

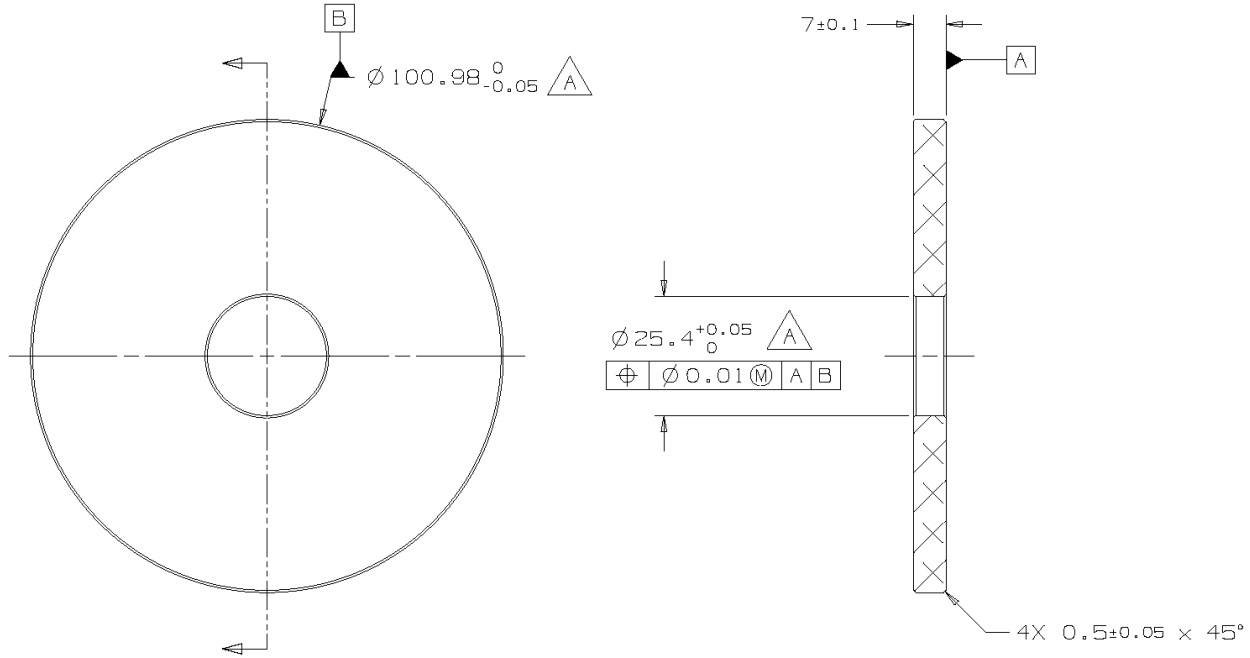
CoorsTek ceramics measurements, 40 pc.

S. Kazakov

07/15/2020

DESCRIPTION: CERAMIC WINDOW
 PROJECT: PIP-11_HB650_Cav_DM
 CATEGORY: WINDOW


REV	REVISION CONTROL DOCUMENT	DATES		SIGNATURES	
A	F10133029 - A - RCD	25-Mar-2020	DRAWN	T.SPERRY	
		31-Mar-2020	APPROVED	O.PRONTICHEV	



