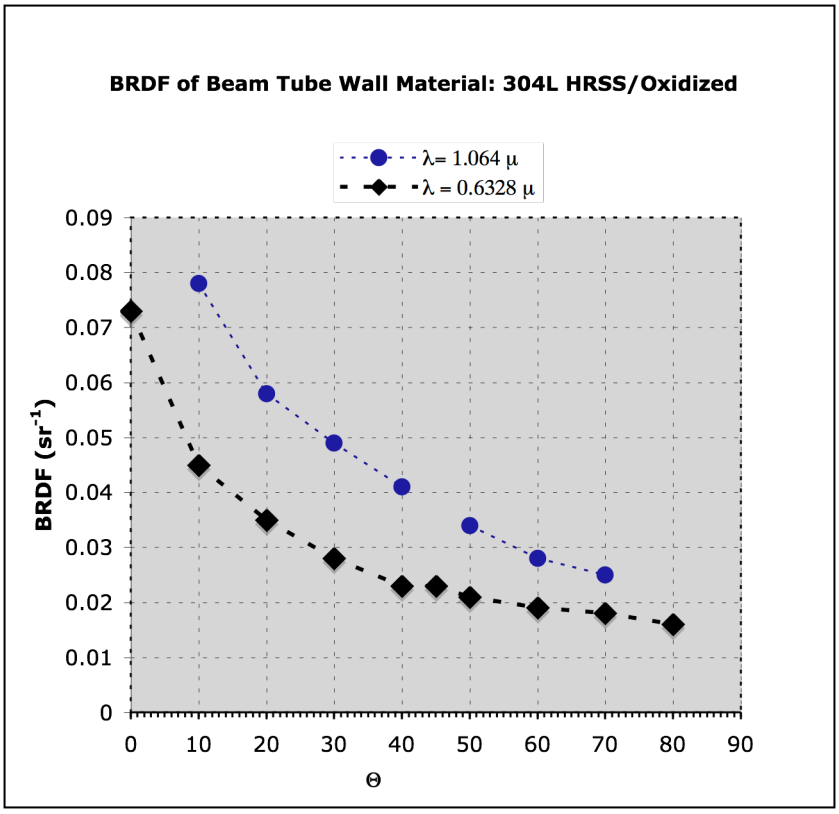
Table 1: Beam Tube Wall Optical Properties[1]

Reflectance	BRDF @ 55^{o}	BRDF @ 20^{o}	λ (μm)
diffuse	30×10^{-3}	60×10^{-3}	1.064
diffuse	20×10^{-3}	35×10^{-3}	0.6328

Table 1 shows the BRDF data reported by R. Weiss. The table lists data for two specific angles relevant to the beam, tube, and baffle designs. Surface absorption at 0.6328 μm was reported to be A = 0.40. Figure 1 shows the angular dependence of the measured BRDFs for HeNe and Nd:YAG wavelengths.

[1] Properties summarized in LIGO-G970012. Measurements made by R. Weiss on various samples of materials, see, e.g., LIGO DCC documents (unnumbered) entitled, “LIGO Beam Tube Measurements”, “Calculations of Scatter Noise”,

Figure 1: Beam Tube Wall Material BRDF



3. BAFFLES

3.1. SURFACE OPTICAL PROPERTIES

The baffle material selection underwent a number of iterations, including fritted black glass glazing. The glazing, however, was discovered to shed particles at an unacceptable rate. In the end, a simple formulation of oxidizing stainless steel sheet metal baffles was selected. The baffle material is Super #8 Mirror Finished Bright Annealed 304 Stainless Steel. The preparation process is documented in LIGO-T040126. The baffle optical properties were assayed by R. Weiss and others over a 2-year period mid 1995 – early 1997. Representative data for the baffles are listed in Table 2.

Table 2: Beam Tube Baffle Optical Properties[2]

Reflectivity Averaged over ∥ and ⊥ polarizations	BRDF @ 55°	λ (μm)
0.12	4.8×10^{-3}	1.064

3.2. Baffle placement

The serrated edge of the baffle is 0.500m from the beam tube centerline. Baffle placements are documented in the LIGO-E950083B.

4. LIGO I CORE OPTICS PROPERTIES

As a reference for Advanced LIGO, the core optics installed in the LIGO I interferometers have been analyzed to determine the BRDF of these optics based on an analytical model using surface roughness measurements. The model is described in the Handbook of Optics[3]. PSDs of surface errors were obtained as follows. A number of presently installed optics were selected from the COC data archive maintained by G. Billingsley at the URL http://www.ligo.caltech.edu/~gari/COCAsBuilt.htm and listed in Table 3.

Table 3: Core optics substrate surface errors data used to estimates LIGO I as-built BRDFs

Optics data file type	Mirror Type, Location	File URL
2D phase map	H2 ITM Y	http://www.ligo.caltech.edu/coreopt/mapdata/2ITM02-0-C92401-TP.asc
	H1 ITM X	http://www.ligo.caltech.edu/coreopt/mapdata/4ITM05-180-C_03-28-05-TP.asc
	H1 ETM X	http://www.ligo.caltech.edu/coreopt/mapdata/ETM01-180-C92401-TP.asc
	L1 ITM Y	http://www.ligo.caltech.edu/coreopt/mapdata/4ITM02-180-C92401-TP.asc
	H1 ITM Y	http://www.ligo.caltech.edu/coreopt/mapdata/4ITM06-180-C92401-TP.asc
	H1 ETM Y	http://www.ligo.caltech.edu/coreopt/mapdata/ETM02-180-C92401-TP.asc

[2] Properties summarized in LIGO-G970012. Measurements made by R. Weiss on various samples of materials, see, e.g., LIGO DCC documents (unnumbered) entitled, "Preliminary Results of Baffle Measurements at Firepond." Other baffle analyses are documented in LIGO-E950083 (requirements), LIGO-T950101, LIGO-T950132, and LIGO-T960012(scattering analysis).

[3] The Handbook of Optics, 2nd Ed., Vol. I, McGraw-Hill, Inc. New York, NY (1994). Chapter 7, "Surface Scattering", by E. L. Church and P. Z. Takacs."

Table 3: Core optics substrate surface errors data used to estimates LIGO I as-built BRDFs

Optics data file type	Mirror Type, Location	File URL
2.5X 1D profilometer scans $\delta x = 0.0056$ mm; $L_x = 5.73$ mm	4k ITM04 Side 1 (HR) Sample Location C	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm2-4-5topo1.zip File T24IM41C.asc
	4k ITM05 Side 1 (HR) Sample Location B	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm2-4-5topo1.zip File T24IM51B.asc
	4k ITM06 Side 1 (HR) Sample Location B	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm6.zip File T24IM61B.asc
	4k ITM07 Side 2 (AR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm7&8.zip File T24IM72A.asc
	4k ITM08 Side 1 (HR) Sample Location C	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm7&8.zip File T24IM81C.asc
	4k ITM02 Side 1 (HR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm2-4-5topo1.zip File T24im21a.asc
	4k ETM01 Side 1 (HR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/ETMtopo/t2em011a.asc
	4k ETM02 Side 1 (HR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/ETMtopo/t2em021b.asc

Table 3(continued): Core optics substrate surface errors data used to estimates LIGO I as-built BRDFs[3]

