New way to accelerating high current beam in ERL

Speaker: Zhenchao Liu, IHEP

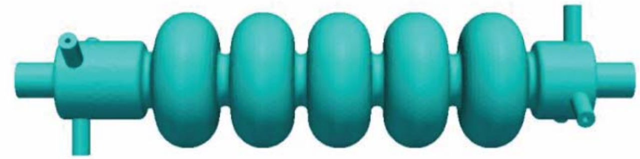
What is the design principle?

- Low cell number
- Big iris and big pipe
- Proper shape
- Efficient HOMs absorber

What we have done?

- Jlab
  - 750MHz/1.5GHz
  - 100mA
- Cornell
  - 1.3GHz
  - 100mA
- BNL
  - 704MHz BNL3 cavity
  - 50/300 mA
- KEK
  - 1.3GHz
  - >100mA
- ANL&PKU
  - 1.3GHz
  - 100mA
- …


N. Valles, ERL2011




WEPPC113, IPAC2012


WEPEC030 IPAC10


MOPC096, IPAC2011

What is the main problem for high current cavity?

- HOM damping?
- Heating?
- Power?

BBU limit

$$I_{\text{th}} = -\frac{2c^2}{e \cdots \omega_\lambda} \frac{1}{T_{12} \sin \omega_\lambda t_r},$$

HOM impedance $\left(\frac{R}{Q}\right)_\lambda Q_\lambda$

G. H. Hoffstaetter and I. V. Bazarov, Phys. Rev. ST Accel. Beams **7** 054401 (2004)

HOMs absorbing

- 1990, Y. Chen, D. Proch, and J. Sekutowicz experimentally investigated a broadband damping of monopole, dipole, and quadrupole modes by implementing small longitudinal slots near the equatorial region of a single-cell copper cavity

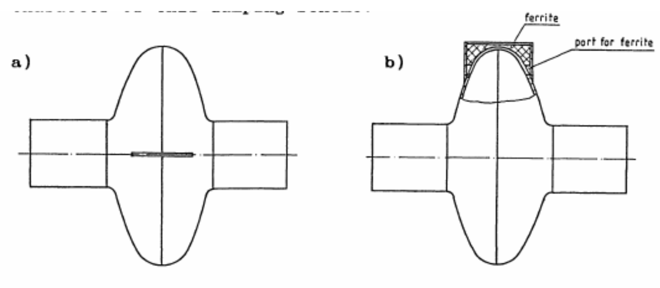


FIGURE 1 a) Location of the slot. b) Slot covered with the ferrite.

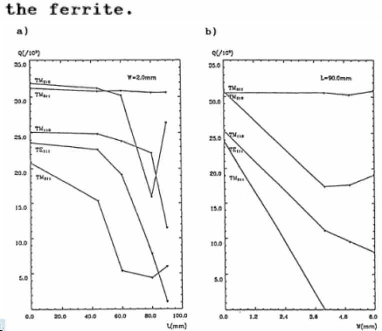


FIGURE 2. a) Q vs.L W=2mm. b) Q vs.W L=90 mm

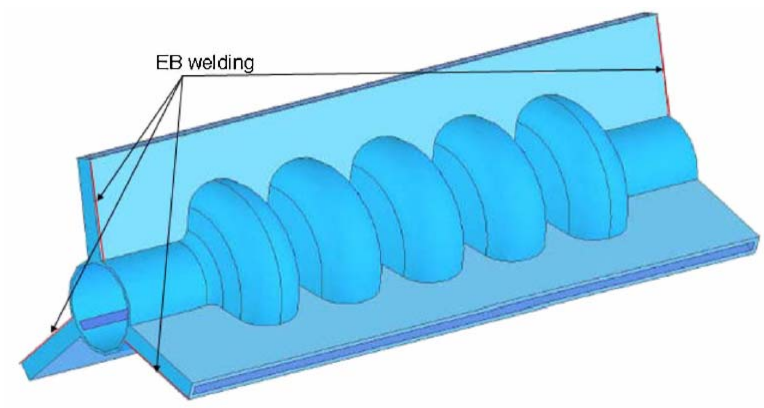
TABLE 1 HOM spectrum of the 1-cell cavity with no slotes and with 8 slotes.

