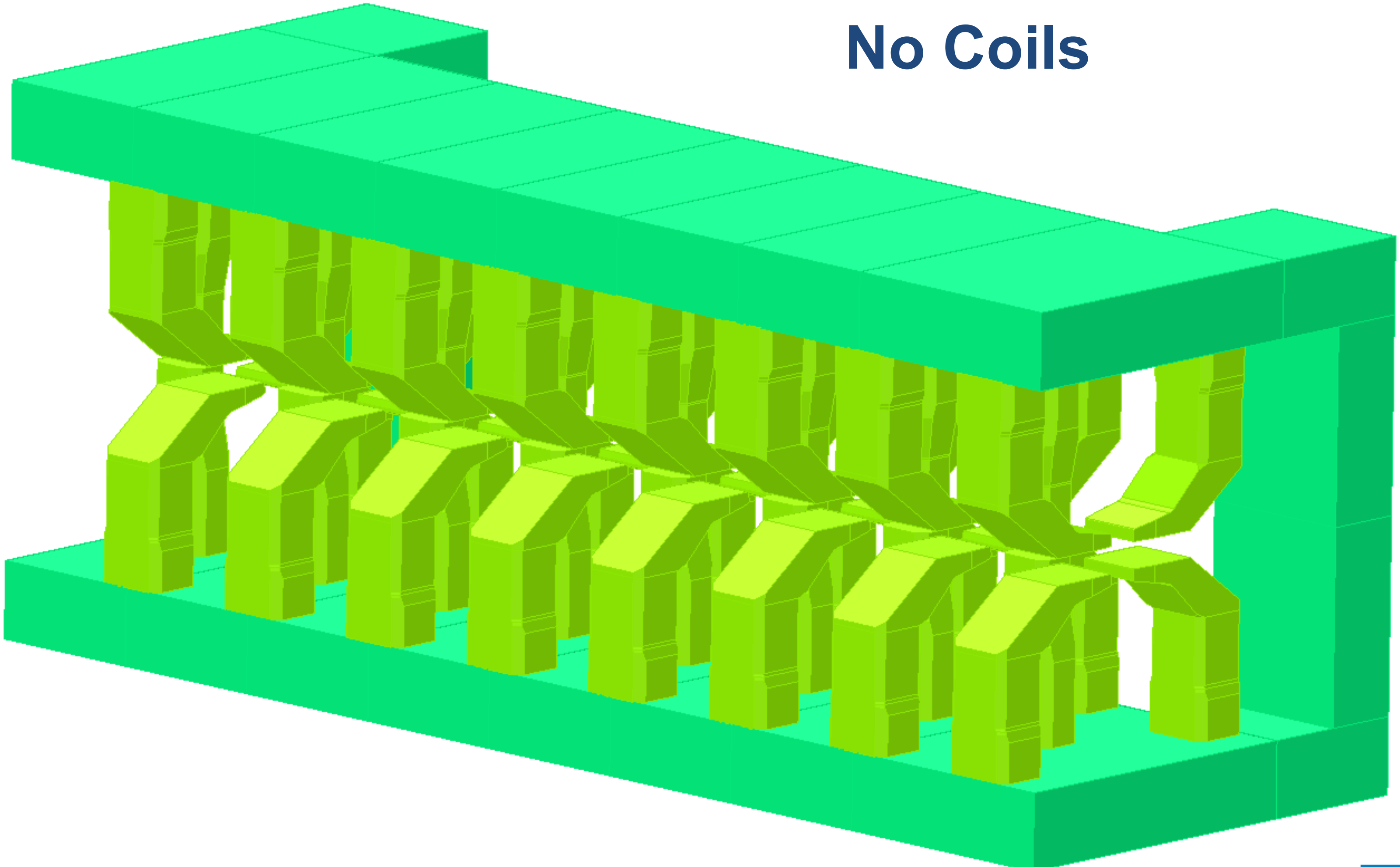
IEX Multipoles, Trim Coil Settings, and Look-Up Tables

By Mark Jaski

OPERA 4 Period Model For Prototype

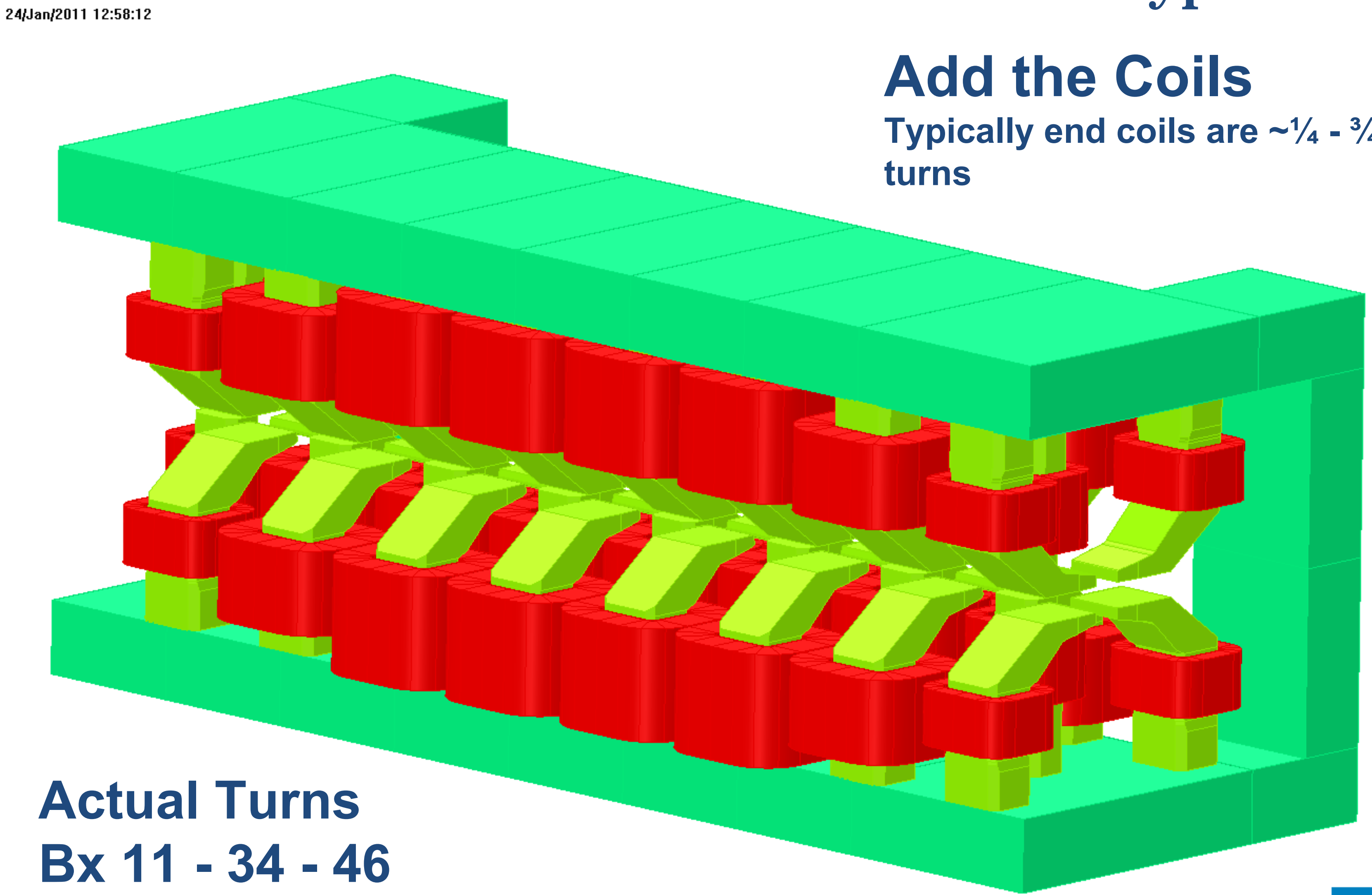
24/Jan/2011 12:59:10

No Coils



Opera

OPERA 4 Period Model For Prototype



Add the Coils

Typically end coils are ~¼ - ¾ - 1 turns

Actual Turns

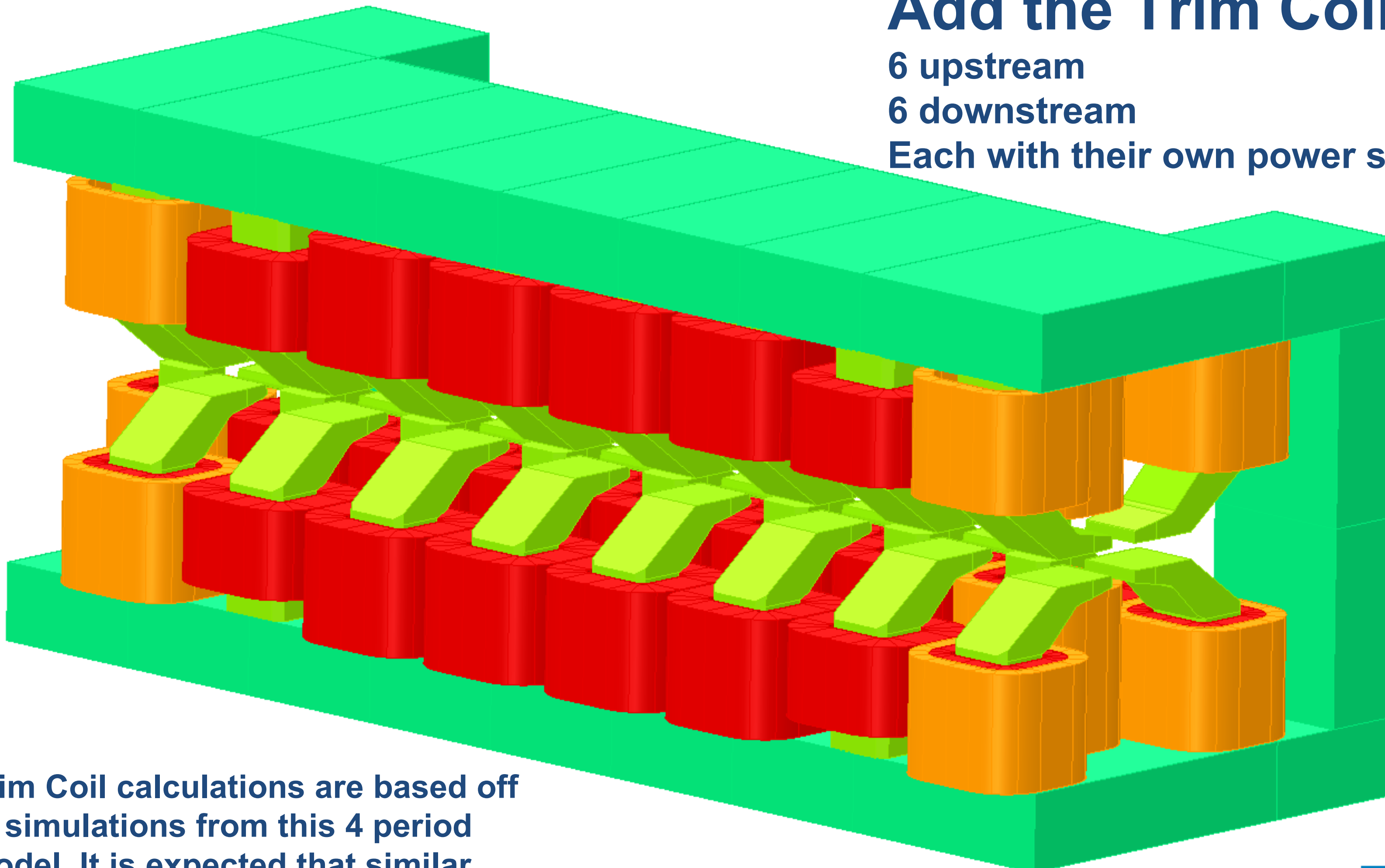
Bx 11 - 34 - 46

By 15 - 42 - 62

Opera

OPERA 4 Period Model For Prototype

24/Jan/2011 12:57:06



Add the Trim Coils

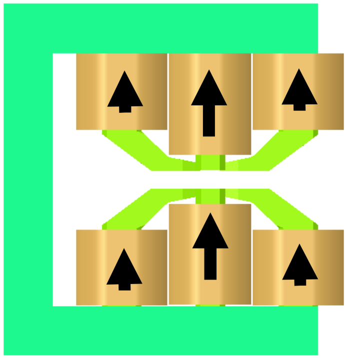
6 upstream
6 downstream
Each with their own power supply

Trim Coil calculations are based off of simulations from this 4 period model. It is expected that similar values for trim coils will be obtained for the 38 period device.