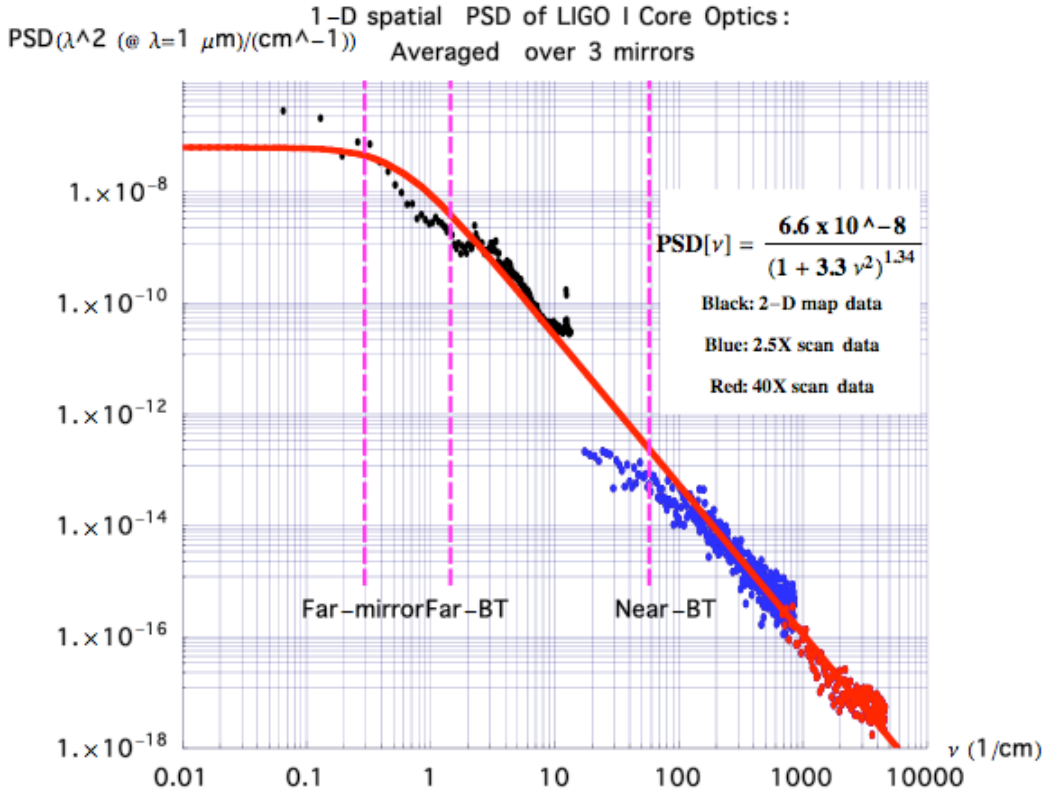
Optics data file type	Mirror Type, Location	File URL
40X scan profilometer (1-D) $\delta x = 0.342$ μm; $L_x = 0.350$ mm	4k ITM04 Side 1 (HR) Sample Location C	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm2-4-5topo1.zip File T44IM41C.asc
	4k ITM05 Side 1 (HR) Sample Location B	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm2-4-5topo1.zip File T44IM51B.asc
	4k ITM06 Side 1 (HR) Sample Location B	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm6.zip File T44IM61B.asc
	4k ITM07 Side 2 (AR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm7&8.zip File T44IM72A.asc
	4k ITM08 Side 1 (HR) Sample Location C	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm7&8.zip File T44IM81C.asc
	4k ITM02 Side 1 (HR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/4ITM_topo/4itm2-4-5topo1.zip File T44im21a.asc
	4k ETM01 Side 1 (HR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/ETMtopo/t4em011a.asc
	4k ETM02 Side 1 (HR) Sample Location A	http://www.ligo.caltech.edu/~coreopt/L1COC/ETMtopo/t4em021b.asc

These data were analyzed as follows. The 1-D scans were Fourier transformed and spliced together to produce a PSD cover the spatial frequencies 2 $cm^{-1} \le \nu \le 5000\ cm^{-1}$. The 2-D phase maps were Fourier transformed to produce 2-D spatial frequency maps. The 2-D maps were averaged over azimuthal angle, $(k_x, k_y) \rightarrow (|k|,\phi)$ to produce a corresponding low-ν 1-D PSD,

$$S_{1D}(|k|) = k/(2\pi) \int d\phi\ S_{2D}(|k|,\phi)$$

Figure 2 shows the representative 1-D PSD derived from averages over all data sets listed in Table 3. The PSD at high $\nu \approx 10^{-8}/\nu^{2.7}$.

Figure 2: Representative 1-D power spectrum for the LIGO I mirror substrates. PSD was obtained by averaging individual power spectra from data listed in Table 3. The vertical dashed lines indicate the spatial frequencies $\nu_i \approx \theta_i / \lambda$, where the θ_i are determined by the geometry of the mirror and beam tube dimensions and layout. The regime of spatial frequencies that communicates with the beam tubes is between the Far-BT and Near-BT lines.

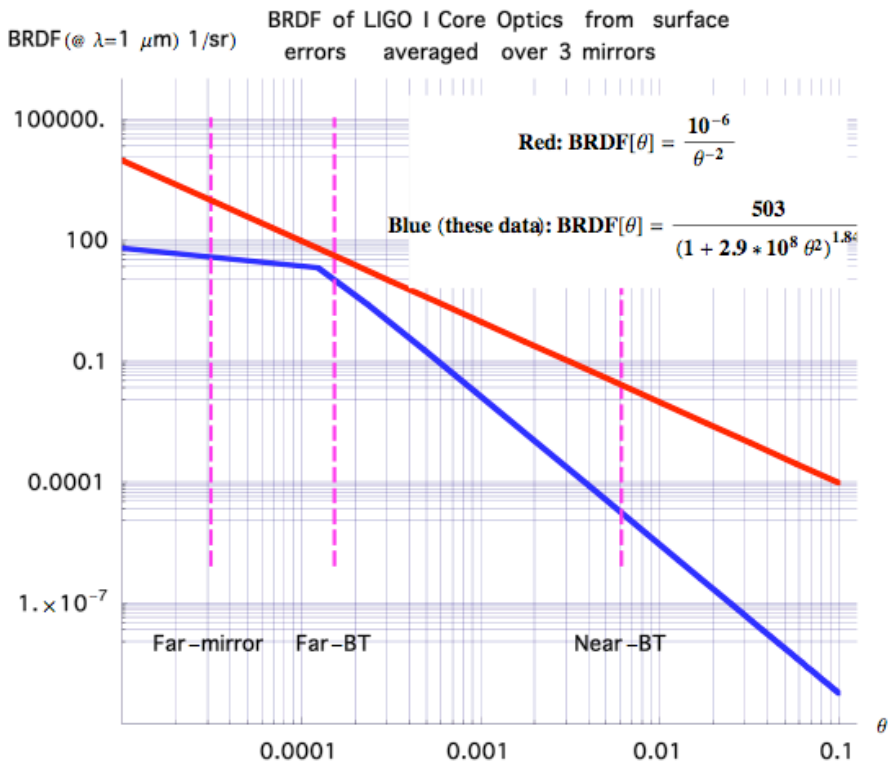


By fitting a simple pole model to the data, $S_{1D}[\nu] \approx A[1 + (2\pi\nu d)^2]^{-c/2}$, the corresponding analytical expression for the 2-D PSD is given as $S_{2D}[\nu] \approx A\delta \sqrt{\pi}\ (\Gamma[(c+1)/2]/\Gamma[(c)/2])\ [1 + (2\pi\nu d)^2]^{-(c+1)/2}$. In turn, S_{2D} leads to an analytical expression for the BRDF.

$$BRDF[\theta] = (4\pi/\lambda)^2\ S_{2D}[\nu = \theta/\lambda].$$

Note that the PSDs S_{1D}, S_{2D} as used above must be given in units of waves of light and *not* meters. If the PSDs are in units of meters, then an extra factor of λ^{-2} is required in the definition of BRDF. Figure 3 presents the results of the BRDF model consistent with the data for S_{1D}. The BRDF at high $\theta \approx 10^{-13}/\theta^{3.7}$. Shown in the figure is the pre-LIGO I assumption for the BRDF of the initial mirrors, based on best performance mirrors at that time: $BRDF[\theta] \approx 10^{-6}/\theta^2$. The pristine LIGO I mirrors substrates are considerably better than this.

Figure 3 Representative BRDF for the LIGO I mirror substrates. BRDF was obtained from S_{2D} as described in the text and using the S_{1D} data and fit shown in Figure 2. As before, the vertical dashed lines indicate the characteristic angles, θ_i, determined by the geometry of the mirror and beam tube dimensions and layout. The regime of scattering angles that communicate with the beam tubes is between the Far-BT and Near-BT lines.



4.1. Actual performance of installed mirrors

Experience has shown that the scattering observed for mirrors, after installation and during the commissioning and science runs, is much worse than the BRDF shown in the figure. It appears that the excess scatter comes from what may be characterized as discrete point defects or scattering sites distributed on the face of the Core Optics. Forensics is presently ongoing to reconcile pristine substrate expectations and observations. It seems likely that the principal source of these point defects is in the high-reflection multi-layer dielectric coatings. Details are documented in LIGO-G030660.