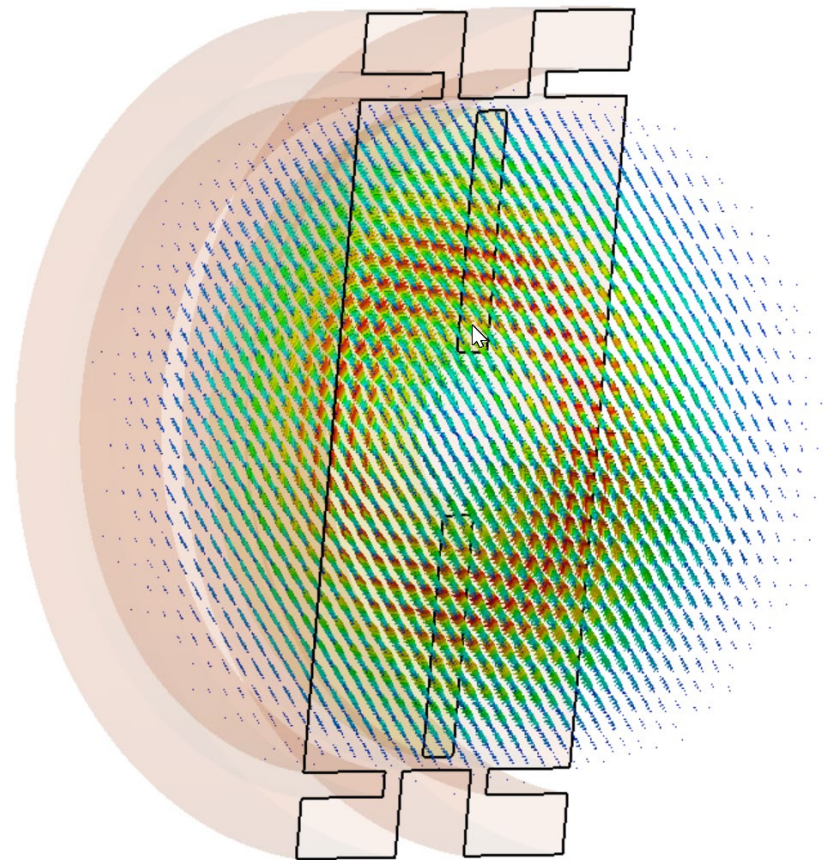
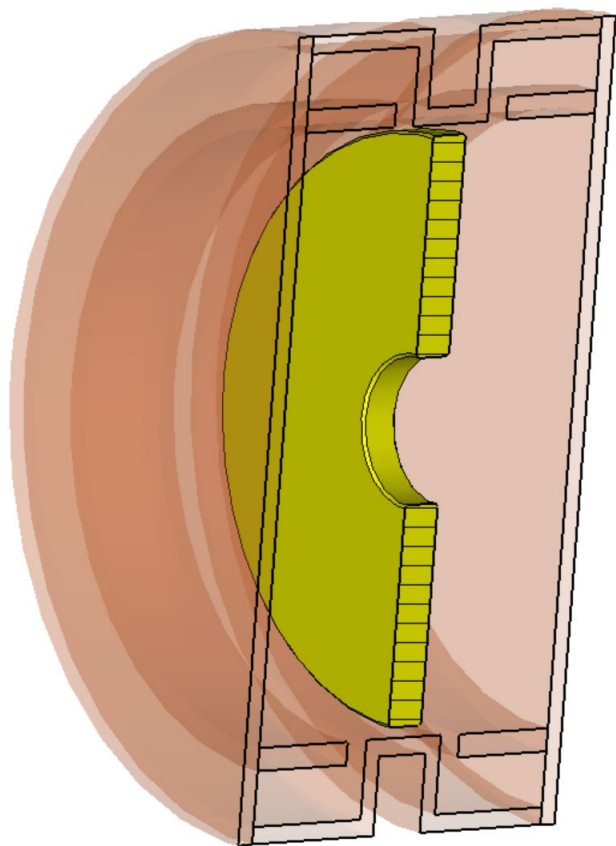
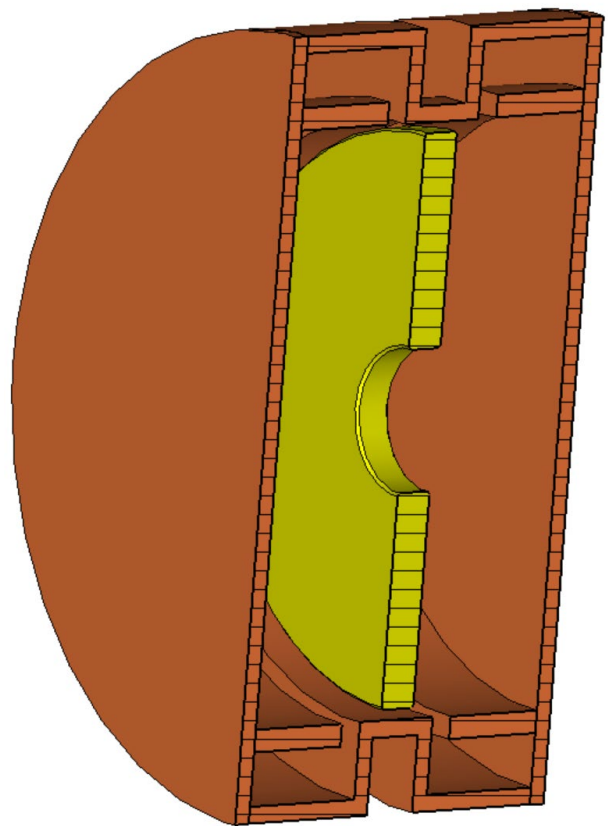
NOTES (UNLESS OTHERWISE SPECIFIED):

- MATERIAL: COORS TEK AD-998 ALUMINA (99.8% PURE) WITH DIELECTRIC LOSS (TAN DELTA) $< 10^{-4}$ AT ROOM TEMPERATURE, OR EQUIVALENT.
- $\triangle A$
- VENDOR SHALL SUPPLY THE PART SUFFICIENTLY PACKAGED TO PROTECT THE FINISH AND INTEGRITY DURING SHIPMENT AND STORAGE. THE PACKAGE SHALL BE PROMINENTLY MARKED WITH THE PART NUMBER AND REVISION LEVEL.