Opera

End Coil Multi-pole Field Configurations

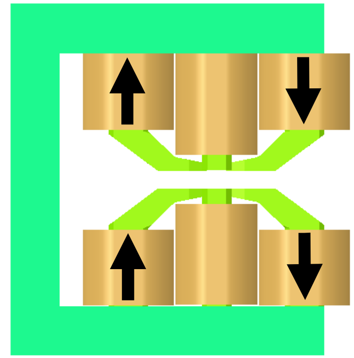
7/Jan/2011 07:26:04



Normal Dipole

Opera

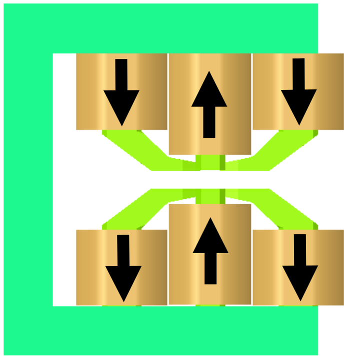
7/Jan/2011 07:26:04



Normal Quadrupole

Opera

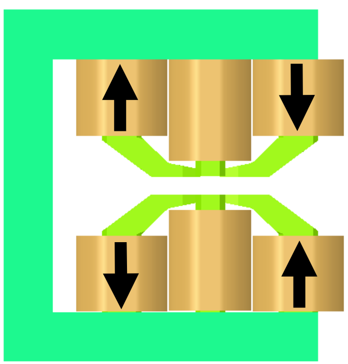
7/Jan/2011 07:26:04



Normal Sextupole

Opera

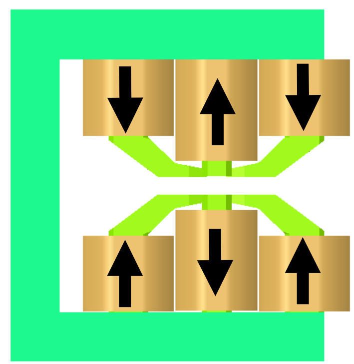
7/Jan/2011 07:26:04



Skew Dipole

Opera

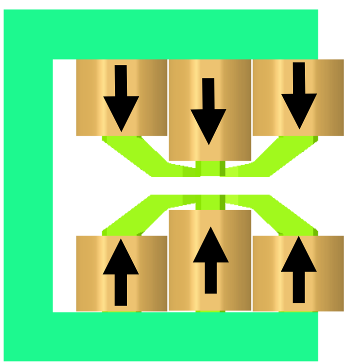
7/Jan/2011 07:26:04



Skew Quadrupole

Opera

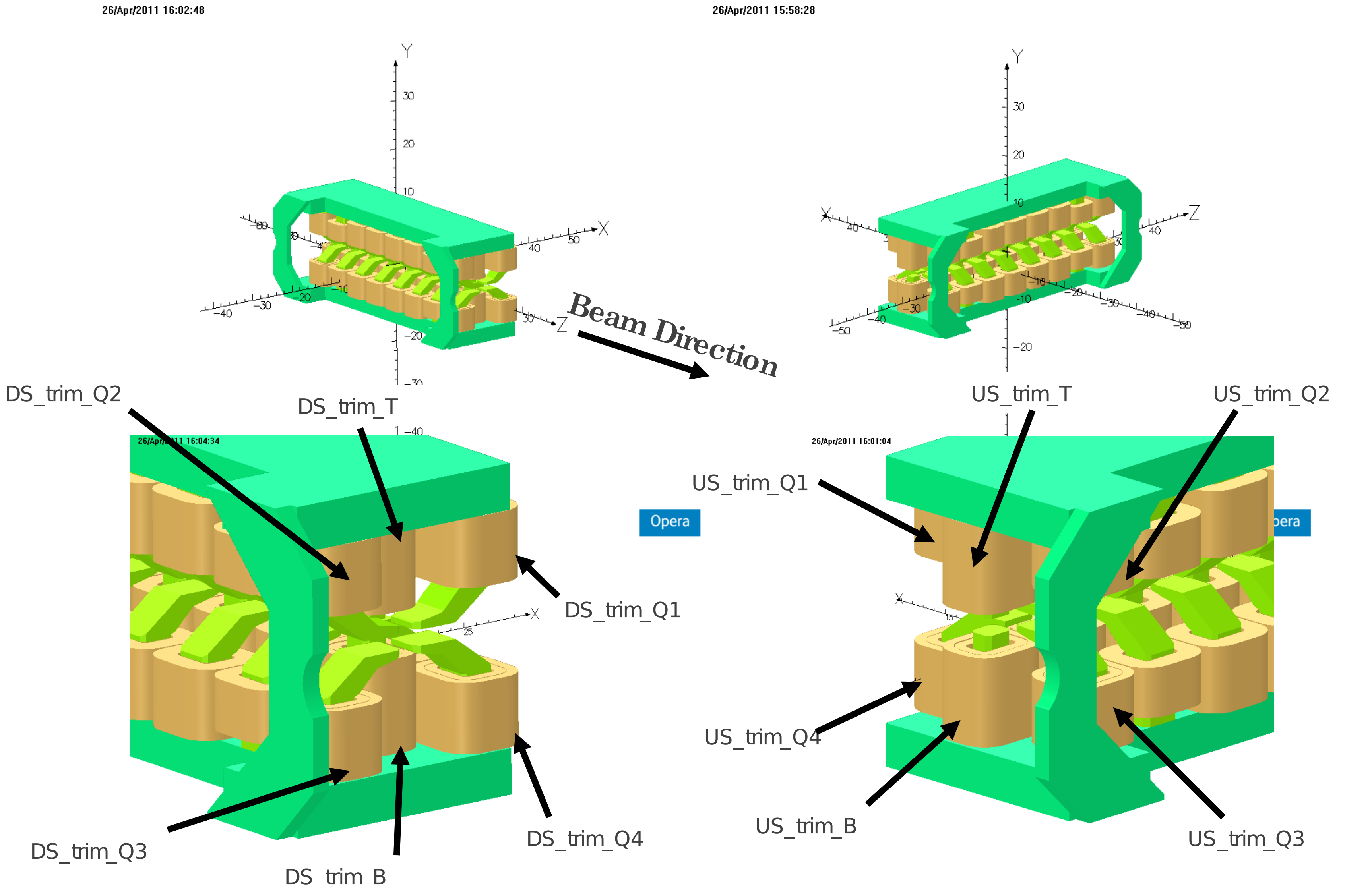
7/Jan/2011 07:26:04



Skew Octupole

Opera

Coordinate System



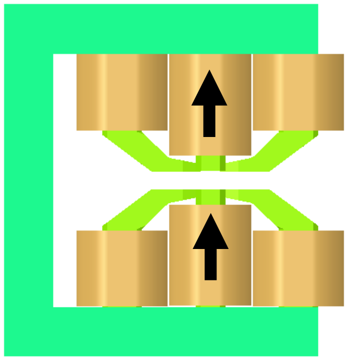
All trim coils wired so a positive By field is obtained with positive current

Set up the US Normal Dipole

7/Jan/2011 07:26:04

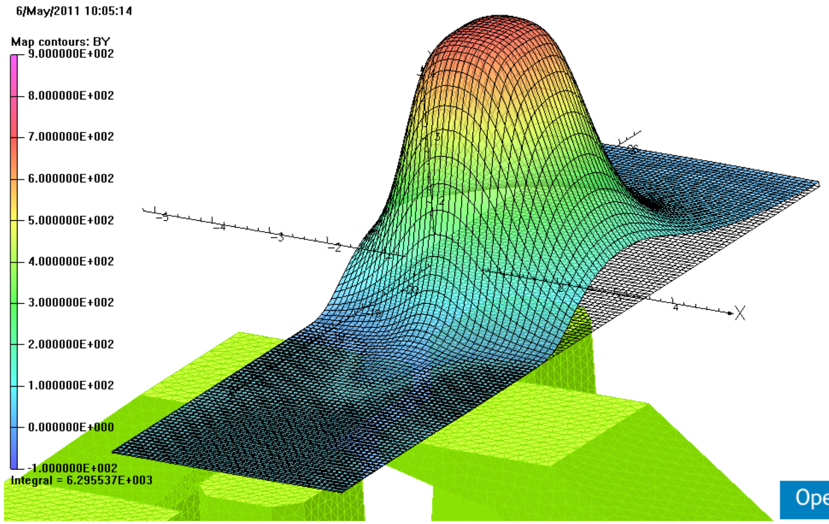
Integrated multi-poles inside a 0.6 cm diameter cylinder centered on the z axis.

#US_By_dipole_A	#US_D_Bxadd_rat	#B_1	#B_2	#B_3	#B_4	#BS_1	#BS_2	#BS_3	#BS_4
A		G-cm	G	G/cm	G/cm^2	G-cm	G	G/cm	G/cm^2
1	0	2098	-2	-586	-2	0	-1	-1	6
0	0.382	263	-2	586	-2	0	0	-1	-3
1	0.382	2361	-4	1	-4	0	-1	-2	3



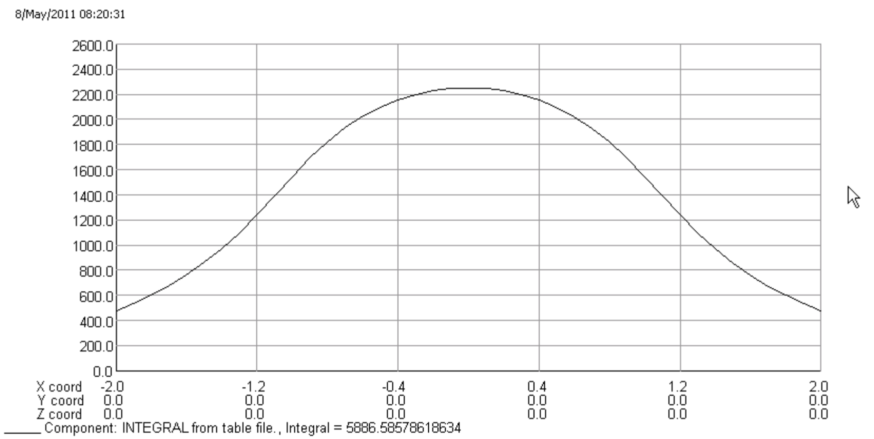
Normal Dipole

Opera



Opera

Plot of By on the (x, 0, z) plane

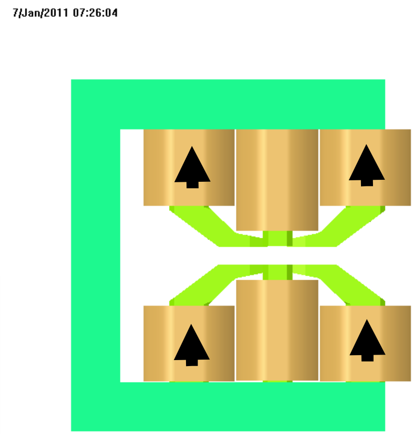


(Integral of By(x, 0, z)dz for z→ -∞ to +∞) plotted for x = -2 cm to +2 cm

Set up the US Normal Dipole

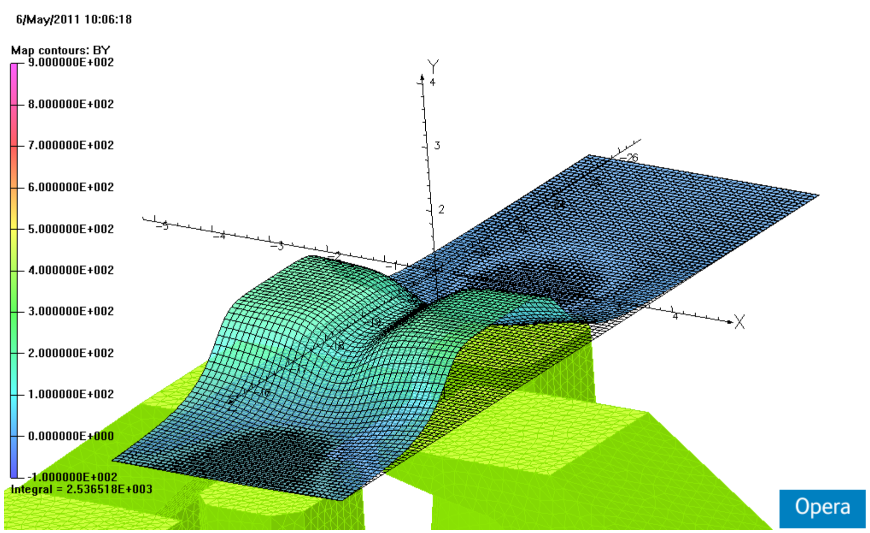
Integrated multi-poles inside a 0.6 cm diameter cylinder centered on the z axis.