With regard to the purpose of the present note, the presence of defects on the coatings, while of crucial importance, does not immediately affect the derivation of surface roughness specifications for mirror fabrication. *The excess scattering indicates that additional diligence is*

required in understanding and controlling the coating, cleaning, and contamination control procedures.

5. OPTICAL PARAMETERS OF THE LONG FABRY-PEROT ARMS

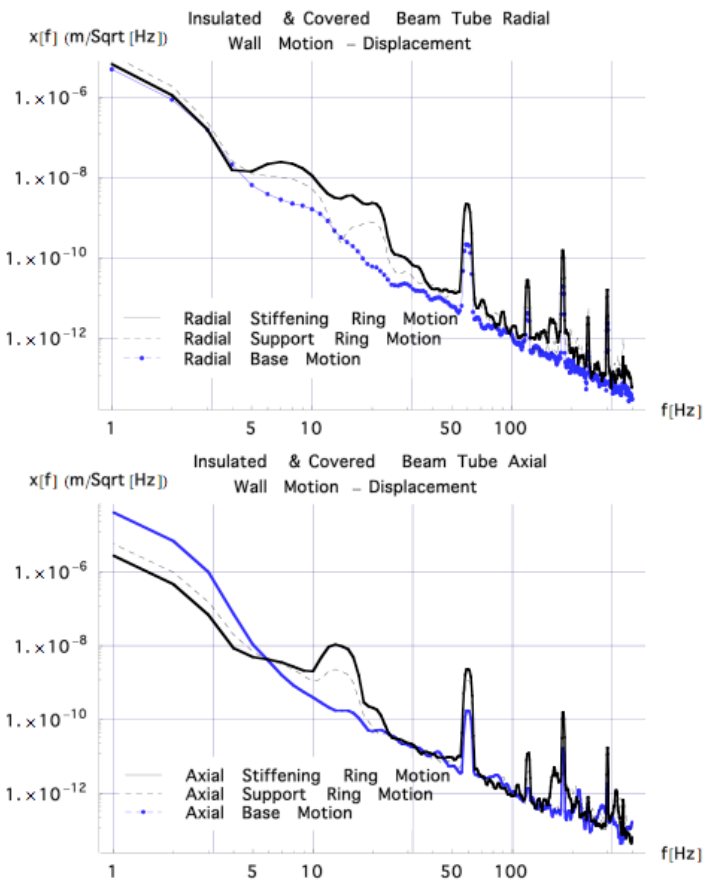
T010075-00 defines the baseline beam size on Advanced LIGO test masses as 0.06 m, corresponding to a symmetric arm cavity with *g* factor chosen to make beam spot size, w (defined as the e^{-2} power radius) 0.06m on both test masses. Hence, the minimum beam waist is at the mid-point of the Fabry-Perot arm cavities. Per T000127-01, the radius of curvature (ROC) for both ETM & ITM is 2076 m: the minimum beam waist is 0.0115 m. The baseline beam centers at LHO are ±0.200 m horizontally and -0.101 m vertically with respect to the beam tube centerline.

6. BEAM TUBE WALL MOTION

Beam tube wall motion was measured during and immediately after construction at Hanford. Acceleration data were measured at various points along the beam tube, including support points and between support points. Motions transverse to and along the beam tube were measured. The results for the uninsulated and partially covered beam tube are summarized in the (unnumbered) document entitled “Beam Tube Dynamics” by R.Weiss and S. Chatterji. Additional data taken at the end of construction for a completely covered and insulated beam tube are not included in the report and are shown below.

Figure 4 shows displacement spectra for motion in the horizontal plane, both transverse and parallel to the optical axis.

Figure 4 Insulated and Covered Beam Tune Wall Motion



Numerical data are listed in Table 4 (radial motion) and Table 5 (axial motion).

Table 4 Radial Beam Tube Motion for Covered & Insulated System

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*
1	4.85E-06	1.10E-05	6.48E-06	201	2.66E-13	3.60E-13	5.45E-13
2	8.55E-07	1.84E-06	1.10E-06	202	2.76E-13	4.22E-13	4.80E-13
3	1.52E-07	2.36E-07	1.57E-07	203	2.61E-13	3.69E-13	3.92E-13

Table 4 Radial Beam Tube Motion for Covered & Insulated System

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*
4	2.09E-08	2.53E-08	1.50E-08	204	2.21E-13	5.02E-13	3.22E-13
5	6.41E-09	1.24E-08	1.37E-08	205	1.61E-13	5.79E-13	3.43E-13
6	3.84E-09	1.08E-08	2.12E-08	206	1.42E-13	5.24E-13	3.57E-13
7	2.79E-09	1.00E-08	2.42E-08	207	1.66E-13	4.27E-13	4.61E-13
8	2.23E-09	9.20E-09	2.16E-08	208	1.89E-13	5.05E-13	5.27E-13
9	1.96E-09	7.07E-09	1.66E-08	209	1.93E-13	6.46E-13	5.55E-13
10	1.61E-09	5.18E-09	1.10E-08	210	1.73E-13	7.59E-13	5.79E-13
11	1.24E-09	3.07E-09	6.22E-09	211	1.47E-13	8.67E-13	5.40E-13
12	8.18E-10	1.22E-09	3.91E-09	212	1.47E-13	9.52E-13	4.68E-13
13	4.66E-10	4.25E-10	3.12E-09	213	1.59E-13	9.79E-13	3.72E-13
14	3.18E-10	2.29E-10	2.92E-09	214	1.73E-13	9.43E-13	2.69E-13
15	2.44E-10	4.46E-10	3.45E-09	215	1.86E-13	8.11E-13	2.20E-13
16	1.92E-10	5.81E-10	3.51E-09	216	1.77E-13	6.70E-13	2.32E-13
17	1.44E-10	5.93E-10	2.82E-09	217	1.52E-13	5.90E-13	2.57E-13
18	9.55E-11	6.94E-10	2.22E-09	218	1.30E-13	5.23E-13	3.19E-13
19	6.93E-11	7.98E-10	2.13E-09	219	1.30E-13	5.70E-13	3.51E-13
20	6.00E-11	7.76E-10	2.27E-09	220	1.34E-13	6.62E-13	3.31E-13
21	5.71E-11	6.94E-10	2.18E-09	221	1.28E-13	6.86E-13	3.13E-13
22	4.69E-11	5.51E-10	1.68E-09	222	1.33E-13	6.59E-13	3.32E-13
23	3.73E-11	2.87E-10	8.88E-10	223	1.59E-13	5.43E-13	3.62E-13
24	2.86E-11	9.75E-11	3.28E-10	224	1.66E-13	4.10E-13	3.73E-13
25	2.13E-11	6.19E-11	1.53E-10	225	1.46E-13	3.20E-13	3.75E-13
26	2.05E-11	4.56E-11	1.19E-10	226	1.31E-13	3.66E-13	3.42E-13
27	2.03E-11	3.77E-11	1.16E-10	227	1.40E-13	4.09E-13	3.29E-13
28	2.15E-11	4.11E-11	1.09E-10	228	1.57E-13	3.46E-13	3.59E-13
29	2.26E-11	4.51E-11	1.01E-10	229	1.63E-13	3.07E-13	3.49E-13
30	2.20E-11	4.41E-11	8.99E-11	230	1.52E-13	3.47E-13	2.94E-13
31	1.97E-11	4.00E-11	7.75E-11	231	1.15E-13	3.95E-13	2.34E-13
32	1.66E-11	3.20E-11	6.37E-11	232	1.08E-13	4.20E-13	1.98E-13
33	1.51E-11	2.49E-11	6.09E-11	233	1.05E-13	4.09E-13	1.88E-13
34	1.50E-11	2.40E-11	5.90E-11	234	8.15E-14	4.00E-13	1.95E-13
35	1.47E-11	2.29E-11	5.09E-11	235	5.32E-14	4.02E-13	2.21E-13
36	1.50E-11	2.27E-11	3.75E-11	236	7.52E-14	3.78E-13	2.25E-13
37	1.38E-11	2.30E-11	2.59E-11	237	1.32E-13	1.17E-12	6.60E-13
38	1.12E-11	2.16E-11	2.23E-11	238	2.96E-13	3.76E-12	2.12E-12
39	9.28E-12	2.14E-11	1.83E-11	239	4.29E-13	5.65E-12	3.18E-12
40	9.05E-12	2.14E-11	1.65E-11	240	4.47E-13	5.80E-12	3.27E-12
41	9.57E-12	1.98E-11	1.60E-11	241	4.50E-13	5.57E-12	3.16E-12
42	9.99E-12	1.67E-11	1.68E-11	242	3.43E-13	3.78E-12	2.18E-12
43	1.03E-11	1.41E-11	1.65E-11	243	1.94E-13	1.22E-12	7.58E-13
44	1.00E-11	1.16E-11	1.49E-11	244	1.48E-13	2.79E-13	2.89E-13
45	9.05E-12	1.07E-11	1.46E-11	245	1.28E-13	2.10E-13	2.28E-13
46	8.35E-12	1.03E-11	1.62E-11	246	1.15E-13	1.97E-13	1.82E-13
47	7.93E-12	1.00E-11	1.61E-11	247	1.18E-13	1.82E-13	1.59E-13
48	7.65E-12	1.13E-11	1.47E-11	248	1.12E-13	1.80E-13	1.38E-13
49	6.71E-12	1.31E-11	1.42E-11	249	1.03E-13	1.77E-13	1.05E-13
50	6.09E-12	1.42E-11	1.46E-11	250	1.02E-13	1.88E-13	1.04E-13