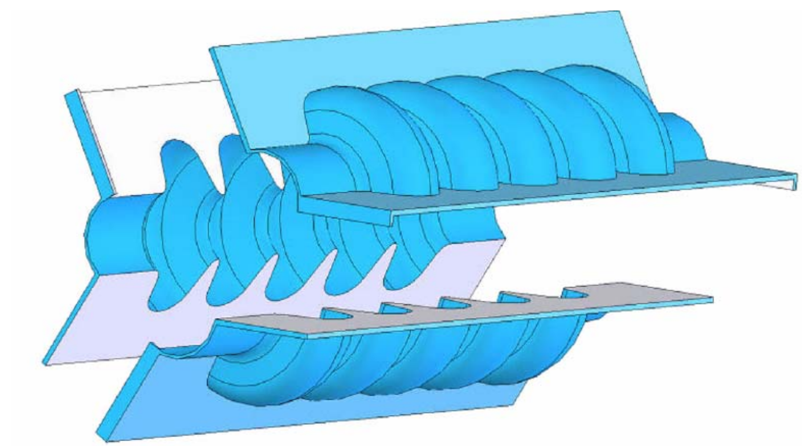
	Computed (by URMEL-T)		Measured					
			No Slot on Cavity			Eight Slots on Cavity*		
MODE	F(MHz)	R/Q (Ω)	F(MHz)	Q	Imp.(KΩ)	F(MHz)	Q	Imp.(KΩ)
TM_{010}	999.36	111.646	987.9	29400	3286.2	986.0	26520	2960.9
TE_{111}	1359.64	19.540	1366.7	23600	461.1	—	≤50	≤1.0
			1368.3	23500	458.8	—	≤50	≤1.0
TM_{110}	1411.26	44.094	1407.4	24700	1088.6	1403.2	2200	97.0
			1407.7	25100	1107.7	1406.4	2700	117.4
TM_{210}	1873.01	3.800	1865.6	31900	121.1	1859.8	1000	3.9
			1866.3	32600	123.9	1860.4	900	3.5
TM_{011}	1971.05	33.932	1957.5	31200	1058.6	1958.8	30700(400**)	1040.9(13.6**)
TM_{020}	2025.07	0.030	2031.6	32600	1.0	2015.3	29600	0.9
TM_{120}	2148.15	2.652	2110.4	18000	47.7	2123.1	1100	3.0
			2112.4	18000	47.7	2123.9	1300	3.3
TM_{310}	2235.40	0.656	2235.3	33100	21.7	2232.8	1900	1.2
			2239.1	37700	24.7	2236.1	1700	1.1
TE_{311}	2300.27	0.112	2303.3	27600	3.1	2281.0	500	0.1
			2303.8	27600	3.1	2288.4	400	0.0
TM_{211}	2654.06	10.802	2638.5	21000	226.8	2634.9	500	5.5
			2639.0	22500	243.0	—	≤20	≤0.2
TE_{411}	2707.86	0.002	2719.1	25400	0.1	2701.7	1200	0.0
			2719.5	36700	0.1	2721.9	400	0.0
TM_{212}	2761.04	15.890	2787.4	28300	450.0	2781.0	3100	49.9
			2789.0	25000	397.6	2783.6	3700	59.5
TE_{124}	2935.96	1.900	2939.1	38700	73.6	2946.0	400	0.7
			2939.2	36200	68.9	2957.8	600	1.1

Y. Chen, D. Proch, and J. Sekutowicz, in Proceedings of the 14th International Conference on High Energy Accelerators, Tsukuba, Japan (Gordon and Breach, New York, 1989); Part. Accel. 29, 741 (1990).

New cavity shape proposed

- 2010 **Z. Liu** and A. Nassiri proposed a novel rf structure for high current beam transportation.