#US_By_dipole_A	#US_D_Bxadd_rat	#B_1	#B_2	#B_3	#B_4	#BS_1	#BS_2	#BS_3	#BS_4
A		G-cm	G	G/cm	G/cm^2	G-cm	G	G/cm	G/cm^2
1	0	2098	-2	-586	-2	0	-1	-1	6
0	0.382	263	-2	586	-2	0	0	-1	-3
1	0.382	2361	-4	1	-4	0	-1	-2	3

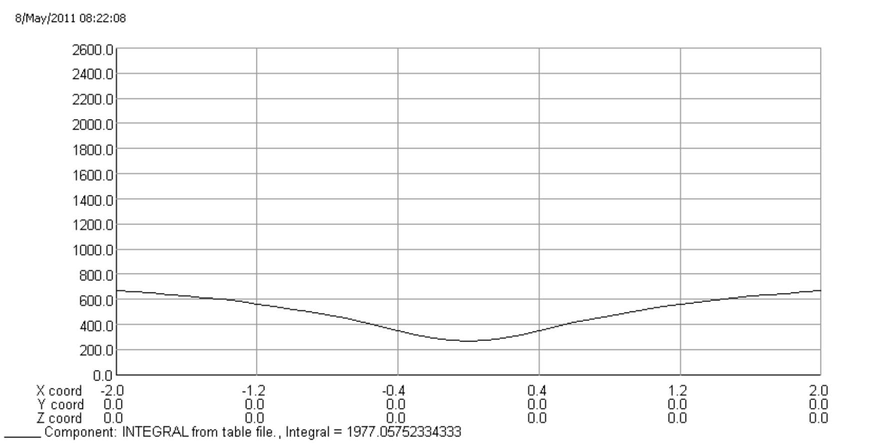


Normal Dipole

Opera



Plot of By on the (x, 0, z) plane

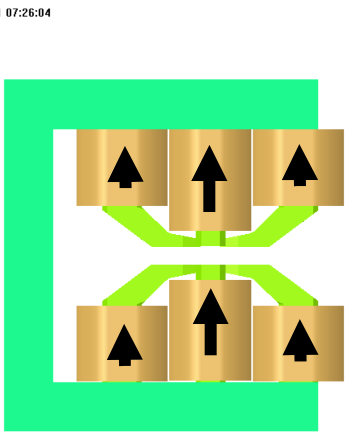


(Integral of By(x, 0, z)dz for z→ -∞ to +∞) plotted for x =-2 cm to +2 cm

Set up the US Normal Dipole

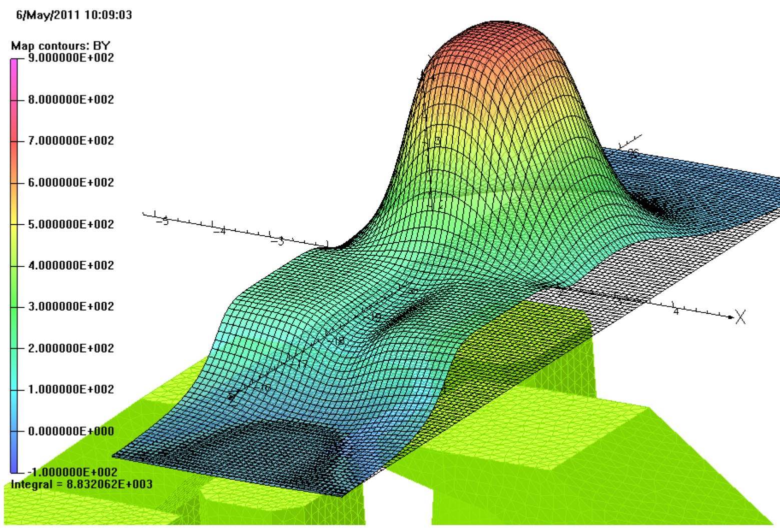
Integrated multi-poles inside a 0.6 cm diameter cylinder centered on the z axis.

#US_By_dipole_A	#US_D_Bxadd_rat	#B_1	#B_2	#B_3	#B_4	#BS_1	#BS_2	#BS_3	#BS_4
A		G-cm	G	G/cm	G/cm^2	G-cm	G	G/cm	G/cm^2
1	0	2098	-2	-586	-2	0	-1	-1	6
0	0.382	263	-2	586	-2	0	0	-1	-3
1	0.382	2361	-4	1	-4	0	-1	-2	3



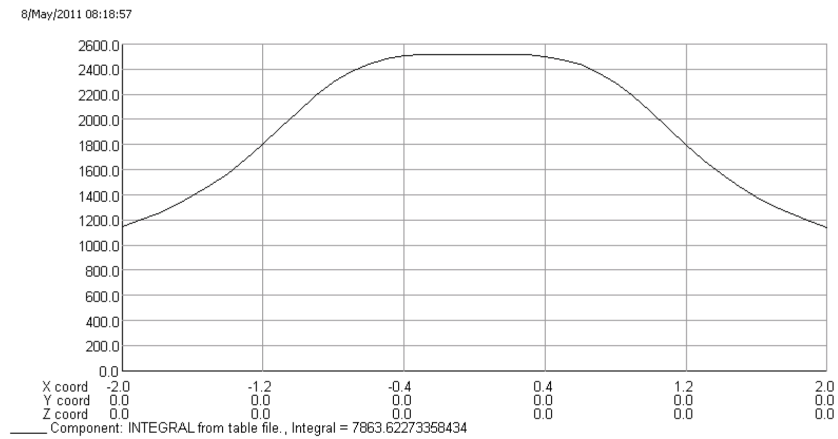
Normal Dipole

Opera



Opera

Plot of By on the (x, 0, z) plane



(Integral of By(x, 0, z)dz for z→ -∞ to +∞) plotted for x = -2 cm to +2 cm

How to set the currents for the trim Power Supplies for the US Normal Dipole

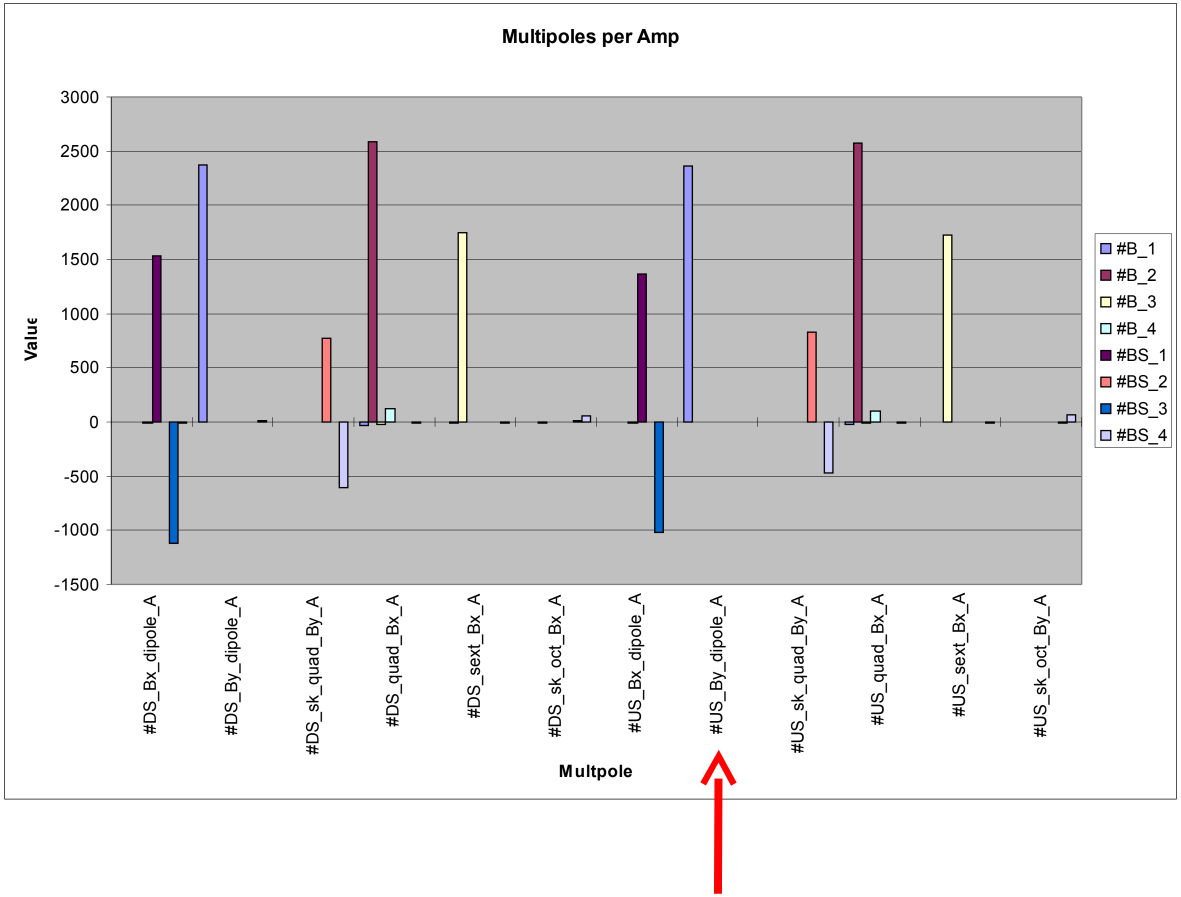
Right now I have this equal to the amperage of the dominant trim coil

The remaining multi-poles will be presented at the end

- Set the US_By_dipole_A
  - (maximum current is in the By coils, 2378 G-cm/A)
- US_D = US_By_dipole_A
  - (Current added to the top and bottom coils)
- US_D_Bxadd_rat = .382
  - (Bx current ratio)
- What currents need to be added to each individual up stream trim power supply
  - US_DT = US_D
  - US_DB = US_D
  - US_D_minus_SQ1 = US_D *US_D_Bxadd_rat
  - US_D_minus_SQ2 = US_D *US_D_Bxadd_rat
  - US_D_minus_SQ3 = US_D *US_D_Bxadd_rat
  - US_D_minus_SQ4 = US_D *US_D_Bxadd_rat

Set up the Remaining Multipoles

- This Process is repeated for the following multipole set points
  - US_Bx_dipole_A
  - US_By_dipole_A
  - US_sk_quad_By_A
  - US_quad_Bx_A
  - US_sext_Bx_A
  - US_sk_oct_By_A
  - DS_Bx_dipole_A
  - DS_By_dipole_A
  - DS_sk_quad_By_A
  - DS_quad_Bx_A
  - DS_sext_Bx_A
  - DS_sk_oct_Bx_A



What Multipole Values are Required?

- Reduce the unwanted multipoles to zero.
- Additional multipoles operations desires.
  - These may be on all of the time whether the Undulator is powered or not.

Limiting Values

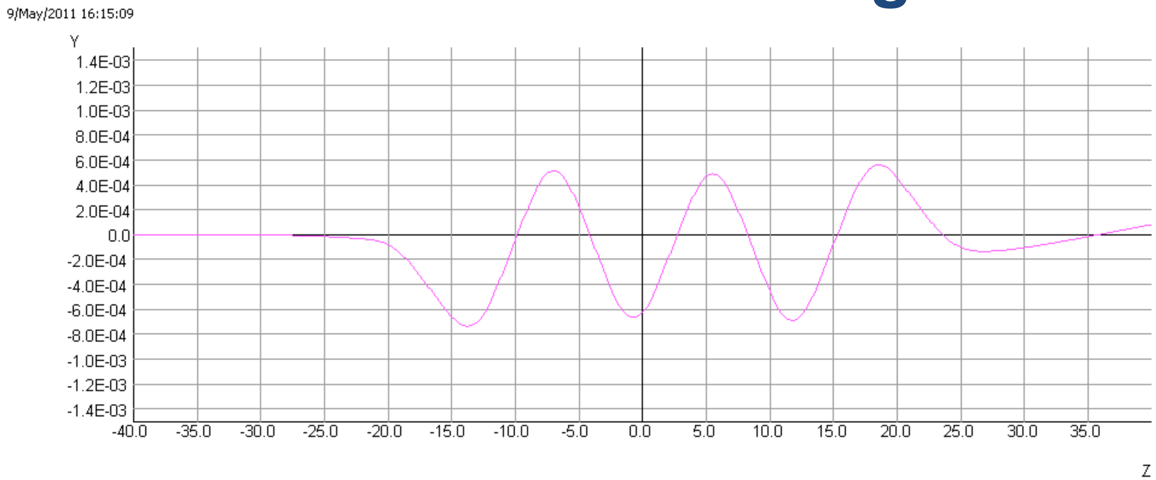
- These are for one 2.4 M long undulator
- IEX is 4.8 M long
- One can argue these values should be doubled

1st_int_Bx	50	Gauss-cm
2nd_int_Bx	100000	Gauss-cm**2
1st_int_By	100	Gauss-cm
2nd_int_By	100000	Gauss-cm**2
B_2	50	Gauss-cm**0
B_3	200	Gauss-cm**-1
B_4	300	Gauss-cm**-2
BS_2	50	Gauss-cm**0
BS_3	100	Gauss-cm**-1
BS_4	50	Gauss-cm**-2