Table 4 Radial Beam Tube Motion for Covered & Insulated System

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*
51	6.03E-12	1.51E-11	1.39E-11	251	1.09E-13	2.11E-13	1.18E-13
52	5.75E-12	1.58E-11	1.29E-11	252	1.17E-13	2.11E-13	1.37E-13
53	4.92E-12	1.62E-11	1.34E-11	253	1.03E-13	2.09E-13	1.45E-13
54	4.27E-12	1.69E-11	1.40E-11	254	9.10E-14	2.09E-13	1.29E-13
55	4.85E-12	1.92E-11	1.45E-11	255	9.38E-14	1.88E-13	1.33E-13
56	6.36E-12	4.30E-11	4.64E-11	256	9.67E-14	1.66E-13	1.41E-13
57	4.66E-11	4.04E-10	4.68E-10	257	1.06E-13	1.67E-13	1.35E-13
58	1.47E-10	1.27E-09	1.48E-09	258	1.17E-13	1.66E-13	1.40E-13
59	2.12E-10	1.84E-09	2.14E-09	259	1.22E-13	1.77E-13	1.69E-13
60	2.11E-10	1.83E-09	2.13E-09	260	1.23E-13	1.76E-13	2.09E-13
61	1.99E-10	1.72E-09	2.01E-09	261	1.10E-13	1.65E-13	2.25E-13
62	1.30E-10	1.13E-09	1.32E-09	262	9.99E-14	1.65E-13	2.19E-13
63	3.92E-11	3.43E-10	4.03E-10	263	1.10E-13	1.75E-13	2.12E-13
64	4.44E-12	3.50E-11	3.86E-11	264	1.17E-13	1.97E-13	2.13E-13
65	2.95E-12	1.19E-11	9.05E-12	265	1.14E-13	2.07E-13	2.04E-13
66	3.01E-12	1.01E-11	6.72E-12	266	1.15E-13	1.80E-13	1.79E-13
67	3.30E-12	9.03E-12	5.46E-12	267	1.10E-13	1.55E-13	1.70E-13
68	3.22E-12	7.84E-12	5.57E-12	268	9.59E-14	1.48E-13	1.95E-13
69	2.79E-12	6.84E-12	6.53E-12	269	8.65E-14	1.40E-13	2.41E-13
70	2.24E-12	6.41E-12	7.84E-12	270	8.81E-14	1.70E-13	2.52E-13
71	1.88E-12	5.89E-12	8.90E-12	271	9.56E-14	2.31E-13	2.24E-13
72	1.77E-12	5.07E-12	8.61E-12	272	9.18E-14	2.76E-13	1.85E-13
73	1.73E-12	4.32E-12	7.34E-12	273	7.44E-14	2.86E-13	1.68E-13
74	1.76E-12	3.85E-12	5.76E-12	274	6.31E-14	2.43E-13	1.63E-13
75	1.98E-12	3.23E-12	4.22E-12	275	7.17E-14	1.84E-13	1.46E-13
76	2.07E-12	2.46E-12	3.68E-12	276	8.34E-14	1.53E-13	1.18E-13
77	2.02E-12	2.66E-12	3.59E-12	277	8.63E-14	1.55E-13	1.19E-13
78	1.94E-12	3.46E-12	3.42E-12	278	7.83E-14	1.47E-13	1.31E-13
79	1.74E-12	3.98E-12	3.43E-12	279	7.16E-14	1.45E-13	1.31E-13
80	1.79E-12	4.28E-12	3.25E-12	280	7.21E-14	1.34E-13	1.25E-13
81	2.06E-12	4.21E-12	2.91E-12	281	7.42E-14	1.07E-13	1.10E-13
82	2.12E-12	4.12E-12	2.37E-12	282	7.11E-14	9.67E-14	8.75E-14
83	1.99E-12	4.41E-12	1.87E-12	283	7.48E-14	9.50E-14	8.35E-14
84	1.78E-12	4.07E-12	1.99E-12	284	8.95E-14	9.54E-14	9.43E-14
85	1.70E-12	3.70E-12	2.25E-12	285	1.01E-13	8.45E-14	1.06E-13
86	1.58E-12	2.74E-12	2.19E-12	286	1.03E-13	8.01E-14	1.15E-13
87	1.26E-12	1.79E-12	2.10E-12	287	9.59E-14	7.89E-14	1.30E-13
88	1.19E-12	2.41E-12	3.34E-12	288	8.52E-14	9.55E-14	1.35E-13
89	1.26E-12	3.05E-12	4.37E-12	289	7.69E-14	1.16E-13	1.25E-13
90	1.45E-12	3.02E-12	4.45E-12	290	7.15E-14	1.19E-13	1.17E-13
91	1.60E-12	2.96E-12	4.44E-12	291	6.90E-14	1.15E-13	1.18E-13
92	1.51E-12	2.34E-12	3.19E-12	292	7.74E-14	1.16E-13	1.16E-13
93	1.41E-12	1.78E-12	2.00E-12	293	8.26E-14	1.23E-13	1.16E-13
94	1.39E-12	1.67E-12	1.84E-12	294	8.26E-14	1.15E-13	1.21E-13
95	1.38E-12	1.55E-12	1.72E-12	295	7.37E-14	1.02E-13	1.33E-13
96	1.37E-12	1.48E-12	1.48E-12	296	4.99E-14	2.17E-13	2.98E-13
97	1.37E-12	1.28E-12	1.30E-12	297	4.49E-13	2.53E-12	3.03E-12