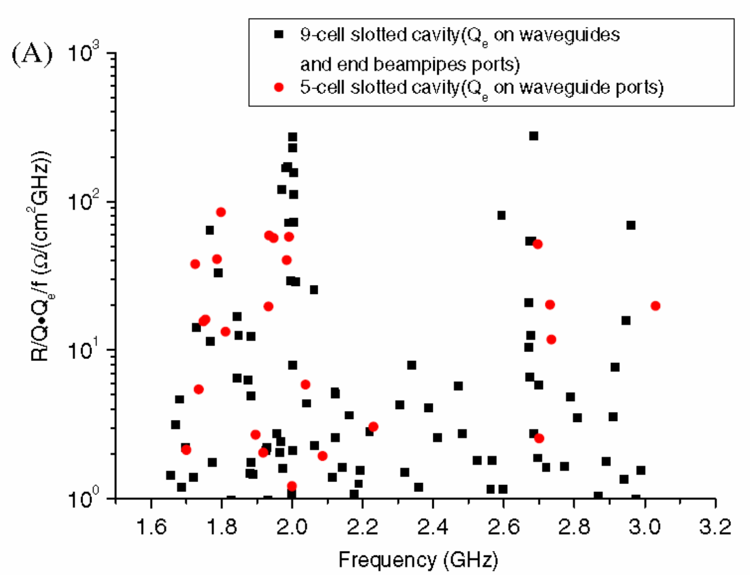




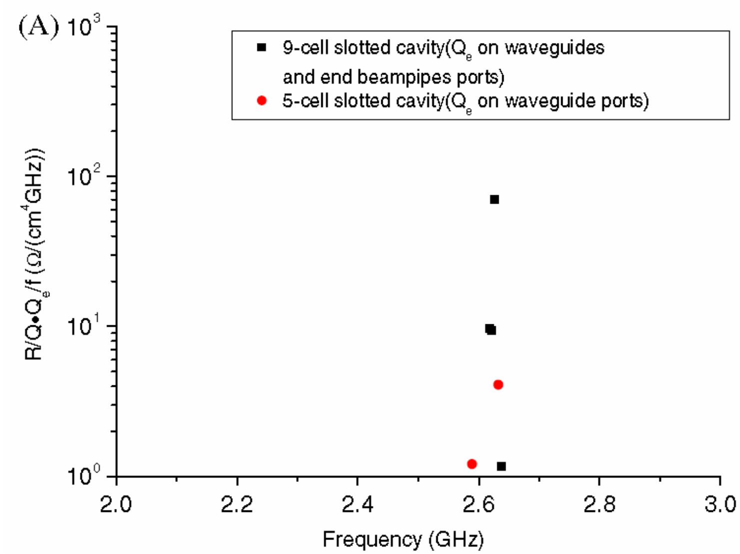
Z. Liu and A. Nassiri, A [illegible] Superconducting rf Structure for Ampere-Class Beam Current for Multi-GeV Energy Recovery Linacs, Phys. Rev. ST Accel. Beams 13, [illegible] (2010)

Problem solved

- HOM damping
  - Ten times higher damping
  - Ampere beam current is available



Dipole



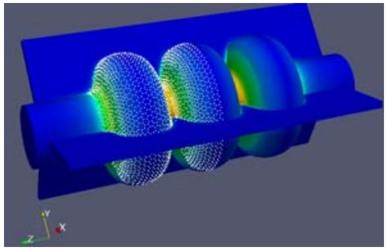
Quadrupole

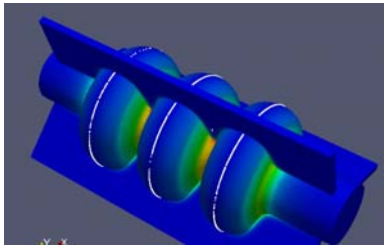
Problems

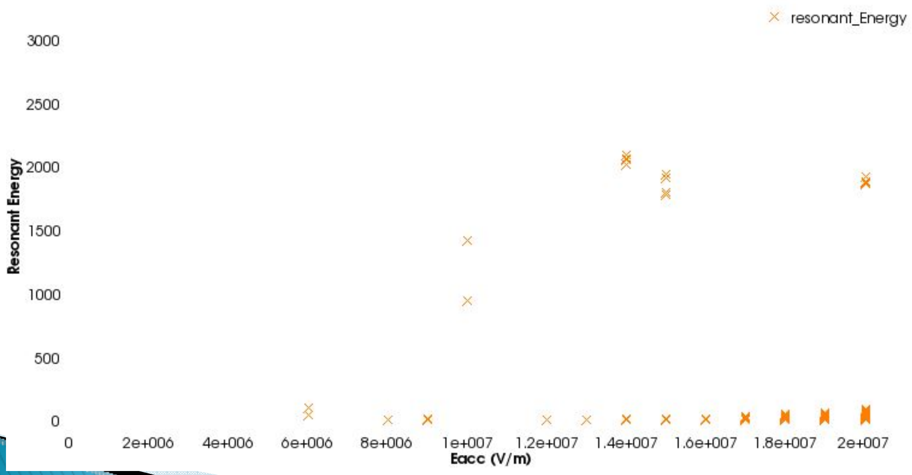
- MP–slotted structure may cause MP between cells
- Tuning–can not use the tuning method of push and pull the cavity in axis direction
- Fabrication–large Nb sheet and deep–drawing