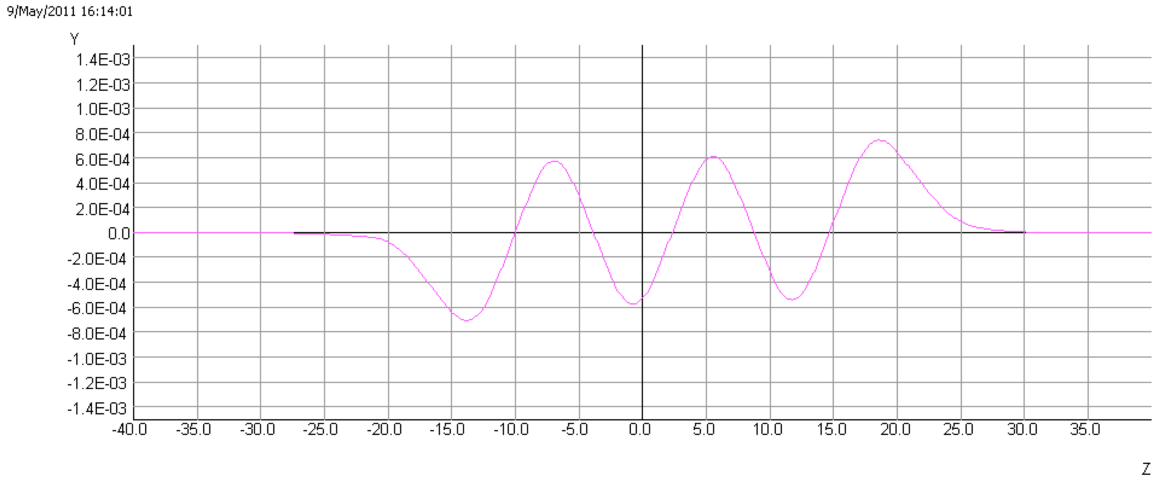
From Document No. 41010101-00002

Technical specification for Undulator A

Zero the 1st and 2nd integrals Bx Full Current



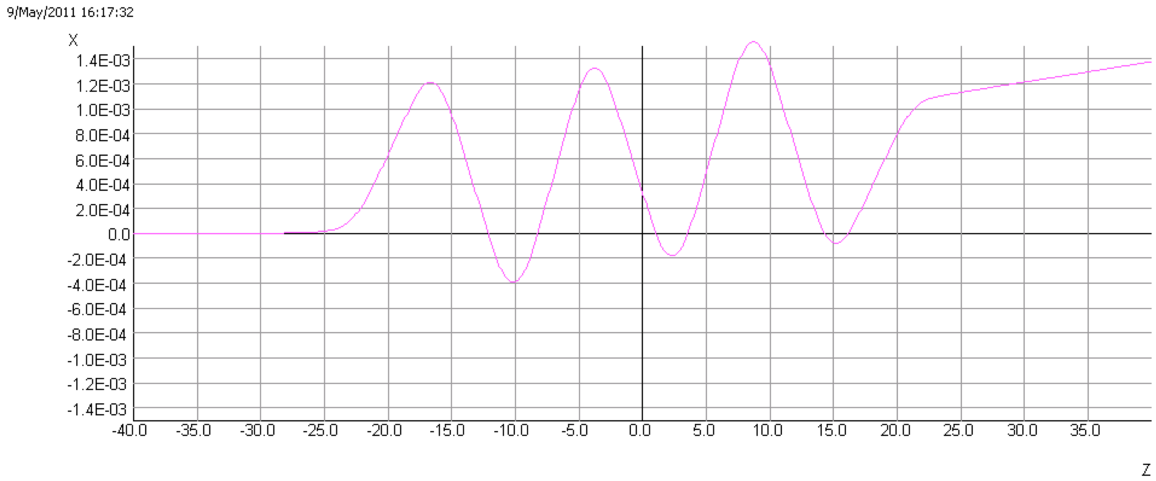
Opera

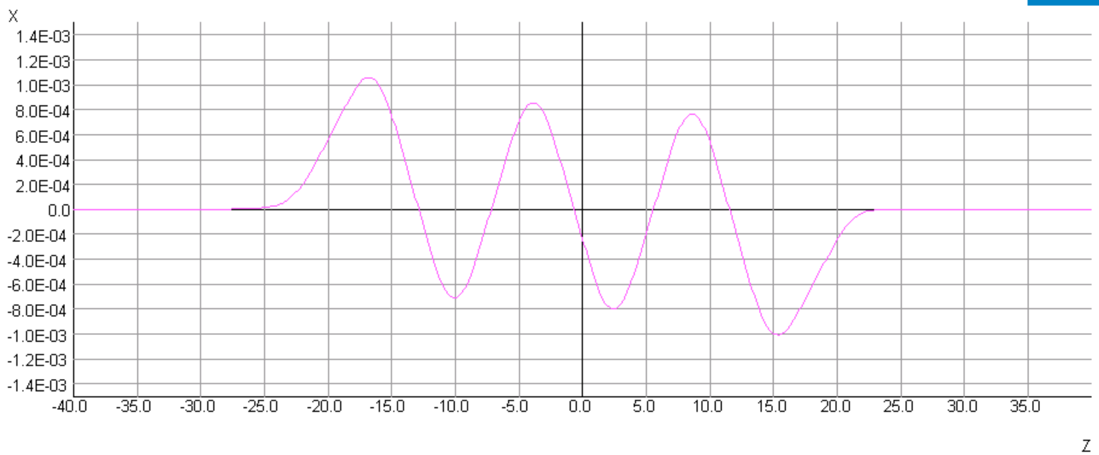


Opera

BxA	50.25	50.25	A	
ByA	0.00	0.00	A	
US_Bx_dipole_A	0.000	-0.075	A	
US_By_dipole_A	0.000	-0.008	A	
US_sk_quad_By_A	0.000	0.000	A	
US_quad_Bx_A	0.000	0.000	A	
US_sext_Bx_A	0.000	0.000	A	
US_sk_oct_By_A	0.000	0.000	A	
DS_Bx_dipole_A	0.000	0.345	A	
DS_By_dipole_A	0.000	-0.003	A	
DS_sk_quad_By_A	0.000	0.000	A	
DS_quad_Bx_A	0.000	0.000	A	
DS_sext_Bx_A	0.000	0.000	A	
DS_sk_oct_Bx_A	0.000	0.000	A	
USQ1A	0.000	0.075	A	
USQ2A	0.000	-0.075	A	
USQ3A	0.000	0.075	A	
USQ4A	0.000	-0.075	A	
DSQ1A	0.000	-0.345	A	
DSQ2A	0.000	0.345	A	
DSQ3A	0.000	-0.345	A	
DSQ4A	0.000	0.345	A	
USTA	0.000	-0.008	A	
USBA	0.000	-0.008	A	
DSTA	0.000	0.003	A	
DSBA	0.000	0.003	A	
Bxeff	3371	3371	Gauss	
Bxmax	3766	3766	Gauss	
Byeff	-1	-1	Gauss	
Bymax	12	12	Gauss	
1st_int_Bx	-466	-4	Gauss-cm	50
2nd_int_Bx	-1932	126	Gauss-cm**2	100000
1st_int_By	23	0	Gauss-cm	100
2nd_int_By	1223	-1	Gauss-cm**2	100000
B_1	23	2	Gauss-cm**1	
B_2	70	70	Gauss-cm**0	50
B_3	-25	-18	Gauss-cm**-1	200
B_4	-153	-153	Gauss-cm**-2	300
BS_1	-471	-27	Gauss-cm**1	
BS_2	-10	-9	Gauss-cm**0	50
BS_3	577	215	Gauss-cm**-1	100
BS_4	19	17	Gauss-cm**-2	50

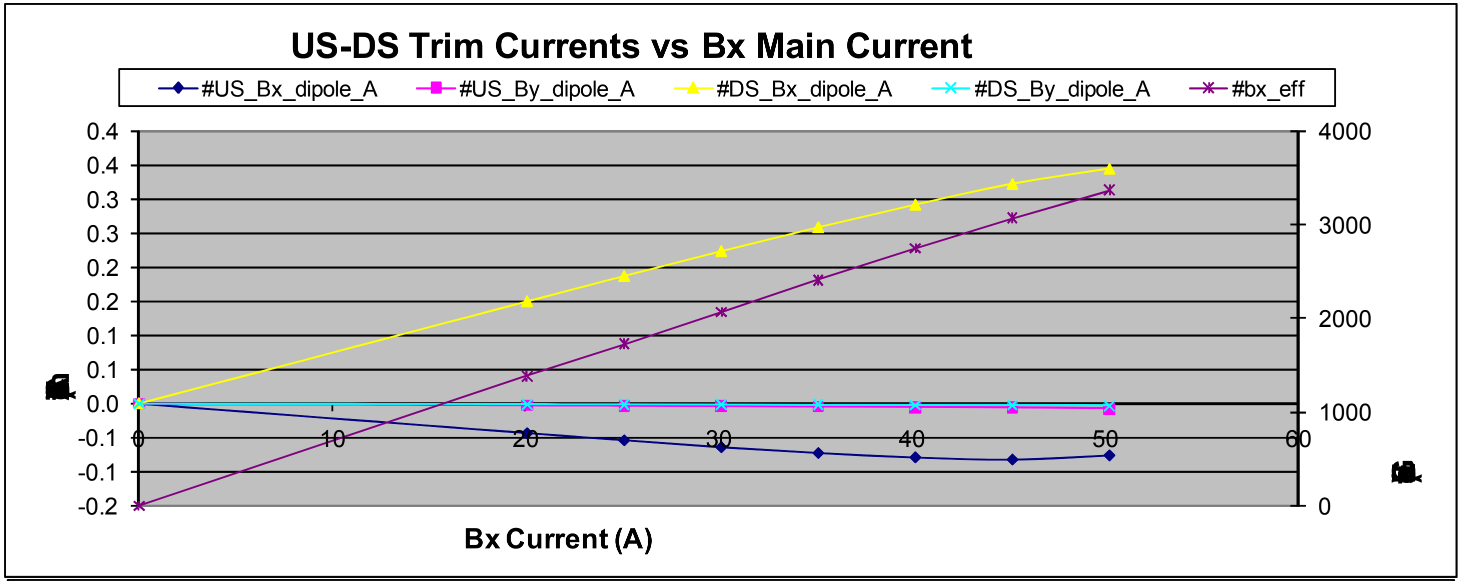
Zero the 1st and 2nd integrals By Full Current