Table 4 Radial Beam Tube Motion for Covered & Insulated System

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*
98	1.37E-12	1.09E-12	1.32E-12	298	1.53E-12	8.49E-12	1.02E-11
99	1.30E-12	1.19E-12	1.58E-12	299	2.32E-12	1.28E-11	1.55E-11
100	1.19E-12	1.14E-12	1.81E-12	300	2.39E-12	1.32E-11	1.60E-11
101	1.04E-12	9.43E-13	1.96E-12	301	2.31E-12	1.28E-11	1.55E-11
102	8.80E-13	8.82E-13	1.99E-12	302	1.58E-12	8.78E-12	1.07E-11
103	7.71E-13	8.79E-13	1.94E-12	303	4.99E-13	2.80E-12	3.48E-12
104	7.86E-13	9.50E-13	1.98E-12	304	7.78E-14	2.82E-13	4.30E-13
105	7.76E-13	9.44E-13	1.83E-12	305	7.87E-14	1.10E-13	2.01E-13
106	6.96E-13	9.15E-13	1.35E-12	306	8.04E-14	1.18E-13	1.81E-13
107	7.08E-13	9.54E-13	1.01E-12	307	7.28E-14	1.24E-13	1.67E-13
108	7.81E-13	1.05E-12	1.03E-12	308	6.82E-14	1.36E-13	1.55E-13
109	7.73E-13	1.08E-12	1.08E-12	309	6.48E-14	1.48E-13	1.43E-13
110	6.84E-13	9.73E-13	1.04E-12	310	6.72E-14	1.51E-13	1.31E-13
111	5.84E-13	8.33E-13	1.01E-12	311	6.89E-14	1.41E-13	1.18E-13
112	5.14E-13	8.54E-13	1.12E-12	312	7.24E-14	1.16E-13	9.26E-14
113	6.12E-13	8.20E-13	1.19E-12	313	7.68E-14	8.89E-14	7.11E-14
114	7.69E-13	7.46E-13	1.18E-12	314	8.78E-14	7.66E-14	5.58E-14
115	8.43E-13	8.08E-13	1.17E-12	315	9.93E-14	8.31E-14	6.11E-14
116	8.79E-13	8.81E-13	1.23E-12	316	9.21E-14	9.03E-14	7.36E-14
117	1.20E-12	4.94E-12	5.67E-12	317	7.50E-14	1.09E-13	9.02E-14
118	2.87E-12	1.56E-11	1.82E-11	318	5.84E-14	1.44E-13	1.09E-13
119	4.11E-12	2.29E-11	2.70E-11	319	4.18E-14	1.61E-13	1.27E-13
120	4.14E-12	2.30E-11	2.75E-11	320	4.15E-14	1.55E-13	1.40E-13
121	3.97E-12	2.18E-11	2.65E-11	321	4.75E-14	1.51E-13	1.46E-13
122	2.67E-12	1.45E-11	1.78E-11	322	5.19E-14	1.61E-13	1.41E-13
123	1.00E-12	4.22E-12	5.63E-12	323	5.67E-14	1.83E-13	1.15E-13
124	4.92E-13	8.32E-13	1.05E-12	324	5.68E-14	2.07E-13	1.16E-13
125	4.34E-13	7.77E-13	9.91E-13	325	5.76E-14	2.36E-13	1.24E-13
126	4.41E-13	5.60E-13	1.01E-12	326	6.84E-14	2.37E-13	1.21E-13
127	4.33E-13	5.21E-13	1.02E-12	327	7.50E-14	2.18E-13	1.02E-13
128	4.79E-13	5.65E-13	1.03E-12	328	7.27E-14	2.31E-13	8.92E-14
129	5.87E-13	6.32E-13	9.79E-13	329	6.81E-14	2.37E-13	8.46E-14
130	6.18E-13	6.69E-13	9.16E-13	330	5.89E-14	2.04E-13	7.93E-14
131	6.14E-13	5.90E-13	9.99E-13	331	4.91E-14	1.63E-13	7.73E-14
132	5.94E-13	4.62E-13	1.17E-12	332	4.40E-14	1.51E-13	8.04E-14
133	6.13E-13	5.13E-13	1.22E-12	333	4.60E-14	1.66E-13	9.55E-14
134	6.08E-13	5.81E-13	1.27E-12	334	4.81E-14	1.73E-13	9.62E-14
135	5.68E-13	5.85E-13	1.24E-12	335	4.93E-14	2.15E-13	9.97E-14
136	5.69E-13	6.25E-13	1.01E-12	336	4.98E-14	2.46E-13	1.12E-13
137	5.27E-13	5.95E-13	9.42E-13	337	5.12E-14	2.66E-13	1.20E-13
138	4.44E-13	5.16E-13	9.49E-13	338	5.71E-14	3.04E-13	1.47E-13
139	3.74E-13	4.84E-13	1.06E-12	339	6.09E-14	3.43E-13	1.60E-13
140	4.18E-13	4.45E-13	1.33E-12	340	5.54E-14	3.65E-13	1.62E-13
141	4.74E-13	4.37E-13	1.44E-12	341	4.81E-14	3.56E-13	1.61E-13
142	4.53E-13	4.19E-13	1.40E-12	342	4.68E-14	3.02E-13	1.63E-13
143	4.06E-13	4.34E-13	1.35E-12	343	5.44E-14	2.44E-13	1.65E-13
144	3.79E-13	4.80E-13	1.47E-12	344	5.53E-14	2.23E-13	1.61E-13

Table 4 Radial Beam Tube Motion for Covered & Insulated System

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*
145	3.71E-13	4.57E-13	1.56E-12	345	5.75E-14	2.17E-13	1.49E-13
146	3.83E-13	4.43E-13	1.51E-12	346	6.02E-14	2.21E-13	1.27E-13
147	3.98E-13	4.75E-13	1.36E-12	347	6.06E-14	2.04E-13	1.20E-13
148	4.09E-13	6.44E-13	1.12E-12	348	5.80E-14	1.89E-13	1.25E-13
149	4.00E-13	8.02E-13	1.03E-12	349	4.80E-14	2.10E-13	1.24E-13
150	3.57E-13	7.89E-13	9.19E-13	350	4.06E-14	2.29E-13	1.13E-13
151	3.28E-13	7.34E-13	7.53E-13	351	3.85E-14	2.08E-13	1.19E-13
152	3.40E-13	5.63E-13	7.95E-13	352	3.87E-14	1.82E-13	1.16E-13
153	3.23E-13	4.78E-13	1.37E-12	353	4.24E-14	1.91E-13	1.05E-13
154	3.08E-13	5.06E-13	2.07E-12	354	5.07E-14	2.05E-13	1.12E-13
155	3.10E-13	5.00E-13	2.69E-12	355	5.69E-14	1.98E-13	1.17E-13
156	3.74E-13	4.77E-13	3.02E-12	356	5.99E-14	1.82E-13	1.16E-13
157	4.14E-13	4.08E-13	2.74E-12	357	7.42E-14	2.57E-13	1.11E-13
158	4.06E-13	4.01E-13	2.41E-12	358	1.14E-13	6.37E-13	2.12E-13
159	3.78E-13	4.48E-13	2.59E-12	359	1.46E-13	9.43E-13	3.22E-13
160	3.48E-13	4.98E-13	2.88E-12	360	1.45E-13	9.64E-13	3.37E-13
161	3.59E-13	6.41E-13	2.87E-12	361	1.45E-13	9.37E-13	3.32E-13
162	3.56E-13	7.97E-13	2.61E-12	362	1.14E-13	6.52E-13	2.45E-13
163	3.58E-13	8.22E-13	2.32E-12	363	7.02E-14	2.38E-13	1.12E-13
164	3.37E-13	7.40E-13	2.37E-12	364	6.00E-14	1.29E-13	7.73E-14
165	3.01E-13	5.78E-13	2.24E-12	365	6.06E-14	1.40E-13	8.27E-14
166	2.77E-13	4.41E-13	1.75E-12	366	6.02E-14	1.42E-13	9.23E-14
167	2.38E-13	4.52E-13	1.40E-12	367	6.62E-14	1.46E-13	1.24E-13
168	2.18E-13	4.51E-13	1.21E-12	368	6.93E-14	1.63E-13	1.61E-13
169	2.43E-13	3.75E-13	9.88E-13	369	6.25E-14	1.86E-13	1.90E-13
170	2.73E-13	3.85E-13	7.73E-13	370	5.31E-14	2.14E-13	2.01E-13
171	3.18E-13	6.26E-13	8.16E-13	371	4.32E-14	2.31E-13	1.77E-13
172	3.44E-13	9.19E-13	1.11E-12	372	4.00E-14	2.15E-13	1.54E-13
173	3.41E-13	1.07E-12	1.39E-12	373	4.84E-14	1.72E-13	1.41E-13
174	3.25E-13	1.15E-12	1.42E-12	374	5.43E-14	1.40E-13	1.30E-13
175	3.12E-13	1.23E-12	1.47E-12	375	5.43E-14	1.36E-13	1.42E-13
176	4.29E-13	2.22E-12	2.96E-12	376	5.10E-14	1.42E-13	1.55E-13
177	3.89E-12	2.32E-11	2.99E-11	377	5.41E-14	1.54E-13	1.51E-13
178	1.28E-11	7.59E-11	9.83E-11	378	5.89E-14	1.59E-13	1.39E-13
179	1.90E-11	1.13E-10	1.47E-10	379	5.64E-14	1.39E-13	1.33E-13
180	1.94E-11	1.15E-10	1.50E-10	380	5.16E-14	1.09E-13	1.30E-13
181	1.87E-11	1.11E-10	1.45E-10	381	4.98E-14	7.94E-14	1.18E-13
182	1.26E-11	7.47E-11	9.82E-11	382	4.66E-14	7.89E-14	1.16E-13
183	3.94E-12	2.33E-11	3.08E-11	383	3.77E-14	1.07E-13	1.20E-13
184	4.24E-13	2.46E-12	2.74E-12	384	2.69E-14	1.40E-13	1.26E-13
185	2.56E-13	9.38E-13	1.34E-12	385	2.81E-14	1.50E-13	1.37E-13
186	2.35E-13	7.17E-13	1.50E-12	386	3.66E-14	1.44E-13	1.34E-13
187	2.00E-13	6.92E-13	1.60E-12	387	4.12E-14	1.23E-13	1.23E-13
188	1.86E-13	7.56E-13	1.48E-12	388	4.06E-14	8.41E-14	1.09E-13
189	2.18E-13	7.72E-13	1.26E-12	389	3.90E-14	7.11E-14	1.00E-13
190	2.52E-13	6.88E-13	1.30E-12	390	4.10E-14	7.39E-14	1.07E-13
191	2.80E-13	5.53E-13	1.26E-12	391	4.28E-14	7.42E-14	1.06E-13