Multipacting

- Properly choose cell shape





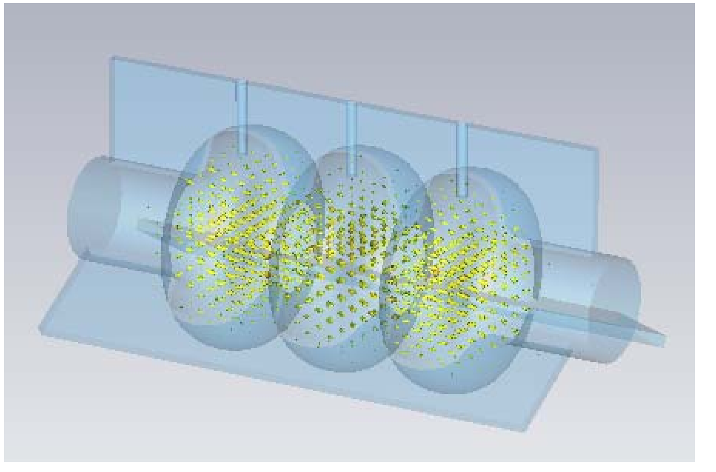


	Center cell	End cell
L (mm)	57.7	57.7
Riris (cm)	41.152	48.733
Requator(mm)	103.899	103.899
A(mm)	37.904	35.434
B(mm)	23.825	23.55
a(mm)	10.83	16.786
b(mm)	16.244	16.244
Frequency(GHz)	1.30108	
E_p/E_{acc}	3.57	
H_p/E_{acc}mT/(MV/m)	5.72	
r/Q [Ω]	268.9	
k [%]	2.7%	
Field flatness [%]	>97%	

Tuning method

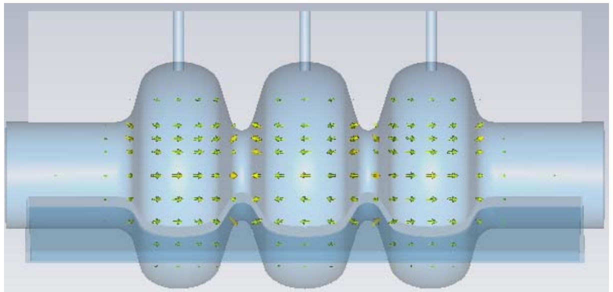
Field perturbation in each cell

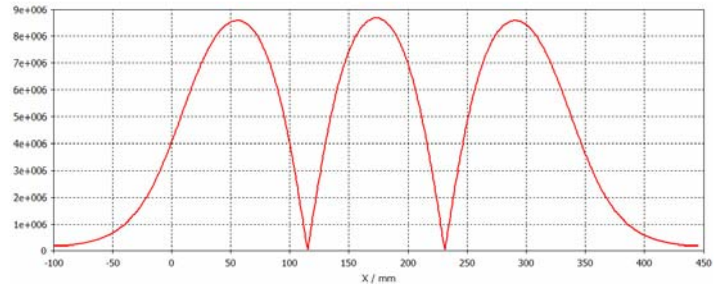
- Put sticks in one slot for perturbation
- Move stick in and out to tune the cavity frequency
- Properly choose the perturbation stick shape to avoid MP
- Properly choose the perturbation stick shape and position to avoid large Epk/Eacc and Bpk/Eacc increasing.
- Properly choose the perturbation stick size to make enough tuning range
- Perturbating in the same position in each cell



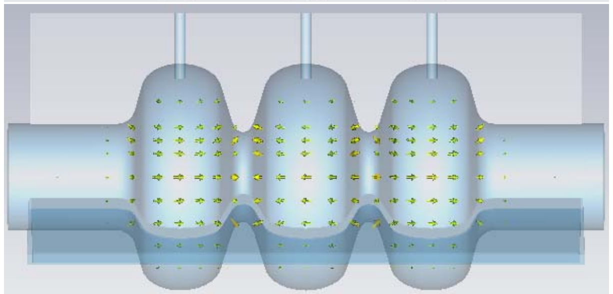
Tuning results (1)