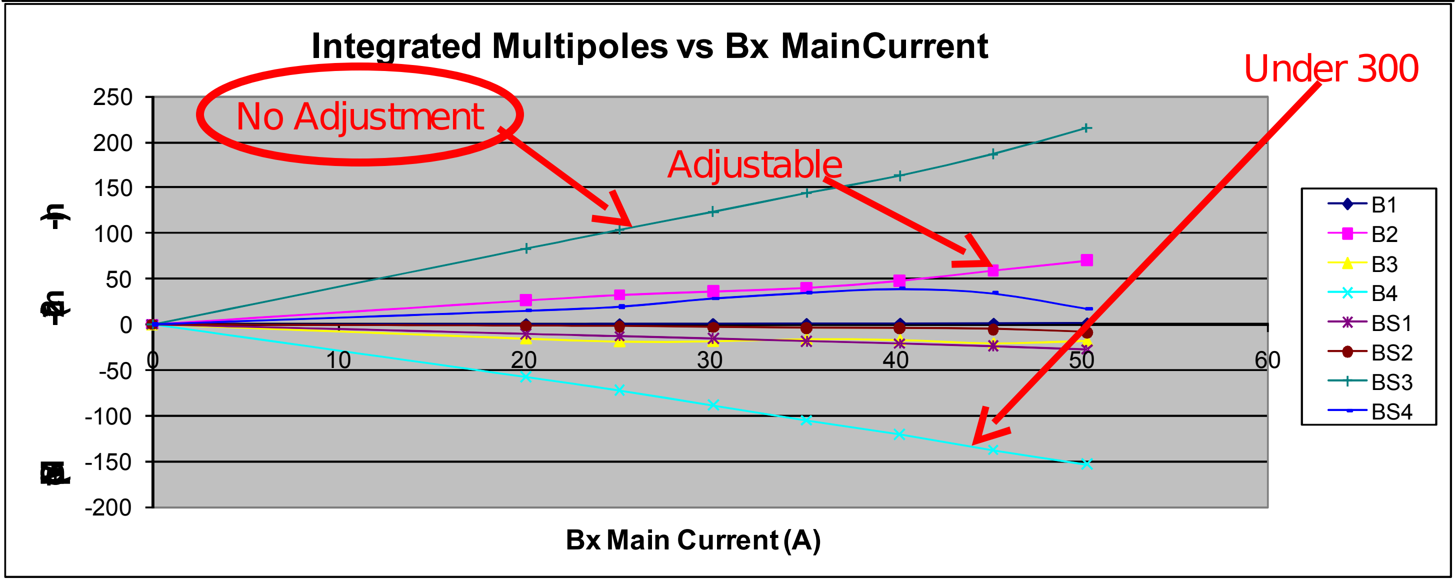




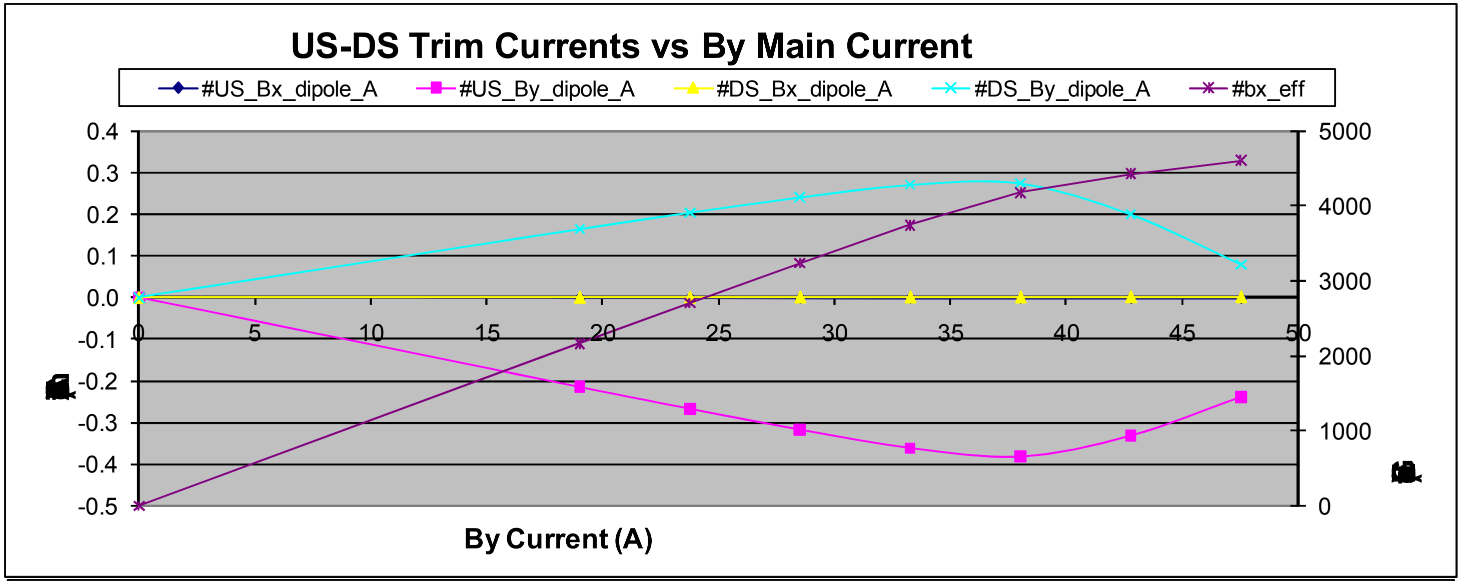
BxA	0.00	0.00	A	
ByA	47.54	47.54	A	
US_Bx_dipole_A	0.000	-0.001	A	
US_By_dipole_A	0.000	-0.239	A	
US_sk_quad_By_A	0.000	0.000	A	
US_quad_Bx_A	0.000	0.000	A	
US_sext_Bx_A	0.000	0.000	A	
US_sk_oct_By_A	0.000	0.000	A	
DS_Bx_dipole_A	0.000	0.002	A	
DS_By_dipole_A	0.000	0.080	A	
DS_sk_quad_By_A	0.000	0.000	A	
DS_quad_Bx_A	0.000	0.000	A	
DS_sext_Bx_A	0.000	0.000	A	
DS_sk_oct_Bx_A	0.000	0.000	A	
USQ1A	0.000	0.004	A	
USQ2A	0.000	0.001	A	
USQ3A	0.000	0.004	A	
USQ4A	0.000	0.001	A	
DSQ1A	0.000	-0.003	A	
DSQ2A	0.000	0.001	A	
DSQ3A	0.000	-0.003	A	
DSQ4A	0.000	0.001	A	
USTA	0.000	-0.239	A	
USBA	0.000	-0.239	A	
DSTA	0.000	-0.080	A	
DSBA	0.000	-0.080	A	
Bxeff	0	0	Gauss	
Bxmax	2	2	Gauss	
Byeff	4608	4608	Gauss	
Bymax	5460	5461	Gauss	
1st_int_Bx	-1	0	Gauss-cm	50
2nd_int_Bx	73	0	Gauss-cm**2	100000
1st_int_By	379	0	Gauss-cm	100
2nd_int_By	32175	39	Gauss-cm**2	100000
B_1	378	24	Gauss-cm**1	
B_2	-18	-17	Gauss-cm**0	50
B_3	367	446	Gauss-cm**-1	200
B_4	111	111	Gauss-cm**-2	300
BS_1	-1	0	Gauss-cm**1	
BS_2	2	2	Gauss-cm**0	50
BS_3	-7	-7	Gauss-cm**-1	100
BS_4	-108	-110	Gauss-cm**-2	50

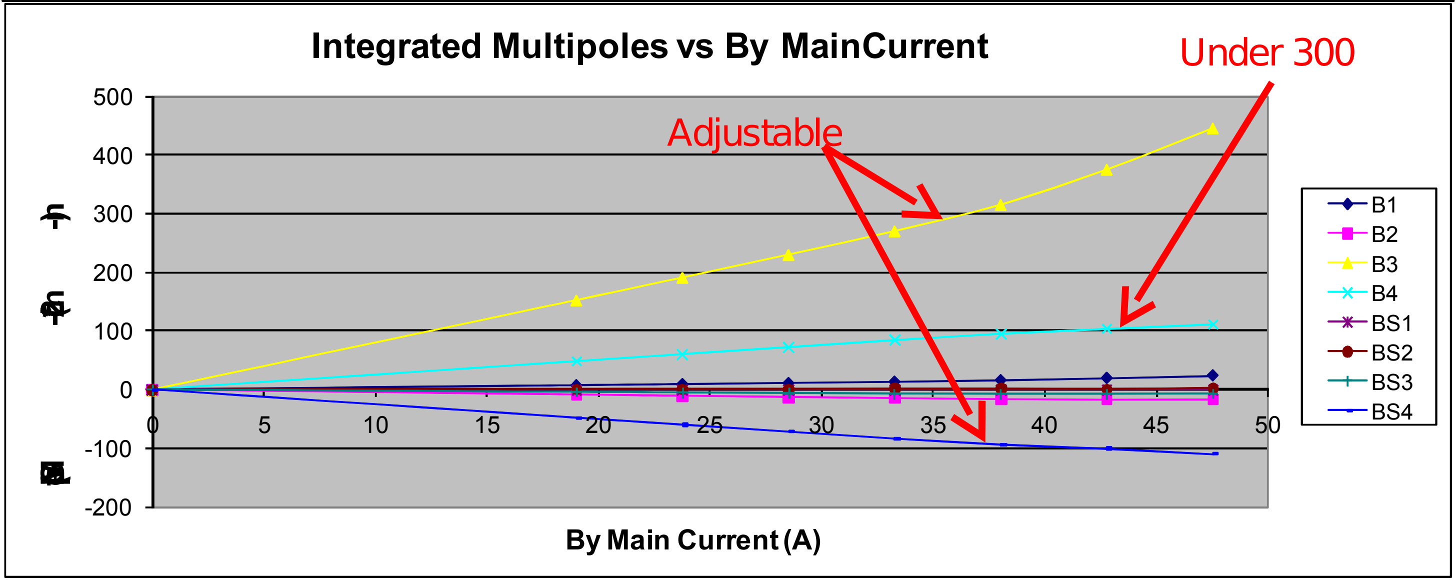
One Step Further – Do a Current Scan – for Bx



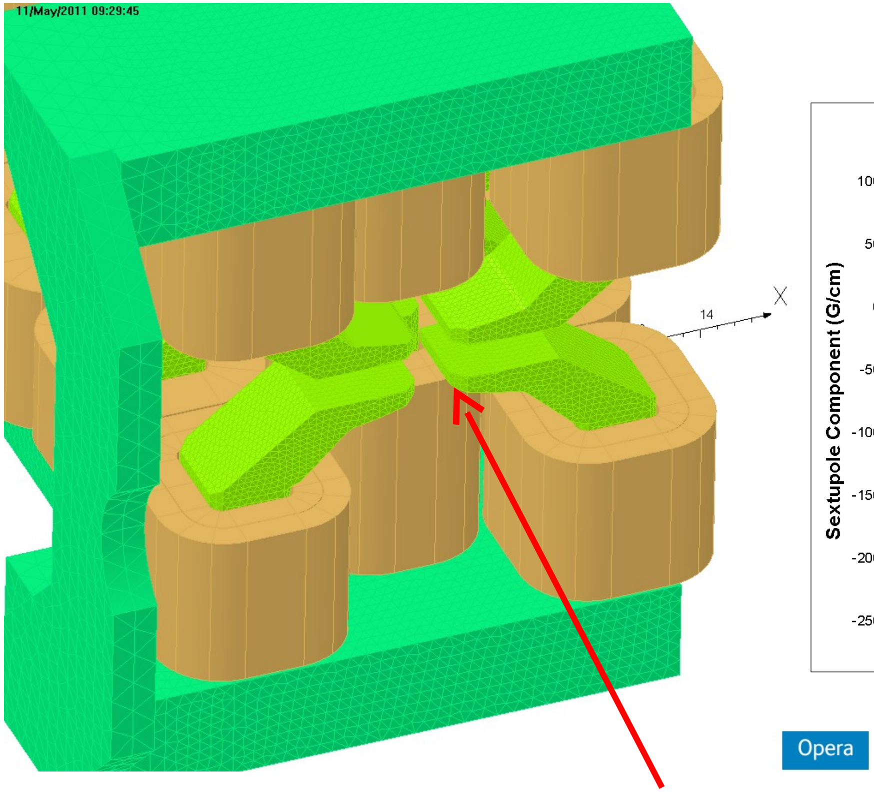


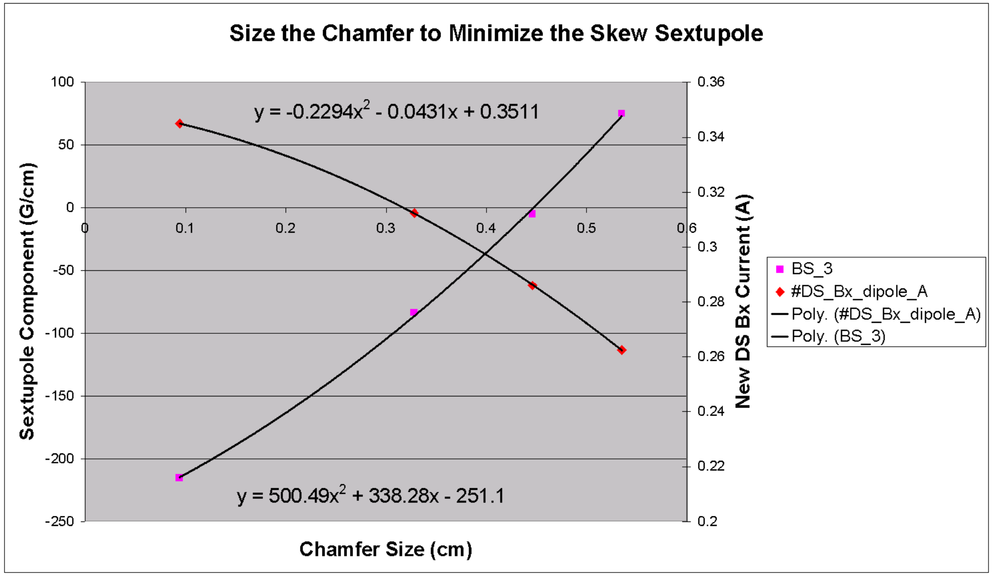
One Step Further – Do a Current Scan – for By