Table 4 Radial Beam Tube Motion for Covered & Insulated System

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring, x[f] m/Sqrt[Hz]*
192	2.86E-13	4.61E-13	1.19E-12	392	4.03E-14	7.26E-14	1.02E-13
193	2.54E-13	5.31E-13	9.65E-13	393	3.66E-14	7.65E-14	1.04E-13
194	1.88E-13	6.58E-13	6.67E-13	394	3.59E-14	8.31E-14	9.33E-14
195	1.35E-13	9.03E-13	4.95E-13	395	3.55E-14	8.71E-14	7.39E-14
196	1.42E-13	1.54E-12	4.30E-13	396	3.48E-14	7.81E-14	6.22E-14
197	1.47E-13	1.91E-12	4.27E-13	397	3.24E-14	7.22E-14	6.31E-14
198	1.54E-13	1.80E-12	4.60E-13	398	3.08E-14	7.42E-14	6.09E-14
199	1.90E-13	1.35E-12	4.76E-13	399	2.91E-14	7.43E-14	5.74E-14
200	2.33E-13	6.28E-13	5.57E-13				

Table 5 Axial Tube Motion for Covered & Insulated Beam Tube

f[Hz]	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring x[f] m/Sqrt[Hz]*	*f[Hz]*	*Base (ground) x[f] m/Sqrt[Hz]*	*Support Ring x[f] m/Sqrt[Hz]*	*Stiffening Ring x[f] m/Sqrt[Hz]*
1	4.00E-05	5.61E-06	2.69E-06	201	3.24E-13	1.15E-12	3.14E-13
2	6.78E-06	9.61E-07	4.54E-07	202	3.14E-13	9.66E-13	4.16E-13
3	9.79E-07	1.50E-07	6.80E-08	203	3.24E-13	1.10E-12	4.79E-13
4	7.26E-08	1.99E-08	8.60E-09	204	3.46E-13	1.42E-12	4.98E-13
5	1.06E-08	6.90E-09	4.84E-09	205	3.73E-13	1.61E-12	4.74E-13
6	3.84E-09	3.97E-09	4.19E-09	206	4.21E-13	1.65E-12	4.28E-13
7	1.57E-09	3.11E-09	3.54E-09	207	4.73E-13	1.58E-12	4.49E-13
8	8.46E-10	2.23E-09	2.67E-09	208	5.27E-13	1.39E-12	6.25E-13
9	5.56E-10	1.55E-09	2.10E-09	209	5.70E-13	1.22E-12	7.67E-13
10	3.94E-10	1.06E-09	2.01E-09	210	5.99E-13	1.09E-12	7.66E-13
11	2.84E-10	1.26E-09	4.76E-09	211	6.60E-13	1.08E-12	6.60E-13
12	2.11E-10	2.07E-09	9.23E-09	212	7.99E-13	1.09E-12	5.62E-13
13	1.74E-10	2.30E-09	1.08E-08	213	1.01E-12	1.09E-12	6.16E-13
14	1.73E-10	2.01E-09	9.55E-09	214	1.20E-12	1.04E-12	6.15E-13
15	1.76E-10	1.65E-09	7.93E-09	215	1.26E-12	9.68E-13	5.70E-13
16	1.49E-10	9.68E-10	4.82E-09	216	1.23E-12	8.91E-13	4.56E-13
17	1.08E-10	3.34E-10	1.55E-09	217	1.18E-12	7.46E-13	2.95E-13
18	7.27E-11	1.28E-10	2.88E-10	218	1.08E-12	6.55E-13	2.46E-13
19	4.99E-11	8.73E-11	2.30E-10	219	9.00E-13	6.83E-13	2.24E-13
20	4.78E-11	6.17E-11	2.09E-10	220	6.92E-13	6.74E-13	2.26E-13
21	5.15E-11	4.41E-11	1.80E-10	221	5.26E-13	6.71E-13	2.45E-13
22	5.19E-11	3.92E-11	1.27E-10	222	4.23E-13	6.80E-13	2.52E-13
23	4.66E-11	4.26E-11	7.23E-11	223	3.53E-13	5.78E-13	2.53E-13
24	4.03E-11	4.52E-11	4.28E-11	224	2.96E-13	4.63E-13	2.48E-13
25	3.61E-11	4.13E-11	3.23E-11	225	2.60E-13	4.09E-13	2.63E-13
26	3.22E-11	3.41E-11	3.03E-11	226	2.27E-13	3.94E-13	2.91E-13
27	2.54E-11	2.56E-11	2.96E-11	227	2.07E-13	3.95E-13	2.91E-13
28	2.17E-11	2.14E-11	2.73E-11	228	2.03E-13	3.87E-13	2.74E-13
29	2.16E-11	2.23E-11	2.44E-11	229	1.74E-13	3.58E-13	2.74E-13
30	2.04E-11	2.23E-11	2.29E-11	230	1.35E-13	3.43E-13	2.90E-13