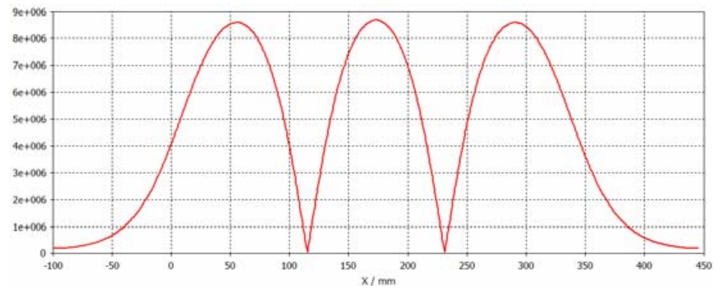
95mm



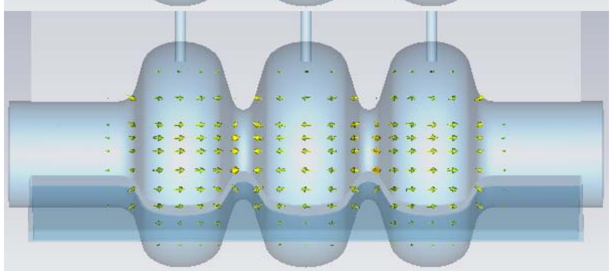


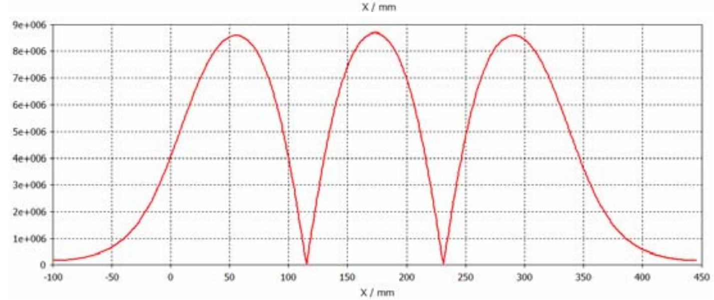
90mm





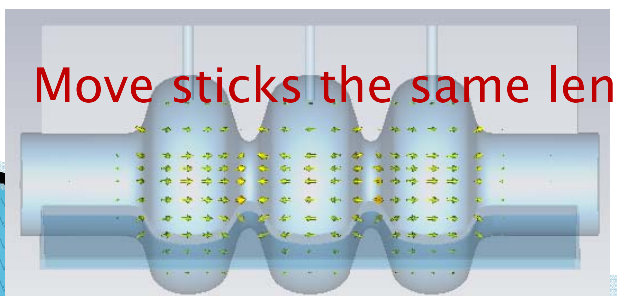
85mm

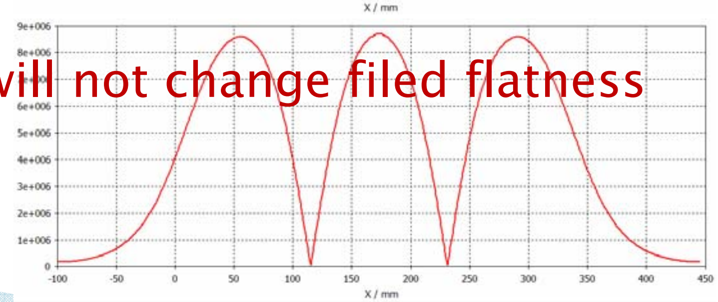