Remove the skew Sextupole component from Bx

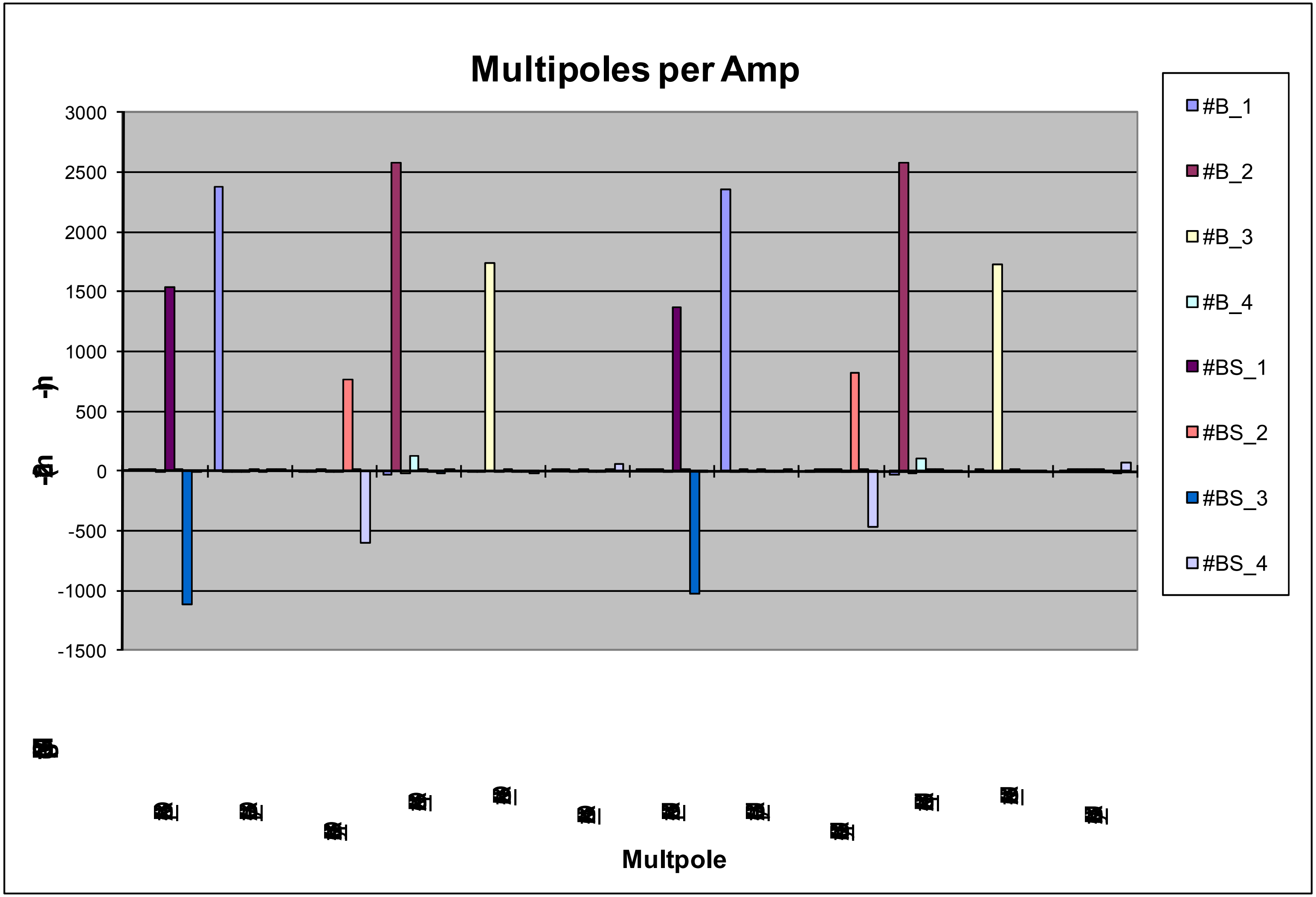




Chamfer the downstream pole tips

0.446 cm chamfer is optimal

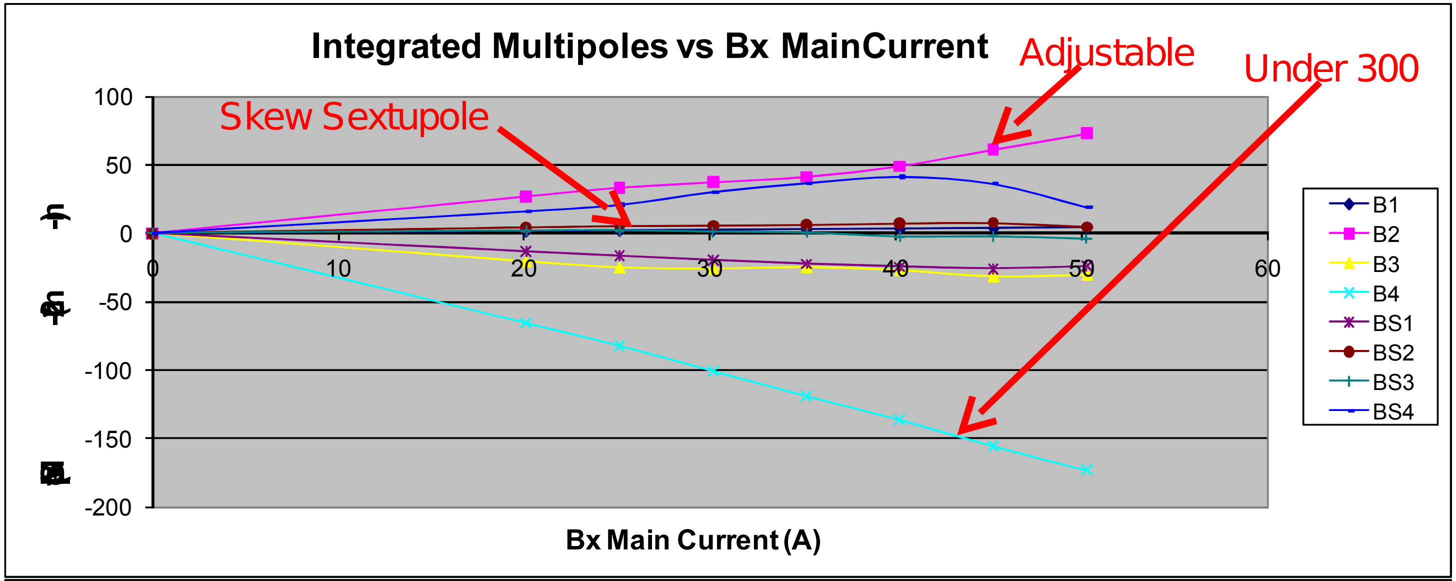
Redo the Multi-pole Fields Trim Coils

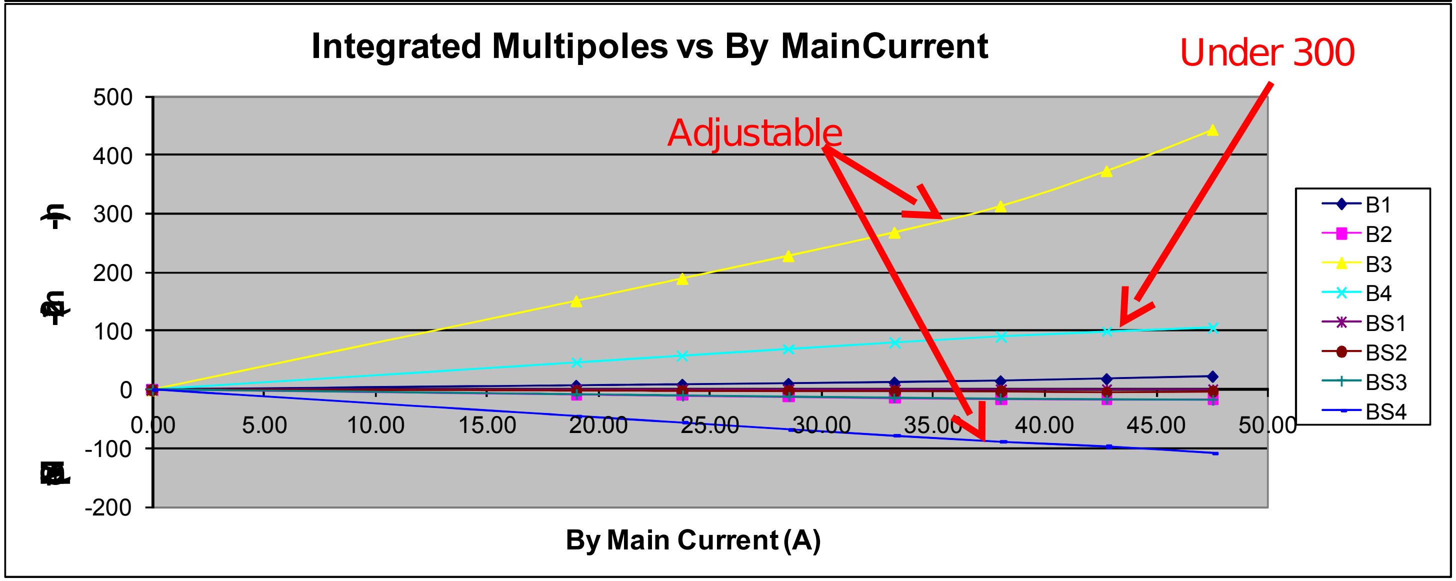


Redo the Multi-pole Fields Trim Coils

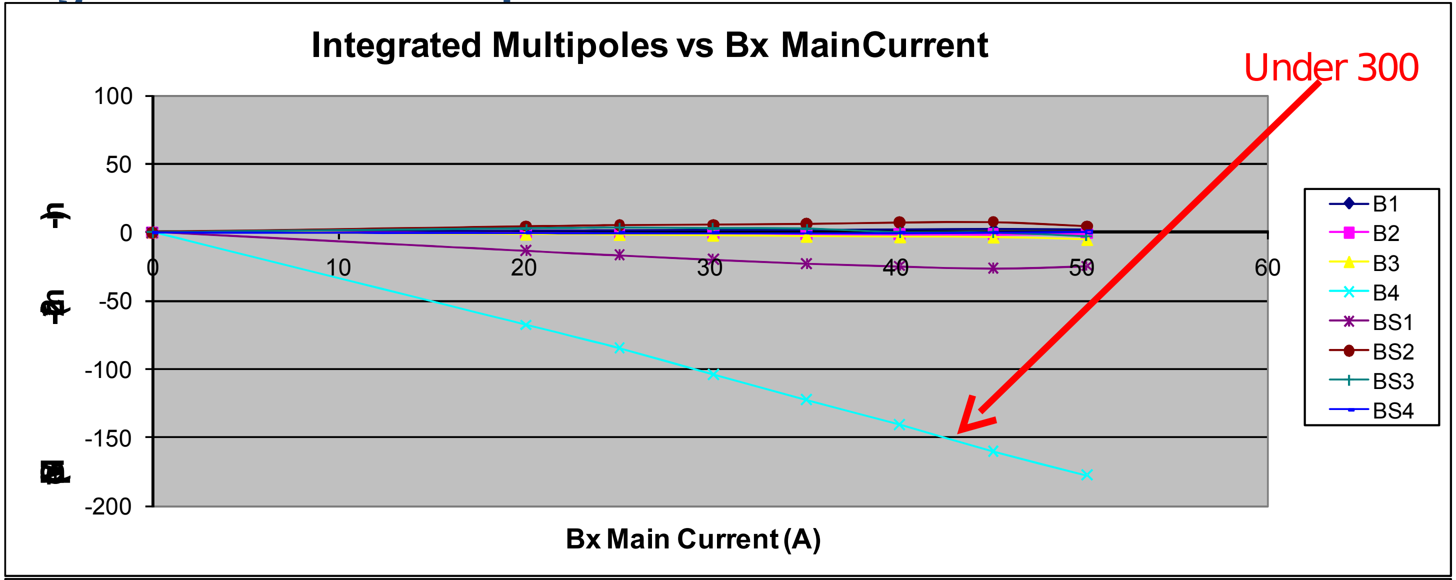
Multipole per Ampere		
Description	Value	Units
#DS_Bx_dipole_A	1537	G-cm
#DS_By_dipole_A	2378	G-cm
#DS_sk_quad_By_A	769	G
#DS_quad_Bx_A	2582	G
#DS_sext_Bx_A	1744	G/cm
#DS_sk_oct_Bx_A	59	G/cm^2
#US_Bx_dipole_A	1370	G-cm
#US_By_dipole_A	2361	G-cm
#US_sk_quad_By_A	826	G
#US_quad_Bx_A	2580	G
#US_sext_Bx_A	1727	G/cm
#US_sk_oct_By_A	68	G/cm^2

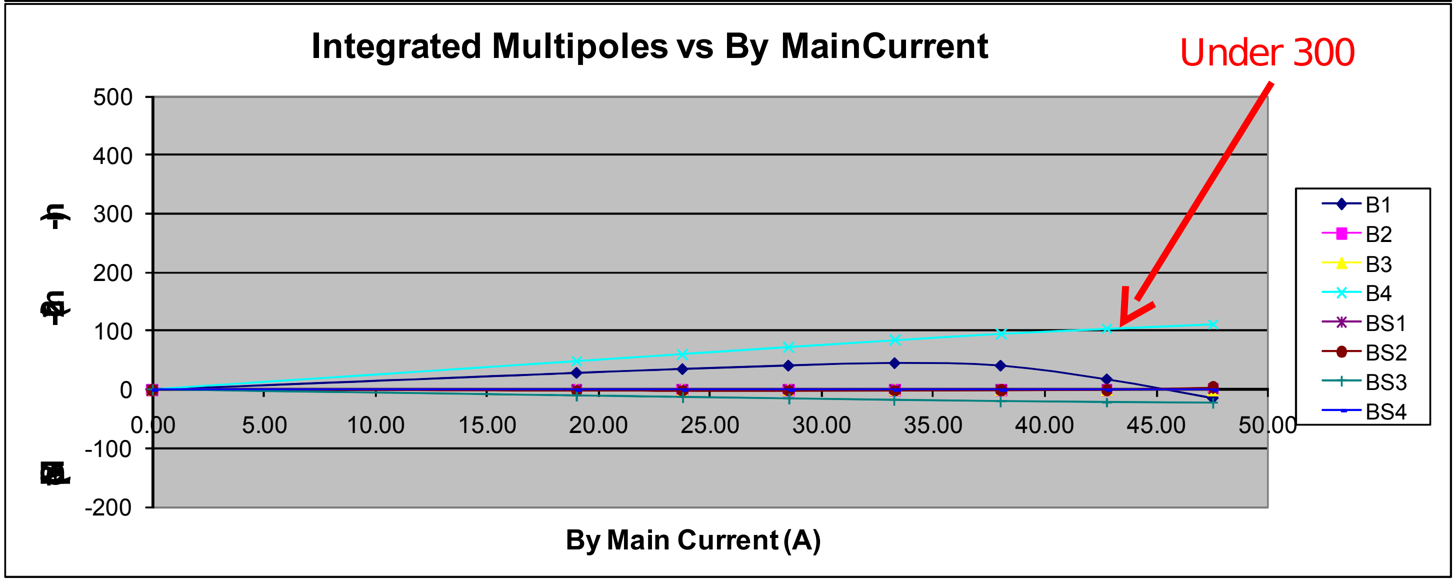
Re-Do a Current Scans –With 0.446 Chamfer





Re-Do a Current Scans –With 0.446 Chamfer – With Corrected Multipoles
Half magnitude of the Multipoles are corrected US and the other half DS.