31	1.85E-11	2.13E-11	2.23E-11	231	1.13E-13	3.60E-13	3.10E-13
32	1.75E-11	1.71E-11	2.00E-11	232	1.07E-13	3.93E-13	3.00E-13
33	1.76E-11	1.49E-11	1.71E-11	233	1.29E-13	4.02E-13	2.77E-13
34	1.71E-11	1.33E-11	1.34E-11	234	1.61E-13	3.97E-13	2.43E-13
35	1.53E-11	1.30E-11	1.16E-11	235	1.83E-13	3.47E-13	2.03E-13
36	1.26E-11	1.38E-11	1.33E-11	236	1.84E-13	3.05E-13	1.87E-13
37	1.10E-11	1.29E-11	1.36E-11	237	1.79E-13	2.60E-13	2.25E-13
38	1.01E-11	1.09E-11	1.30E-11	238	3.01E-13	3.15E-13	5.10E-13
39	1.05E-11	9.10E-12	1.20E-11	239	4.23E-13	4.42E-13	7.48E-13
40	1.14E-11	8.03E-12	1.15E-11	240	4.39E-13	4.63E-13	7.90E-13
41	1.26E-11	8.17E-12	1.11E-11	241	4.23E-13	4.93E-13	7.76E-13
42	1.35E-11	8.40E-12	9.43E-12	242	3.01E-13	4.02E-13	5.76E-13
43	1.32E-11	7.67E-12	9.24E-12	243	1.51E-13	2.92E-13	3.51E-13
44	1.14E-11	6.56E-12	9.33E-12	244	1.15E-13	2.98E-13	3.21E-13
45	9.06E-12	6.92E-12	9.14E-12	245	1.01E-13	3.08E-13	3.31E-13
46	7.56E-12	7.78E-12	9.12E-12	246	8.89E-14	3.22E-13	3.09E-13
47	6.57E-12	7.98E-12	9.40E-12	247	9.12E-14	2.91E-13	2.88E-13
48	5.44E-12	7.68E-12	9.65E-12	248	9.70E-14	2.61E-13	2.40E-13
49	5.26E-12	6.67E-12	9.48E-12	249	1.01E-13	2.46E-13	1.80E-13
50	5.65E-12	5.80E-12	9.34E-12	250	1.01E-13	2.63E-13	1.72E-13
51	5.60E-12	5.32E-12	8.08E-12	251	1.16E-13	3.05E-13	1.85E-13
52	4.92E-12	4.66E-12	8.23E-12	252	1.37E-13	3.64E-13	1.81E-13
53	4.38E-12	4.31E-12	9.47E-12	253	1.65E-13	4.00E-13	1.74E-13
54	3.82E-12	4.83E-12	1.03E-11	254	1.75E-13	3.51E-13	1.80E-13
55	3.43E-12	5.87E-12	9.83E-12	255	1.73E-13	2.58E-13	1.88E-13
56	3.82E-12	2.35E-11	4.39E-11	256	1.72E-13	2.11E-13	1.88E-13
57	3.73E-11	2.53E-10	5.02E-10	257	1.55E-13	2.34E-13	1.88E-13
58	1.20E-10	7.94E-10	1.59E-09	258	1.45E-13	2.36E-13	1.80E-13
59	1.74E-10	1.14E-09	2.30E-09	259	1.46E-13	2.46E-13	1.66E-13
60	1.74E-10	1.14E-09	2.30E-09	260	1.49E-13	2.40E-13	1.71E-13
61	1.64E-10	1.07E-09	2.16E-09	261	1.59E-13	2.22E-13	1.74E-13
62	1.07E-10	6.98E-10	1.42E-09	262	1.70E-13	2.29E-13	1.52E-13
63	3.26E-11	2.09E-10	4.29E-10	263	1.87E-13	2.63E-13	1.32E-13
64	4.36E-12	1.72E-11	3.62E-11	264	2.09E-13	2.73E-13	1.32E-13
65	3.27E-12	4.92E-12	4.44E-12	265	2.19E-13	2.20E-13	1.46E-13
66	3.26E-12	4.33E-12	4.78E-12	266	2.23E-13	1.85E-13	1.50E-13
67	3.04E-12	4.09E-12	4.17E-12	267	2.19E-13	1.87E-13	1.50E-13
68	2.89E-12	3.84E-12	3.39E-12	268	2.25E-13	2.25E-13	1.53E-13
69	2.86E-12	3.60E-12	3.16E-12	269	2.48E-13	2.61E-13	1.45E-13
70	2.85E-12	3.12E-12	2.92E-12	270	2.75E-13	3.01E-13	1.34E-13
71	2.70E-12	2.84E-12	2.76E-12	271	3.06E-13	3.32E-13	1.35E-13
72	2.58E-12	2.89E-12	2.84E-12	272	3.36E-13	3.59E-13	1.47E-13
73	2.63E-12	2.70E-12	2.38E-12	273	3.47E-13	4.24E-13	1.48E-13
74	2.68E-12	2.41E-12	1.76E-12	274	3.51E-13	4.31E-13	1.38E-13
75	2.64E-12	2.28E-12	1.71E-12	275	3.61E-13	4.02E-13	1.32E-13
76	2.64E-12	2.35E-12	2.08E-12	276	3.76E-13	3.56E-13	1.34E-13
77	2.77E-12	2.27E-12	2.39E-12	277	3.99E-13	2.38E-13	1.28E-13
78	2.78E-12	2.12E-12	2.28E-12	278	4.29E-13	1.84E-13	1.23E-13
79	2.79E-12	2.14E-12	1.97E-12	279	4.45E-13	1.93E-13	1.32E-13
80	2.87E-12	2.02E-12	1.78E-12	280	4.55E-13	1.75E-13	1.24E-13
81	2.92E-12	1.87E-12	1.49E-12	281	4.69E-13	1.49E-13	1.15E-13
82	3.10E-12	1.76E-12	1.35E-12	282	4.72E-13	1.71E-13	1.17E-13
83	3.20E-12	1.54E-12	1.40E-12	283	4.69E-13	1.94E-13	1.26E-13

84	3.14E-12	1.38E-12	1.55E-12	284	4.69E-13	2.19E-13	1.36E-13
85	3.04E-12	1.34E-12	1.91E-12	285	4.60E-13	2.32E-13	1.37E-13
86	2.79E-12	1.49E-12	1.84E-12	286	4.45E-13	2.30E-13	1.30E-13
87	2.52E-12	1.75E-12	1.54E-12	287	4.28E-13	2.00E-13	1.36E-13
88	2.17E-12	2.31E-12	1.40E-12	288	4.14E-13	1.68E-13	1.52E-13
89	1.87E-12	2.70E-12	1.40E-12	289	4.00E-13	1.25E-13	1.56E-13
90	1.72E-12	2.73E-12	1.39E-12	290	3.78E-13	1.07E-13	1.45E-13
91	1.64E-12	2.64E-12	1.40E-12	291	3.53E-13	1.12E-13	1.35E-13
92	1.68E-12	2.08E-12	1.40E-12	292	3.33E-13	1.15E-13	1.30E-13
93	1.80E-12	1.60E-12	1.23E-12	293	3.19E-13	1.09E-13	1.29E-13
94	1.77E-12	1.48E-12	1.08E-12	294	3.02E-13	1.05E-13	1.35E-13
95	1.67E-12	1.31E-12	9.32E-13	295	2.88E-13	1.16E-13	1.39E-13
96	1.45E-12	1.10E-12	9.29E-13	296	2.75E-13	1.96E-13	2.83E-13
97	1.24E-12	1.15E-12	9.86E-13	297	4.07E-13	1.57E-12	3.21E-12
98	1.12E-12	1.26E-12	9.29E-13	298	1.21E-12	5.13E-12	1.09E-11
99	1.04E-12	1.29E-12	8.54E-13	299	1.80E-12	7.66E-12	1.67E-11
100	1.04E-12	1.21E-12	8.43E-13	300	1.85E-12	7.83E-12	1.73E-11
101	1.14E-12	1.04E-12	8.28E-13	301	1.78E-12	7.53E-12	1.68E-11
102	1.15E-12	9.96E-13	8.68E-13	302	1.19E-12	5.07E-12	1.16E-11
103	1.09E-12	9.90E-13	8.92E-13	303	3.79E-13	1.54E-12	3.72E-12
104	1.03E-12	1.04E-12	1.10E-12	304	1.77E-13	1.98E-13	3.69E-13
105	9.41E-13	1.18E-12	1.53E-12	305	1.67E-13	2.01E-13	2.19E-13
106	8.15E-13	1.23E-12	1.68E-12	306	1.60E-13	1.90E-13	2.24E-13
107	8.53E-13	1.20E-12	1.70E-12	307	1.63E-13	2.01E-13	2.19E-13
108	9.23E-13	1.27E-12	1.43E-12	308	1.71E-13	2.45E-13	2.03E-13
109	8.06E-13	1.30E-12	1.00E-12	309	1.79E-13	2.54E-13	1.79E-13
110	7.24E-13	1.16E-12	9.13E-13	310	1.86E-13	2.26E-13	1.94E-13
111	6.80E-13	9.07E-13	8.68E-13	311	1.85E-13	1.90E-13	2.19E-13
112	6.75E-13	7.23E-13	7.71E-13	312	1.86E-13	1.77E-13	2.27E-13
113	6.12E-13	7.02E-13	7.11E-13	313	1.89E-13	1.83E-13	2.38E-13
114	6.09E-13	6.55E-13	6.59E-13	314	1.95E-13	1.96E-13	2.46E-13
115	7.04E-13	5.57E-13	6.71E-13	315	2.02E-13	2.15E-13	2.55E-13
116	7.43E-13	5.38E-13	6.98E-13	316	2.06E-13	2.28E-13	2.69E-13
117	8.65E-13	1.10E-12	2.46E-12	317	2.12E-13	2.35E-13	2.81E-13
118	1.12E-12	2.84E-12	7.88E-12	318	2.24E-13	2.30E-13	2.92E-13
119	1.37E-12	3.99E-12	1.17E-11	319	2.32E-13	2.68E-13	2.85E-13
120	1.40E-12	3.94E-12	1.19E-11	320	2.23E-13	3.36E-13	2.84E-13
121	1.40E-12	3.68E-12	1.15E-11	321	1.98E-13	4.23E-13	3.24E-13
122	1.06E-12	2.42E-12	7.83E-12	322	1.69E-13	4.71E-13	3.84E-13
123	6.38E-13	9.02E-13	2.60E-12	323	1.52E-13	4.33E-13	4.28E-13
124	6.23E-13	6.90E-13	8.07E-13	324	1.49E-13	3.82E-13	4.58E-13
125	7.44E-13	6.92E-13	6.52E-13	325	1.55E-13	3.33E-13	4.61E-13
126	7.89E-13	5.68E-13	5.65E-13	326	1.68E-13	3.39E-13	4.94E-13
127	7.46E-13	5.14E-13	5.55E-13	327	1.70E-13	3.47E-13	6.45E-13
128	6.88E-13	4.93E-13	5.41E-13	328	1.65E-13	3.20E-13	8.94E-13
129	6.14E-13	5.07E-13	4.75E-13	329	1.56E-13	3.05E-13	1.02E-12
130	4.69E-13	6.09E-13	4.21E-13	330	1.45E-13	3.25E-13	1.09E-12
131	3.92E-13	6.51E-13	3.94E-13	331	1.40E-13	3.56E-13	1.20E-12
132	3.89E-13	6.30E-13	4.39E-13	332	1.38E-13	4.43E-13	1.21E-12
133	3.77E-13	6.40E-13	5.43E-13	333	1.35E-13	5.69E-13	1.09E-12
134	3.74E-13	6.37E-13	6.30E-13	334	1.33E-13	6.09E-13	1.06E-12
135	3.83E-13	6.28E-13	6.70E-13	335	1.34E-13	5.82E-13	1.09E-12
136	4.45E-13	6.25E-13	7.11E-13	336	1.32E-13	5.41E-13	9.03E-13