UNLESS OTHERWISE SPECIFIED					DRAWN	G. LANGLOIS	DATE	24-Jan-2020
±X	±X.X	±X.XX	±X/X	±X*	CHECKED	J.COGHILL	DATE	20-Feb-2020
0.5	0.2	0.05	N/A	1	APPROVED	O.PRONTICHEV	DATE	20-Feb-2020
BREAK ALL SHARP EDGES, MAX: 0.5					USED ON			
DO NOT SCALE DRAWING					F10132228			
DIMENSIONS BASED ON: ASME Y14.5-2009					MATERIAL			
MAX MACHINE ALL SURFACES: 1.6					ALUMINA CERAMIC, 99.8% PURITY			
DRAWING UNITS: MM					GROUP: Technical Division - Design and Drafting CAGE CODE: OUSR6			
THIRD ANGLE PROJECTION								

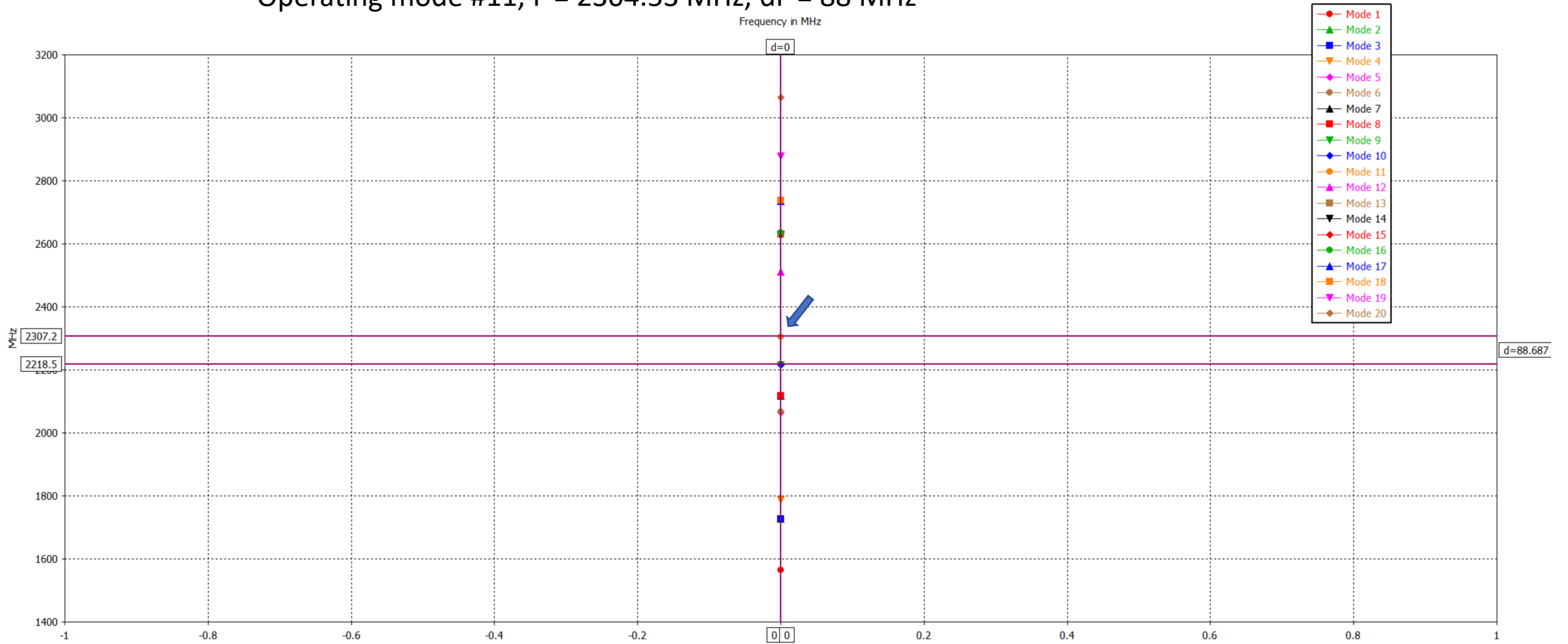
 FERMILAB NATIONAL ACCELERATOR LABORATORY UNITED STATES DEPARTMENT OF ENERGY					NAME				
					CERAMIC WINDOW				
SCALE	SIZE	DRAWING NUMBER		SHEET	REV				
1:1	A3	F10133029		1 OF 1	A				