Look-Up Tables for Bx and By Currents

#Bx_A	#By_A	#US_Bx_dipole_A	#US_By_dipole_A	#DS_Bx_dipole_A	#DS_By_dipole_A	#US_sk_quad_By_A	#US_quad_Bx_A	#US_sext_Bx_A	#US_sk_oct_By_A	#DS_sk_quad_By_A	#DS_quad_Bx_A	#DS_sext_Bx_A	#DS_sk_oct_Bx_A
20.1	0	-0.042729	-0.002625	0.124421	-0.000667	0	-0.005211891	0.005875444	-0.135252711	0	-0.005216678	0.005931193	-0.117349213
25.125	0	-0.053159	-0.00329	0.155268	-0.000879	0	-0.006439749	0.007170611	-0.175646464	0	-0.006445664	0.00723865	-0.152396016
30.15	0	-0.06335	-0.004014	0.185495	-0.001371	0	-0.007209114	0.007401423	-0.256577629	0	-0.007215735	0.007471652	-0.222614265
35.175	0	-0.07186	-0.00479	0.214649	-0.002001	0	-0.007981701	0.007093804	-0.312450062	0	-0.007989032	0.007161114	-0.271090824
40.2	0	-0.078361	-0.005455	0.242092	-0.002238	0	-0.009495702	0.007693721	-0.351855467	0	-0.009504424	0.007766723	-0.305280107
45.225	0	-0.081523	-0.005999	0.267475	-0.002213	0	-0.011836383	0.009017652	-0.307724544	0	-0.011847255	0.009103216	-0.266990826
50.25	0	-0.075356	-0.007657	0.286	-0.00287	0	-0.014102896	0.008669976	-0.160559167	0	-0.014115849	0.008752242	-0.139305835

#Bx_A	#By_A	#US_Bx_dipole_A	#US_By_dipole_A	#DS_Bx_dipole_A	#DS_By_dipole_A	#US_sk_quad_By_A	#US_quad_Bx_A	#US_sext_Bx_A	#US_sk_oct_By_A	#DS_sk_quad_By_A	#DS_quad_Bx_A	#DS_sext_Bx_A	#DS_sk_oct_Bx_A
0	19	-0.000814	-0.214688	0.00068	0.164372	0	0.001246655	-0.04252908	0.375178651	0	0.001247382	-0.04293271	0.32551587
0	24	-0.001015	-0.266991	0.000851	0.203927	0	0.001553287	-0.05314046	0.468944348	0	0.001553945	-0.05364503	0.406869814
0	29	-0.001211	-0.316812	0.001024	0.240697	0	0.001854949	-0.06373202	0.562239614	0	0.001856537	-0.06433689	0.487814959
0	33	-0.001395	-0.360991	0.0012	0.271038	0	0.002137423	-0.0742918	0.658084211	0	0.002138938	-0.07499751	0.570972925
0	38	-0.001536	-0.381721	0.001393	0.274631	0	0.002347282	-0.08474677	0.748637069	0	0.002348718	-0.08555089	0.649539421
0	43	-0.001572	-0.331985	0.001629	0.200396	0	0.002381618	-0.09494779	0.823763467	0	0.00238295	-0.09584889	0.714721849
0	48	-0.001459	-0.239089	0.001961	0.079928	0	0.002167973	-0.10526929	0.924400278	0	0.002170165	-0.10626808	0.802037361

Multipoles = f1(Bx amps) + f2(By amps) + f3(operations)

Miscellaneous Simulations Using Look-Up Tables

	Bx	Bx	Bx	By	By	By	Circ		
BxA	50.25	43.00	38.00	0.00	0.00	0.00	34.23	A	
ByA	0.00	0.00	0.00	47.54	40.00	36.00	20.65	A	
US_Bx_dipole_A	-0.075	-0.080	-0.076	-0.001	-0.002	-0.001	-0.071	A	
US_By_dipole_A	-0.008	-0.006	-0.005	-0.239	-0.361	-0.373	-0.237	A	
US_sk_quad_By_A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	A	
US_quad_Bx_A	-0.014	-0.011	-0.009	0.002	0.002	0.002	-0.006	A	
US_sext_Bx_A	0.009	0.008	0.007	-0.105	-0.089	-0.080	-0.039	A	
US_sk_oct_By_A	-0.161	-0.327	-0.335	0.924	0.780	0.710	0.105	A	
DS_Bx_dipole_A	0.286	0.256	0.230	0.002	0.001	0.001	0.210	A	
DS_By_dipole_A	-0.003	-0.002	-0.002	0.080	0.244	0.273	0.176	A	
DS_sk_quad_By_A	0.000	0.000	0.000	0.000	0.000	0.000	0.000	A	
DS_quad_Bx_A	-0.014	-0.011	-0.009	0.002	0.002	0.002	-0.006	A	
DS_sext_Bx_A	0.009	0.009	0.008	-0.106	-0.090	-0.081	-0.039	A	
DS_sk_oct_Bx_A	-0.139	-0.284	-0.290	0.802	0.677	0.616	0.091	A	
USQ1A	-0.051	-0.191	-0.203	0.973	0.882	0.819	0.296	A	
USQ2A	-0.235	-0.383	-0.382	1.004	0.908	0.843	0.144	A	
USQ3A	0.196	0.349	0.353	-0.607	-0.450	-0.393	0.102	A	
USQ4A	0.068	0.200	0.209	-0.584	-0.433	-0.378	-0.024	A	
DSQ1A	-0.142	0.027	0.058	-0.731	-0.713	-0.677	-0.350	A	
DSQ2A	0.406	0.526	0.510	-0.747	-0.725	-0.689	0.055	A	
DSQ3A	-0.449	-0.563	-0.540	0.877	0.645	0.559	-0.180	A	
DSQ4A	0.156	-0.020	-0.053	0.853	0.623	0.539	0.250	A	
USTA	0.150	0.319	0.327	-1.129	-1.112	-1.056	-0.330	A	
USBA	-0.171	-0.336	-0.342	0.720	0.448	0.363	-0.119	A	
DSTA	0.071	0.137	0.139	-0.499	-0.597	-0.595	-0.237	A	
DSBA	-0.057	-0.124	-0.128	0.239	0.025	-0.028	-0.153	A	
Bxeff	3371	2930	2602	0	0	0	2347	Gauss	
Bxmax	3766	3258	2890	5	4	4	2608	Gauss	
Byeff	-1	1	0	4608	4301	4015	2356	Gauss	
Bymax	12	11	10	5462	5096	4735	2768	Gauss	
1st_int_Bx	-3	-7	-8	1	1	1	-7	Gauss-cm	50
2nd_int_Bx	70	74	20	149	122	111	-11	Gauss-cm**2	100000
1st_int_By	-1	0	0	-22	28	41	25	Gauss-cm	100
2nd_int_By	-143	-107	-100	-3584	-4552	-4957	-3697	Gauss-cm**2	100000
B_1	2	2	2	-15	32	43	31	Gauss-cm**1	
B_2	-1	-2	-2	0	0	0	-2	Gauss-cm**0	50
B_3	-5	-3	-3	-1	0	0	-4	Gauss-cm**-1	200
B_4	-177	-151	-132	111	99	91	-64	Gauss-cm**-2	300
BS_1	-24	-25	-24	1	1	1	-22	Gauss-cm**1	
BS_2	5	8	7	4	-1	-1	4	Gauss-cm**0	50
BS_3	-3	-2	2	-23	-21	-20	-7	Gauss-cm**-1	100
BS_4	0	3	0	-1	0	0	-2	Gauss-cm**-2	50

16 Coil Power Supplies (Maximum Currents Shown)

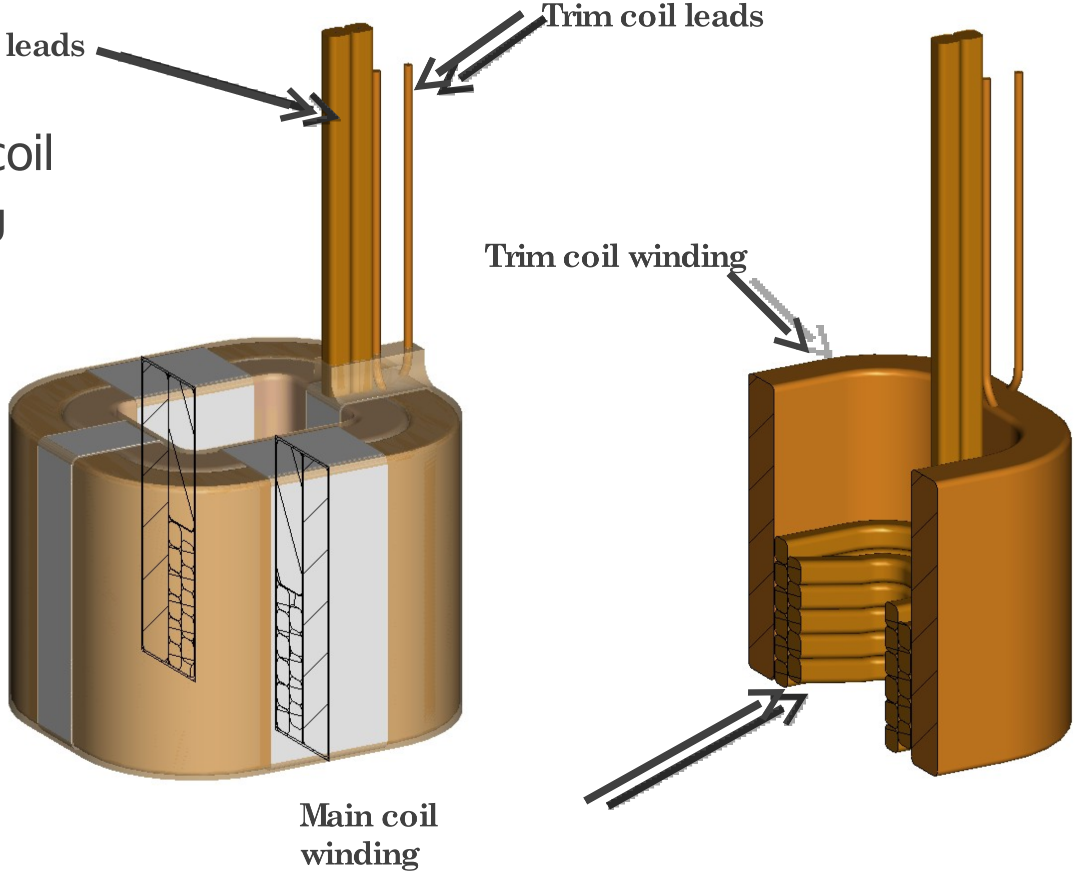
- Main Power Supplies
  1. Bx Coils
     - 50.3 A max
     - 8674 W max
  1. Bx quasi-periodic coils
     - 50.3 A max
     - 3220 W max
  1. By Coils
     - 47.6 A max
     - 4846 W max
  1. By quasi-periodic coils
     - 47.6 A max
     - 1803 W max

- Trim Power Supplies
  5. US top
  6. US btm
  7. US Q1
  8. US Q2
  9. US Q3
  10. US Q4
  11. DS top
  12. DS btm
  13. DS Q1
  14. DS Q2
  15. DS Q3
  16. DS Q4
  - Top and BTM
    - 5.53 A max
    - 45 W max
  - Quadrants
    - 5.87 A max
    - 40 W max

To keep the coil temperature <100°C

Trim Coil Current Limits

- Two windings per coil
  - Main coil winding
  - Trim coil winding



$Ix_{max} = 50.3$ A → 40 W allowed → $I_x^2 * 0.00321 + I_Q^2 * 1.16 < 40$ W → $I_Q < 5.2$ A

$Iy_{max} = 47.6$ A → 45 W allowed → $I_y^2 * 0.00400 + I_{T/B}^2 * 1.47 < 45$ W → $I_{T/B} < 4.9$ A

US Normal Dipole Currents

- Look-up the US_By_dipole_A
- US_D = US_By_dipole_A + f3(operations)
- US_D_Bxadd_rat = .382
- Additional currents for each individual supply
  - US_DT = US_D
  - US_DB = US_D
  - US_D_minus_SQ1 = US_D * US_D_Bxadd_rat
  - US_D_minus_SQ2 = US_D * US_D_Bxadd_rat
  - US_D_minus_SQ3 = US_D * US_D_Bxadd_rat
  - US_D_minus_SQ4 = US_D * US_D_Bxadd_rat

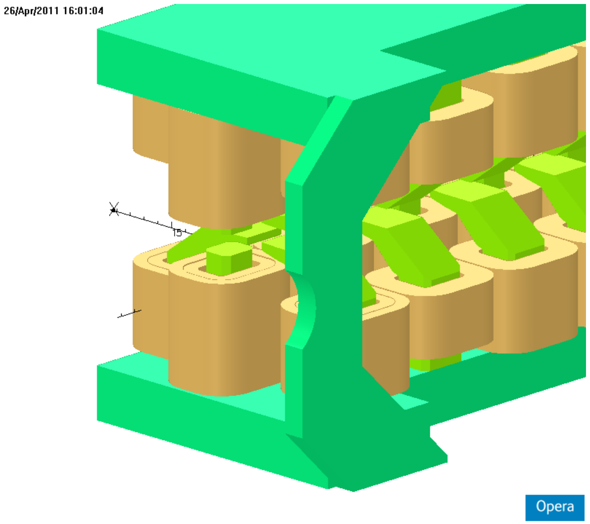
US Skew Dipole Currents

- Look-up the US_Bx_dipole_A
- USSD = US_Bx_dipole_A + f3(operations)
- Additional currents for each individual supply
  - USSDQ1 = USSD
  - USSDQ2 = -USSD
  - USSDQ3 = USSD
  - USSDQ4 = -USSD