137	4.88E-13	6.12E-13	6.93E-13	337	1.28E-13	4.76E-13	6.16E-13
138	5.26E-13	5.95E-13	6.06E-13	338	1.19E-13	4.24E-13	4.78E-13
139	5.29E-13	5.62E-13	4.55E-13	339	1.04E-13	4.76E-13	4.19E-13
140	5.23E-13	5.52E-13	3.45E-13	340	9.26E-14	5.62E-13	3.92E-13
141	4.95E-13	5.38E-13	3.22E-13	341	8.31E-14	5.99E-13	3.37E-13
142	4.40E-13	5.01E-13	4.28E-13	342	6.98E-14	6.08E-13	3.03E-13
143	4.05E-13	4.86E-13	5.81E-13	343	6.23E-14	6.05E-13	2.66E-13
144	3.87E-13	4.76E-13	6.80E-13	344	6.60E-14	6.19E-13	2.22E-13
145	3.66E-13	4.76E-13	6.91E-13	345	6.77E-14	6.88E-13	2.14E-13
146	3.77E-13	4.79E-13	6.66E-13	346	6.93E-14	7.62E-13	2.30E-13
147	4.78E-13	4.48E-13	6.64E-13	347	6.79E-14	7.40E-13	2.18E-13
148	4.84E-13	5.15E-13	6.63E-13	348	5.96E-14	6.68E-13	1.63E-13
149	4.12E-13	6.08E-13	5.89E-13	349	4.64E-14	5.72E-13	1.40E-13
150	3.94E-13	6.50E-13	5.21E-13	350	4.30E-14	4.77E-13	1.28E-13
151	4.63E-13	6.79E-13	4.83E-13	351	5.44E-14	4.08E-13	1.17E-13
152	5.16E-13	5.54E-13	5.85E-13	352	6.11E-14	3.52E-13	1.07E-13
153	5.10E-13	4.57E-13	7.38E-13	353	6.62E-14	3.66E-13	9.17E-14
154	4.67E-13	4.56E-13	8.03E-13	354	6.70E-14	3.63E-13	8.01E-14
155	4.11E-13	4.66E-13	9.60E-13	355	6.06E-14	3.23E-13	7.60E-14
156	3.58E-13	4.99E-13	1.50E-12	356	5.23E-14	3.21E-13	8.91E-14
157	3.05E-13	4.66E-13	2.18E-12	357	4.58E-14	3.58E-13	1.52E-13
158	2.56E-13	4.10E-13	2.75E-12	358	7.54E-14	5.01E-13	4.24E-13
159	2.37E-13	4.12E-13	2.97E-12	359	1.06E-13	6.34E-13	6.42E-13
160	2.88E-13	3.84E-13	3.13E-12	360	1.12E-13	6.36E-13	6.63E-13
161	3.38E-13	3.64E-13	4.08E-12	361	1.11E-13	6.30E-13	6.47E-13
162	3.48E-13	3.45E-13	5.01E-12	362	8.07E-14	4.92E-13	4.51E-13
163	3.67E-13	3.39E-13	4.92E-12	363	6.08E-14	2.96E-13	1.56E-13
164	3.46E-13	3.66E-13	4.15E-12	364	6.60E-14	2.46E-13	7.79E-14
165	2.99E-13	4.25E-13	2.96E-12	365	6.60E-14	2.27E-13	9.21E-14
166	2.97E-13	4.76E-13	3.04E-12	366	5.91E-14	2.37E-13	1.08E-13
167	3.00E-13	5.15E-13	3.57E-12	367	6.42E-14	2.66E-13	1.10E-13
168	3.07E-13	5.33E-13	3.40E-12	368	7.36E-14	2.80E-13	9.91E-14
169	3.24E-13	4.80E-13	2.89E-12	369	7.97E-14	2.75E-13	9.08E-14
170	3.47E-13	4.08E-13	2.30E-12	370	8.40E-14	2.67E-13	8.63E-14
171	3.57E-13	3.63E-13	1.98E-12	371	8.40E-14	2.68E-13	9.09E-14
172	3.39E-13	3.58E-13	2.15E-12	372	8.73E-14	2.61E-13	8.40E-14
173	2.98E-13	3.35E-13	2.30E-12	373	9.44E-14	2.50E-13	6.66E-14
174	2.69E-13	3.18E-13	2.27E-12	374	1.00E-13	2.39E-13	6.11E-14
175	2.68E-13	3.32E-13	2.20E-12	375	1.06E-13	2.15E-13	7.16E-14
176	3.57E-13	1.41E-12	3.36E-12	376	1.11E-13	1.82E-13	7.88E-14
177	3.37E-12	1.57E-11	3.10E-11	377	1.18E-13	1.75E-13	8.48E-14
178	1.10E-11	5.09E-11	1.02E-10	378	1.21E-13	1.76E-13	8.66E-14
179	1.62E-11	7.53E-11	1.53E-10	379	1.21E-13	1.78E-13	8.77E-14
180	1.65E-11	7.69E-11	1.57E-10	380	1.23E-13	1.82E-13	8.68E-14
181	1.58E-11	7.39E-11	1.51E-10	381	1.23E-13	1.77E-13	8.06E-14
182	1.06E-11	4.96E-11	1.03E-10	382	1.23E-13	1.61E-13	7.77E-14
183	3.21E-12	1.53E-11	3.28E-11	383	1.19E-13	1.47E-13	7.76E-14
184	3.21E-13	1.41E-12	3.85E-12	384	1.13E-13	1.36E-13	7.37E-14
185	2.19E-13	5.45E-13	1.74E-12	385	1.10E-13	1.22E-13	7.71E-14
186	2.08E-13	7.59E-13	1.44E-12	386	1.08E-13	1.12E-13	7.80E-14
187	1.95E-13	1.06E-12	1.28E-12	387	1.08E-13	1.01E-13	7.45E-14
188	1.90E-13	1.20E-12	1.23E-12	388	1.14E-13	1.06E-13	7.32E-14
189	2.37E-13	1.19E-12	1.29E-12	389	1.16E-13	1.37E-13	6.59E-14

190	2.99E-13	1.33E-12	1.24E-12	390	1.15E-13	1.51E-13	5.84E-14
191	3.25E-13	1.52E-12	1.07E-12	391	1.13E-13	1.37E-13	5.41E-14
192	3.47E-13	1.45E-12	9.82E-13	392	1.13E-13	1.21E-13	4.95E-14
193	3.42E-13	1.22E-12	8.39E-13	393	1.16E-13	1.12E-13	5.13E-14
194	2.97E-13	1.03E-12	7.59E-13	394	1.22E-13	1.22E-13	5.18E-14
195	2.47E-13	1.05E-12	7.36E-13	395	1.30E-13	1.16E-13	4.44E-14
196	2.04E-13	1.06E-12	7.02E-13	396	1.40E-13	1.06E-13	4.40E-14
197	2.02E-13	1.10E-12	6.64E-13	397	1.53E-13	1.12E-13	5.02E-14
198	2.35E-13	1.10E-12	5.63E-13	398	1.64E-13	1.16E-13	5.90E-14
199	2.89E-13	1.20E-12	4.10E-13	399	1.72E-13	1.23E-13	6.63E-14
200	3.21E-13	1.32E-12	3.13E-13				