TEMPLATE VERSION: 2018.12.03



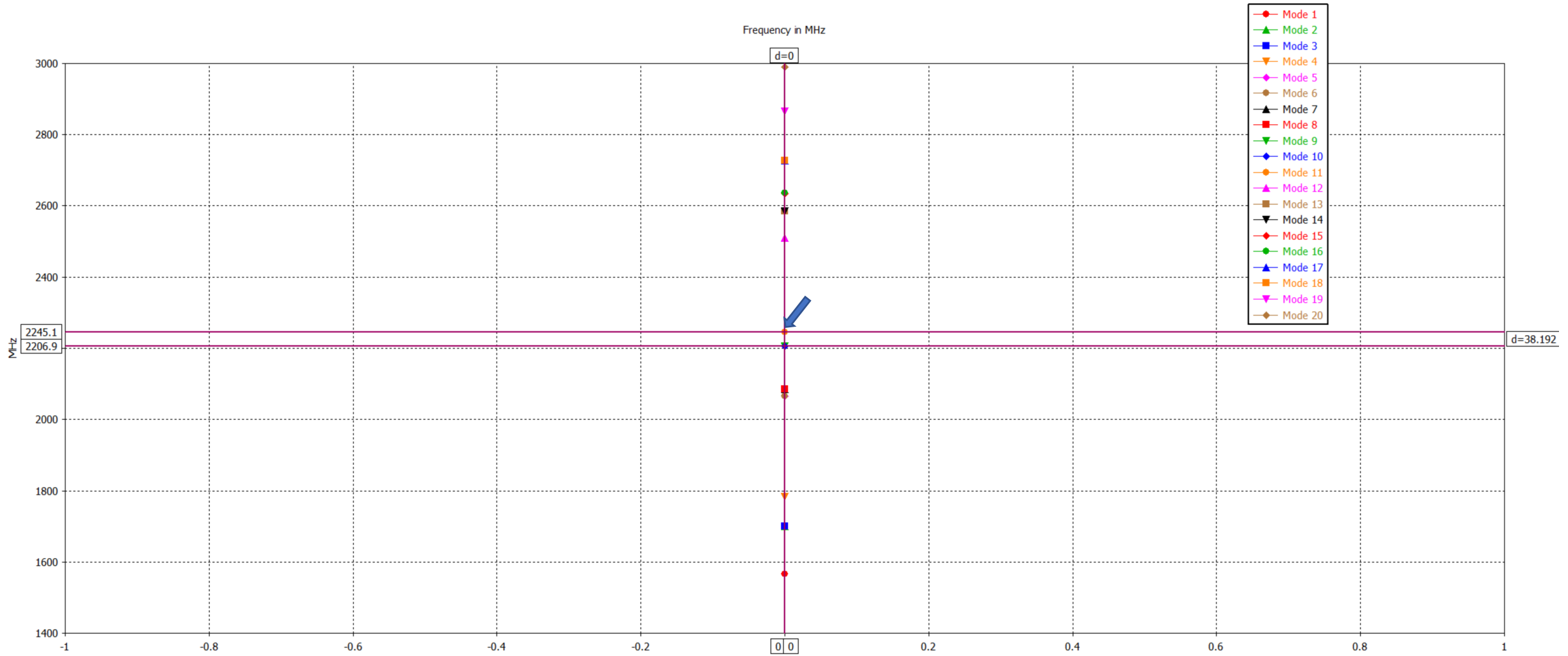
Eps = 9.4

Operating mode #11, F = 2304.53 MHz, dF = 88 MHz



Eps = 10.

Operating mode #11, F = 2245.27 MHz, dF = 38 MHz



Q-Factor Calculation Eps = 9.4

H-Field data: Mode 11

Material/Solid	Conductivity	Mu	Loss/W	Loss/%	Q
Cond. Enclosure	5.8000e+07	1	0.0000e+00	0	
Copper (annealed)	5.8000e+07	1	2.7676e+05	18.6	5.2317e+04
Sum of Surface Losses			2.7676e+05	18.6	5.2317e+04
Volume Losses			1.2129e+06	81.4	1.1938e+04
Sum			1.4896e+06		9.7200e+03

Q-Factor Calculation Eps = 10

H-Field data: Mode 11

Material/Solid	Conductivity	Mu	Loss/W	Loss/%	Q
Cond. Enclosure	5.8000e+07	1	0.0000e+00	0	
Copper (annealed)	5.8000e+07	1	2.7072e+05	18.5	5.2109e+04
Sum of Surface Losses			2.7072e+05	18.5	5.2109e+04
Volume Losses			1.1952e+06	81.5	1.1802e+04
Sum			1.4660e+06		9.6228e+03

Q-Factor Calculation Eps = 9.6

H-Field data: Mode 11

Material/Solid	Conductivity	Mu	Loss/W	Loss/%	Q
Cond. Enclosure	5.8000e+07	1	0.0000e+00	0	
Copper (annealed)	5.8000e+07	1	2.7451e+05	18.5	5.2281e+04
Sum of Surface Losses			2.7451e+05	18.5	5.2281e+04
Volume Losses			1.2070e+06	81.5	1.1891e+04
Sum			1.4815e+06		9.6873e+03

Q-Factor Calculation Eps = 9.8, acc 2 order

H-Field data: Mode 11

Material/Solid	Conductivity	Mu	Loss/W	Loss/%	Q
Cond. Enclosure	5.8000e+07	1	0.0000e+00	0	
Copper (annealed)	5.8000e+07	1	2.7234e+05	18.5	5.2240e+04
Sum of Surface Losses			2.7234e+05	18.5	5.2240e+04
Volume Losses			1.2011e+06	81.5	1.1845e+04
Sum			1.4734e+06		9.6559e+03