US Quadrupole Currents

- Look-up the US_quad_Bx_A
- US_Q = US_quad_Bx_A + f3(operations)
- Additional currents for each individual supply
  - US_QQ1 = US_Q
  - US_QQ2 = -US_Q
  - US_QQ3 = -US_Q
  - US_QQ4 = US_Q

US Skew Quadrupole Currents

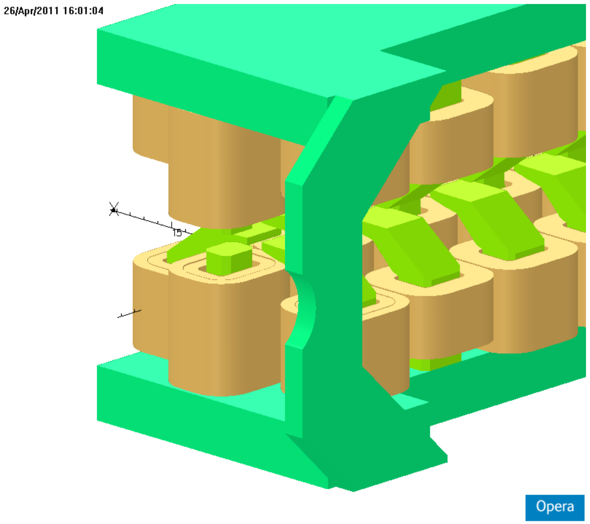


- Look-up the US_sk_quad_By_A
- USSQ = US_sk_quad_By_A + f3(operations)
- USSQ_ratio = .4655
- USSQ_bxadd_rat = 0.0001737
- Additional currents for each individual supply
  - USSQQ1 = USSQ*USSQ_ratio - USSQ *USSQ_bxadd_rat
  - USSQQ2 = USSQ*USSQ_ratio + USSQ *USSQ_bxadd_rat
  - USSQQ3 = -USSQ*USSQ_ratio - USSQ *USSQ_bxadd_rat
  - USSQQ4 = -USSQ*USSQ_ratio + USSQ *USSQ_bxadd_rat
  - USSQT = -USSQ
  - USSQB = USSQ

US Sextupole Currents

- Look-up the US_sext_Bx_A
- US_S = US_sext_Bx_A + f3(operations)
- US_S_ratio = 0.328
- Additional currents for each individual supply
  - US_SQ1 = US_S
  - US_SQ2 = US_S
  - US_SQ3 = US_S
  - US_SQ4 = US_S
  - US_ST = -US_S_ratio*US_S
  - US_SB = -US_S_ratio*US_S

US Skew Octupole Currents



- Look-up the US_sk_oct_By_A
- USSO = US_sk_oct_By_A + f3(operations)
- USSO_ratio = .857
- USSObxadd_rat = -0.016
- Additional currents for each individual supply
  - USSOQ1 = -USSO*USSO_ratio - USSO *USSObxadd_rat
  - USSOQ2 = -USSO*USSO_ratio + USSO *USSObxadd_rat
  - USSOQ3 = USSO*USSO_ratio - USSO *USSObxadd_rat
  - USSOQ4 = USSO*USSO_ratio + USSO *USSObxadd_rat
  - USSOT = -USSO
  - USSOB = USSO

DS Normal Dipole Currents

- Look-up the DS_By_dipole_A
- DS_D = DS_By_dipole_A + f3(operations)
- DS_D_Bxadd_rat = 0.542
- Additional currents for each individual supply
  - DS_DT = DS_D
  - DS_DB = DS_D
  - DS_D_minus_SQ1 = DS_D*DS_D_Bxadd_rat
  - DS_D_minus_SQ2 = DS_D*DS_D_Bxadd_rat
  - DS_D_minus_SQ3 = DS_D*DS_D_Bxadd_rat
  - DS_D_minus_SQ4 = DS_D*DS_D_Bxadd_rat

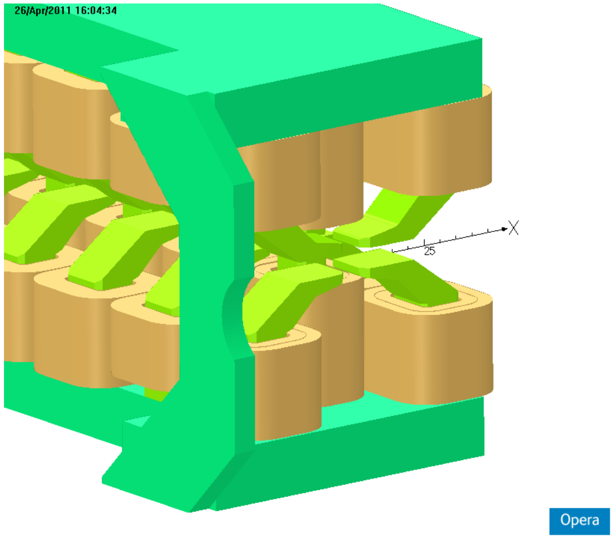
DS Skew Dipole Currents

- Look-up the DS_Bx_dipole_A
- DSSD =DS_Bx_dipole_A + f3(operations)
- Additional currents for each individual supply
  - DSSDQ1 = DSSD
  - DSSDQ2 = -DSSD
  - DSSDQ3 = DSSD
  - DSSDQ4 = -DSSD

DS Quadrupole Currents

- Look-up the DS_quad_Bx_A
- DS_Q = DS_quad_Bx_A + f3(operations)
- Additional currents for each individual supply
  - DS_QQ1 = DS_Q
  - DS_QQ2 = -DS_Q
  - DS_QQ3 = -DS_Q
  - DS_QQ4 = DS_Q

DS Skew Quadrupole Currents



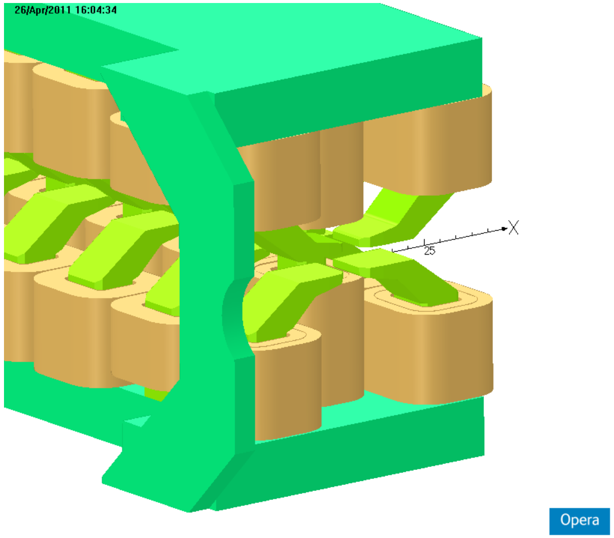
- Look-up the DS_sk_quad_By_A
- DSSQ =DS_sk_quad_By_A +f3(operations)
- DSSQ_ratio =.08
- DSSQ_bxadd_rat =0.0007
- Additional currents for each individual supply
  - DSSQQ1 =DSSQ*DSSQ_ratio - DSSQ *DSSQ_bxadd_rat
  - DSSQQ2 =DSSQ*DSSQ_ratio +DSSQ *DSSQ_bxadd_rat
  - DSSQQ3 =-DSSQ*DSSQ_ratio - DSSQ *DSSQ_bxadd_rat
  - DSSQQ4 =-DSSQ*DSSQ_ratio +DSSQ *DSSQ_bxadd_rat
  - DSSQT =-DSSQ
  - DSSQB =DSSQ

DS Sextupole Currents

- Look-up the DS_sext_Bx_A
- DS_S = DS_sext_Bx_A + f3(operations)
- DS_S_ratio = 0.472
- Additional currents for each individual supply
  - DS_SQ1 = DS_S
  - DS_SQ2 = DS_S
  - DS_SQ3 = DS_S
  - DS_SQ4 = DS_S
  - DS_ST = -DS_S_ratio*DS_S
  - DS_SB = -DS_S_ratio*DS_S

DS Skew Octupole Currents

- Look-up the DS_sk_oct_Bx_A
- DSSO =DS_sk_oct_Bx_A +f3(operations)
- DSSO_ratio =0.46
- DSSObxadd_ratio =-0.015
- Additional currents for each individual supply
  - DSSOQ1 =DSSO+DSSO*DSSObxadd_ratio
  - DSSOQ2 =DSSO- DSSO*DSSObxadd_ratio
  - DSSOQ3 =-DSSO+DSSO*DSSObxadd_ratio
  - DSSOQ4 =-DSSO- DSSO*DSSObxadd_ratio
  - DSSOT =DSSO*DSSO_ratio
  - DSSOB =-DSSO*DSSO_ratio



Add up the Currents

- US_trim_Q1 =USSDQ1 +US_QQ1 +USSOQ1 +US_SQ1 +USSQQ1 +US_D_minus_SQ1
- US_trim_Q2 =USSDQ2 +US_QQ2 +USSOQ2 +US_SQ2 +USSQQ2 +US_D_minus_SQ2
- US_trim_Q3 =USSDQ3 +US_QQ3 +USSOQ3 +US_SQ3 +USSQQ3 +US_D_minus_SQ3
- US_trim_Q4 =USSDQ4 +US_QQ4 +USSOQ4 +US_SQ4 +USSQQ4 +US_D_minus_SQ4
- DS_trim_Q1 =DSSDQ1 +DS_QQ1 +DSSOQ1 +DS_SQ1 +DSSQQ1 +DS_D_minus_SQ1
- DS_trim_Q2 =DSSDQ2 +DS_QQ2 +DSSOQ2 +DS_SQ2 +DSSQQ2 +DS_D_minus_SQ2
- DS_trim_Q3 =DSSDQ3 +DS_QQ3 +DSSOQ3 +DS_SQ3 +DSSQQ3 +DS_D_minus_SQ3
- DS_trim_Q4 =DSSDQ4 +DS_QQ4 +DSSOQ4 +DS_SQ4 +DSSQQ4 +DS_D_minus_SQ4
- US_trim_T =US_DT +USSOT +US_ST +USSQT
- US_trim_B =US_DB +USSOB +US_SB +USSQB
- DS_trim_T =DS_DT +DSSOT +DS_ST +DSSQT
- DS_trim_B =DS_DB +DSSOB +DS_SB +DSSQB

Joe Xu has started the matrix algorithms needed to set the trim coil power supply currents.

$$\begin{pmatrix} UND \\ USD \\ UNQ \\ USQ \\ UNS \\ USO \end{pmatrix} = \begin{pmatrix} 1 & 1 & a & a & a & a \\ 0 & 0 & 1 & -1 & 1 & -1 \\ 0 & 0 & 1 & -1 & -1 & 1 \\ -1 & 1 & b & c & -c & -b \\ -d & -d & 1 & 1 & 1 & 1 \\ -1 & 1 & -e & -f & f & e \end{pmatrix} \begin{pmatrix} UT \\ UB \\ UQ_1 \\ UQ_2 \\ UQ_3 \\ UQ_4 \end{pmatrix}$$

$$= \begin{pmatrix} 1 & 1 & 0.3820000 & 0.3820000 & 0.3820000 & 0.3820000 \\ 0 & 0 & 1 & -1 & 1 & -1 \\ 0 & 0 & 1 & -1 & -1 & 1 \\ -1 & 1 & 0.4653263 & 0.4656737 & -0.4656737 & -0.4653263 \\ -0.3280000 & -0.3280000 & 1 & 1 & 1 & 1 \\ -1 & 1 & -0.4653263 & -0.4656737 & 0.4656737 & 0.4653263 \end{pmatrix} \begin{pmatrix} UT \\ UB \\ UQ_1 \\ UQ_2 \\ UQ_3 \\ UQ_4 \end{pmatrix}$$

Where

UND: Upstream Normal Dipole

USD: Upstream Skew Dipole

UNQ: Upstream Normal Quadrupole

USQ: Upstream Skew Quadrupole

UNS: Upstream Normal Sextupole

USO: Upstream Skew Octupole

Conclusion

- These multi-pole corrections were done with simulation.
- The value presented here are a good place to start including the 0.446 cm chamfer.
- It is difficult to predict the multi-pole from machining tolerances and assembly allowances.
- Introducing quasi-periodic poles will most likely introduce more multipoles.
- Magnet measurement will have to verify the final chamfer size and trim coil current values. This data will be used to finalize the look-up table values.
- A Bx and By look-up table shall be used to set the multi-poles. Linear interpolation shall be used between the data points.
- Additional multi-pole settings shall be allowed for operations within the current limitations.