Q-Factor Calculation Eps = 9.8, acc 3 order

H-Field data: Mode 11

Material/Solid	Conductivity	Mu	Loss/W	Loss/%	Q
Cond. Enclosure	5.8000e+07	1	0.0000e+00	0	
Copper (annealed)	5.8000e+07	1	2.7528e+05	18.6	5.1675e+04
Sum of Surface Losses			2.7528e+05	18.6	5.1675e+04
Volume Losses			1.2010e+06	81.4	1.1844e+04
Sum			1.4763e+06		9.6358e+03

Example of calculation:

+

$$Q_s := 27123$$

$$a_1 := -0.6263$$

$$a_2 := -1.4116$$

$$s_1 := 10^{\frac{a_1}{20}} = 0.93$$

$$s_2 := 10^{\frac{a_2}{20}} = 0.85$$

$$Q_1 := Q_s \cdot \frac{2}{1 - s_1} = 7.798 \times 10^5$$

$$Q_2 := Q_s \cdot \frac{2}{1 - s_2} = 3.616 \times 10^5$$

$$Q_3 := \frac{1}{\frac{1}{Q_s} - \frac{1}{Q_1} - \frac{1}{Q_2}} = 3.047 \times 10^4$$

$$Q_{cer} := \frac{1}{\frac{1}{Q_3} - \frac{1}{Q_c}} = 7.874 \times 10^4$$

$$L_t := \frac{Q_{v1}}{Q_{cer}} \cdot 10^{-4} = 1.551 \times 10^{-5}$$

$$Q_c := 4.97 \cdot 10^4$$

$$Q_{v1} := 1.2215 \cdot 10^4$$

Disk #	F	Q s21	Q s12	Q av	s21	s12	s11	s22	Loss Tng	
40	2.23665	24050	24480	24265	-21.586	-22.544	-3.2218	-0.1969	1.78E-5	+
39	2.24012	25247	25740	25494	-21.628	-22.626	-3.7188	-0.1664	1.50E-5	+
38	2.23459	23500	23910	23705	-21.700	-22.615	-3.0359	-0.2045	1.91E-5	Sml yellow sport at middle
37	2.23784	25303	25837	25570	-21.254	-22.211	-3.5623	-0.1863	1.51E-5	+
36	2.22960	25812	26364	26088	-22.04	-24.167	-3.2116	-0.1224	1.52E-5	+
35	2.23972	25346	25785	25565	-22.273	-24.249	-3.8417	-0.0956	1.49E-5	+
34	2.24034	23677	23992	23835	-21.998	-23.962	-3.2396	-0.1286	1.87E-5	+
33	2.23893	24864	25336	25100	-22.972	-24.950	-4.0416	-0.0753	1.53E-5	+
32	2.24141	25652	26106	25879	-21.668	-23.611	-3.4863	-0.1276	1.50E-5	+
31	2.23841	25418	25902	25660	-21.462	-23.460	-3.4415	-0.1727	1.52E-5	+
30	2.24124	25593	26029	25811	-21.587	-23.527	-3.6202	-0.1594	1.47E-5	+
29	2.22541	26031	26725	26377	-20.206	-22.146	-3.1322	-0.4647	1.40E-5	
28	2.22323	20989	21516	21254	-21.098	-23.019	-3.0123	-0.4574	2.32E-5	
27	2.23865	25240	25748	25494	-19.978	-21.868	-3.7607	-0.424	1.43E-5	
26	2.24403	25021	25451	25236	-20.602	-22.410	-3.9865	-0.3452	1.45E-5	
25	2.22807	24723	25370	25047	-20.907	-22.861	-3.6585	-0.4157	1.51E-5	

Disk #	F	Q s21	Q s12	Q av	s21	s12	s11	s22	Loss Tng	
24	2.22548	25638	26334	25986	-19.976	-21.888	-3.5665	-0.498	1.37E-5	+
23	2.23699	24260	24733	24497	-20.931	22.862	-3.3564	-0.3644	1.67E-5	+
22	2.22538	25067	25793	25430	-20.652	-22.552	-4.155	-0.4157	1.37E-5	Yellow spot near inner hole
21	2.22591	24948	25646	25297	-20.344	-22.299	-4.0406	-0.4162	1.41E-5	+
20	2.23545	23439	23936	23688	-21.237	-23.202	-3.7063	-0.2895	1.72E-5	+
19	2.22435	23606	24206	23906	-21.384	-23.470	-3.2251	-0.2502	1.82E-5	Two white (pale) spots
18	2.22480	26163	26816	26490	-20.341	-22.394	-3.0867	-0.2009	1.46E-5	+
17	2.24101	25906	26413	26160	-20.253	-22.182	-3.6587	-0.1838	1.41E-5	+
16	2.23988	25559	26096	25828	-20.057		-3.8915	0.1868	1.42E-5	+
15	2.22424	24452	25178	24815	-21.947	-24.056	-4.4204	-0.0992	1.50E-5	+
14	2.23134	25460	26080	25770	-20.911	-23.002	-3.9319	-0.1404	1.43E-5	+
13	2.22801	25461	26166	25813	-20.518	22.632	-4.1343	-0.1459	1.39E-5	+
12	2.24119	25788	26440	26114	-19.961	-21.894	-3.841	-0.1981	1.38E-5	+
11	2.22545	26040	26760	26400	-20.487	-22.622	-3.7974	-0.1689	1.36E-5	+
10		26024	26562	26293	-20.368	-22.343	-3.730	-0.1818	1.38E-5	+
9		23811	24377	24094	-21.325	-23.487	-2.992	-0.1653	1.86E-5	+

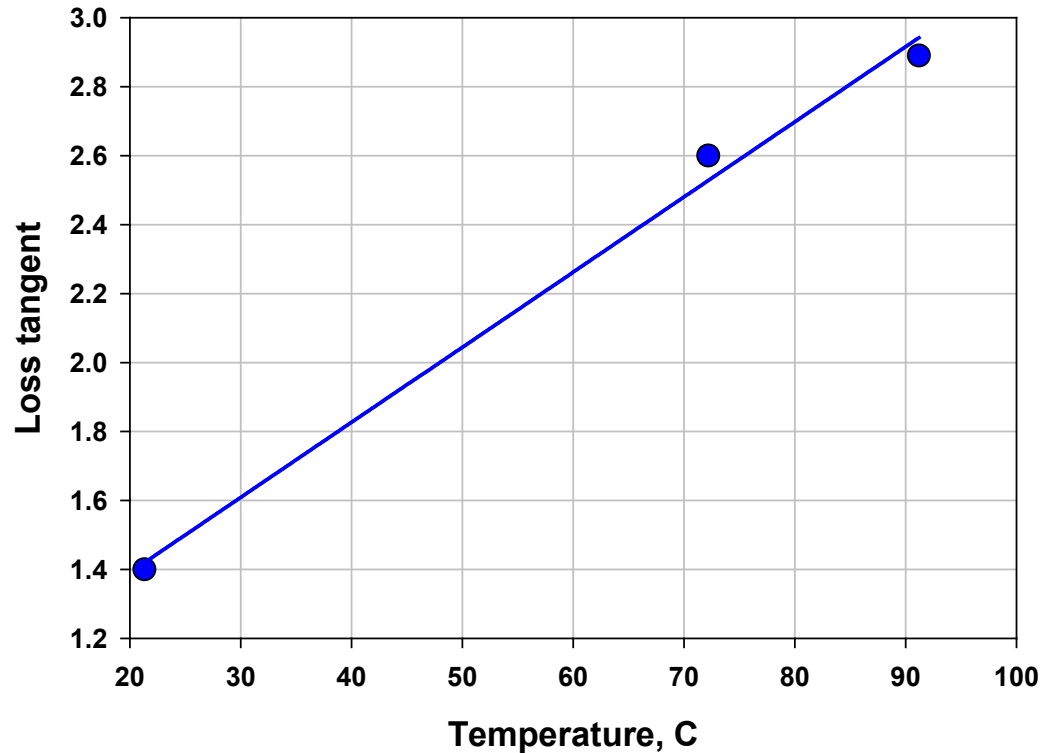
Disk #	F	Q s21	Q s12	Q av	s21	s12	s11	s22	Loss Tng	
1	2.22313	20300	20790	20454	-24.620	-25.551	-3.382	-0.0895	2.54E-5	
28	2.22323	20989	21516	21254	-21.098	-23.019	-3.0123	-0.4574	2.32E-5	
2		22240	22720	22480	-23.228	-24.123	-3.4282	-0.1267	2.08E-5	
7		22873	23459	23166	-22.553	-24.715	-3.39	-1114	1.96E-5	
38	2.23459	23500	23910	23705	-21.700	-22.615	-3.0359	-0.2045	1.91E-5	
34	2.24034	23677	23992	23835	-21.998	-23.962	-3.2396	-0.1286	1.87E-5	
9		23811	24377	24094	-21.325	-23.487	-2.992	-0.1653	1.86E-5	
4	2.22736	23380	23890	23635	-21.582	-22.458	-3.5185	-0.1902	1.83E-5	
19	2.22435	23606	24206	23906	-21.384	-23.470	-3.2251	-0.2502	1.82E-5	Two white (pale) spots
5	2.22839	23776	24300	24038	-21.547	-22.40	-3.212	-0.197	1.82E-5	
40	2.23665	24050	24480	24265	-21.586	-22.544	-3.2218	-0.1969	1.78E-5	
20	2.23545	23439	23936	23688	-21.237	-23.202	-3.7063	-0.2895	1.72E-5	
23	2.23699	24260	24733	24497	-20.931	22.862	-3.3564	-0.3644	1.67E-5	
33	2.23893	24864	25336	25100	-22.972	-24.950	-4.0416	-0.0753	1.53E-5	
36	2.22960	25812	26364	26088	-22.04	-24.167	-3.2116	-0.1224	1.52E-5	
31	2.23841	25418	25902	25660	-21.462	-23.460	-3.4415	-0.1727	1.52E-5	

Disk #	F	Q s21	Q s12	Q av	s21	s12	s11	s22	Loss Tng	
37	2.23784	25303	25837	25570	-21.254	-22.211	-3.5623	-0.1863	1.51E-5	
25	2.22807	24723	25370	25047	-20.907	-22.861	-3.6585	-0.4157	1.51E-5	
15	2.22424	24452	25178	24815	-21.947	-24.056	-4.4204	-0.0992	1.50E-5	
32	2.24141	25652	26106	25879	-21.668	-23.611	-3.4863	-0.1276	1.50E-5	
39	2.24012	25247	25740	25494	-21.628	-22.626	-3.7188	-0.1664	1.50E-5	
35	2.23972	25346	25785	25565	-22.273	-24.249	-3.8417	-0.0956	1.49E-5	
30	2.24124	25593	26029	25811	-21.587	-23.527	-3.6202	-0.1594	1.47E-5	
18	2.22480	26163	26816	26490	-20.341	-22.394	-3.0867	-0.2009	1.46E-5	
3	2.22729	25370	26020	25695	-21.075	-21.931	-3.8129	-0.1965	1.45E-5	
26	2.24403	25021	25451	25236	-20.602	-22.410	-3.9865	-0.3452	1.45E-5	
14	2.23134	25460	26080	25770	-20.911	-23.002	-3.9319	-0.1404	1.43E-5	
27	2.23865	25240	25748	25494	-19.978	-21.868	-3.7607	-0.424	1.43E-5	
8		25701	26226	25964	-20.653	-22.641	-3.80	-0.1643	1.42E-5	
16	2.23988	25559	26096	25828	-20.057		-3.8915	0.1868	1.42E-5	
17	2.24101	25906	26413	26160	-20.253	-22.182	-3.6587	-0.1838	1.41E-5	
21	2.22591	24948	25646	25297	-20.344	-22.299	-4.0406	-0.4162	1.41E-5	

Thermal measurements, disk #14

T, C	F	Q s21	Q s12	Q av	s21	s12	s11	s22	Loss Tng	
21.3	2.23111	25820	26435	26128	-21.22	-22.09	-3.7258	-0.199	1.40E-5	
72.2	2.22566	21800	22150	21975	-23.0	-23.9	-3.009	-0.1515	2.26E-5	
91.2	2.22289	19500	19900	19700	-24.03	-25.0	-2.628	-0.133	2.89E-5	

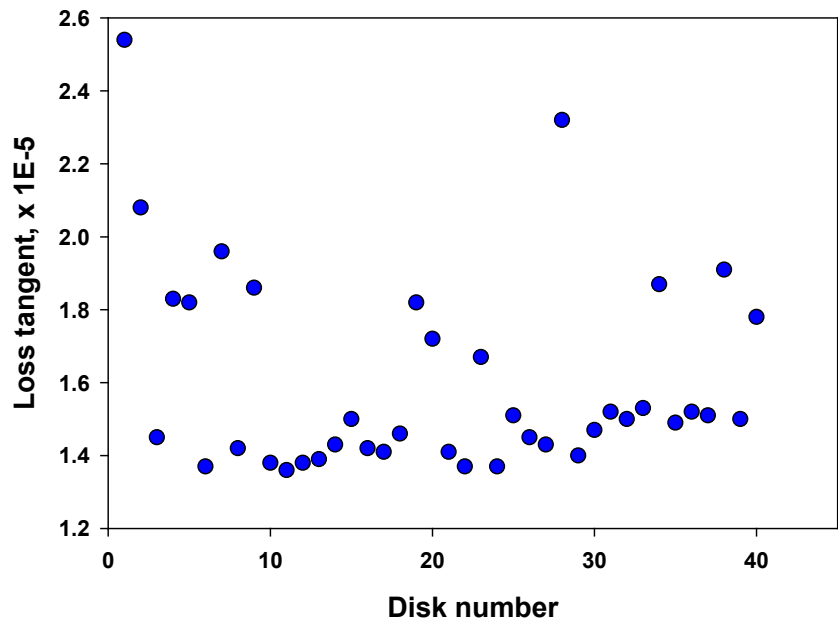
Loss tangent vs temperature,
disk #14.



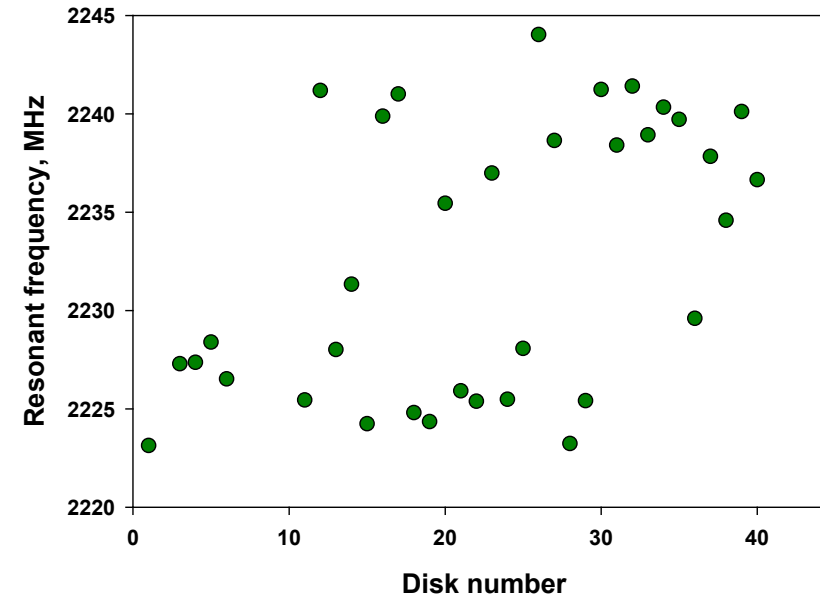
$$L_tng(T) = L_tng(RT) * (1 + 0.0152 * (T - RT)) = L_tng(RT) * F(T)$$

$$T_op \sim 60C \quad dT = 60 - 20 = 40 \quad F(T) = 1 + 0.608 \sim 1.61$$

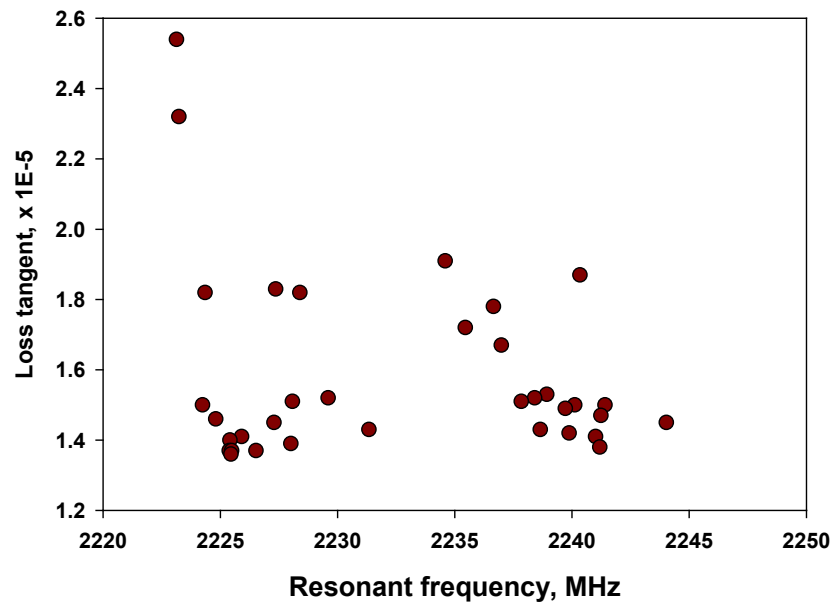
Loss tangent distribution



Frequency distribution



Loss T vs Frequency



Recommendations:

Disks for test brazing: #19, #22 (yellow and pale spots on the surface)

Disks for 325 MHz, form low to high loss tng, 19pc:

32, 15, 25, 37, 31, 36, 33, 23, 20, 40, 5, 4, 9, 34, 38, 7, 2, 28, 1

Disks for 650 MHz, form low to high loss tng, 19pc:

11, 24, 6, 12, 10, 13, 29, 21, 17, 16, 8, 27, 14, 26, 3, 18, 30, 35, 39

Size measurements.

Specifications:

Outer diameter 3.975" +/- 0.001", 100.965mm +/- 0.0254mm (100.34 – 100.99)
Inner diameter 1.001" +/- 0.001", 25.425mm +/- 0.0254mm (25.40 – 25.45)
Thickness 0.276" +/- 0.004", 7.01mm +/- 0.1mm (6.91mm – 7.11mm)

Measurements of disk #19

Outer: 100.97, 100.96, 100.98, 100.97, average: 100.97mm
Inner: 25.44, 25.44, 25.44, 25.44, average: 25.44
Thickness: 7.03, 7.03, 7.02, 7.03, average: 7.028

Measurements of disk #22

Outer: 100.98, 100.98, 100.98, 101.00, average: 100.985mm
Inner: 25.43, 25.43, 25.43, 25.43, average: 25.43
Thickness: 7.05, 7.03, 7.03, 7.04, average: 7.038

# 19	Outer	Inner	Thickness
Company	100.98	25.42	7.050
S. Kazakov	100.97	25.44	7.028

# 22	Outer	Inner	Thickness
Company	100.985	25.42	7.067
S. Kazakov	100.985	25.43	7.038