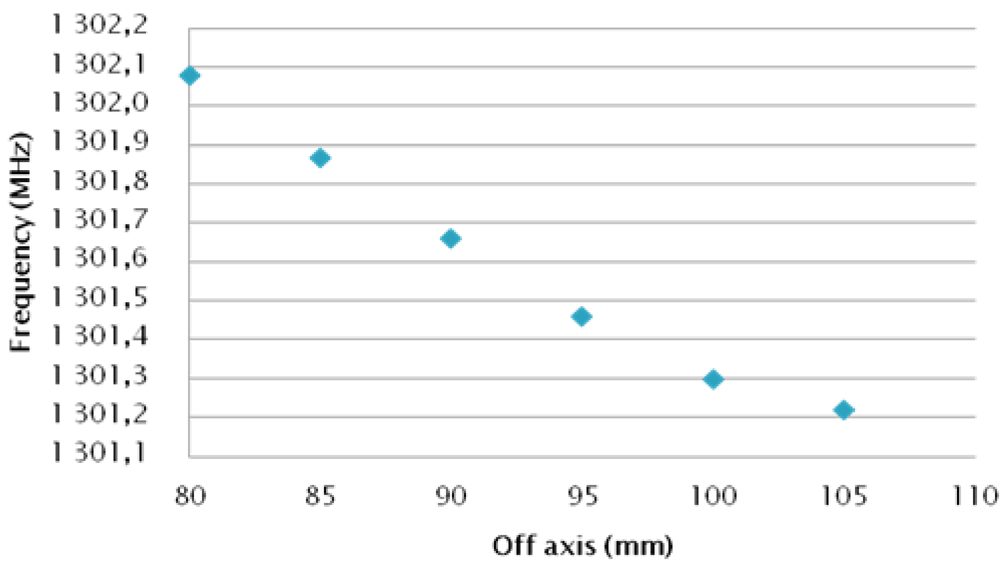
Move sticks the same length will not change filed flatness

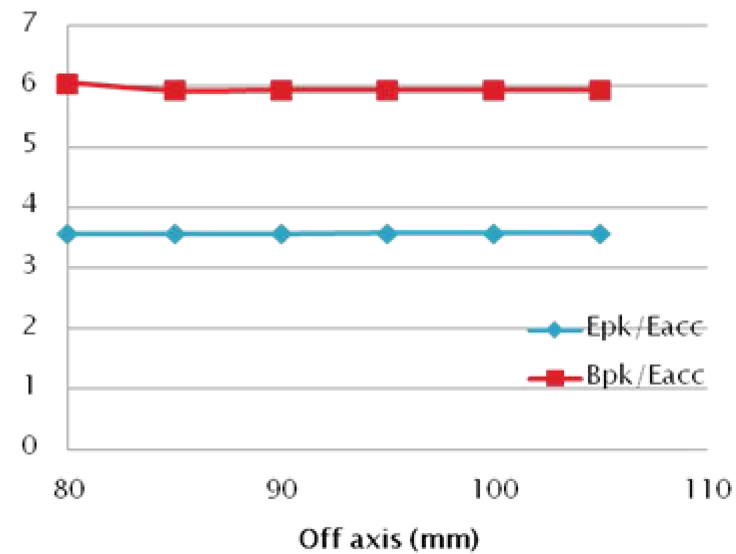
80mm





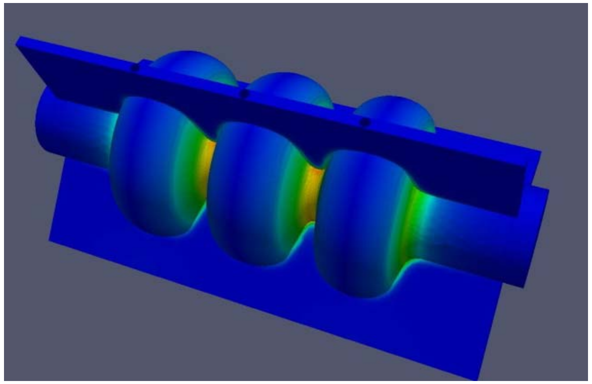
Tuning results (2)

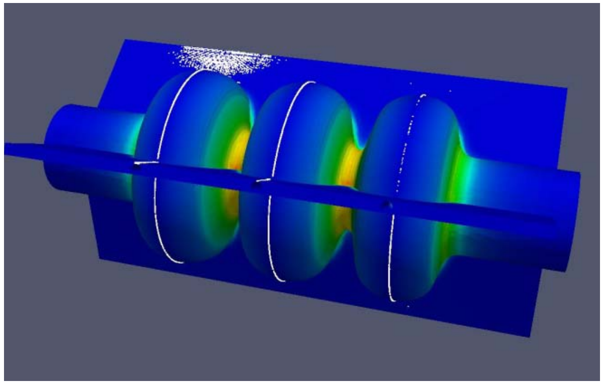


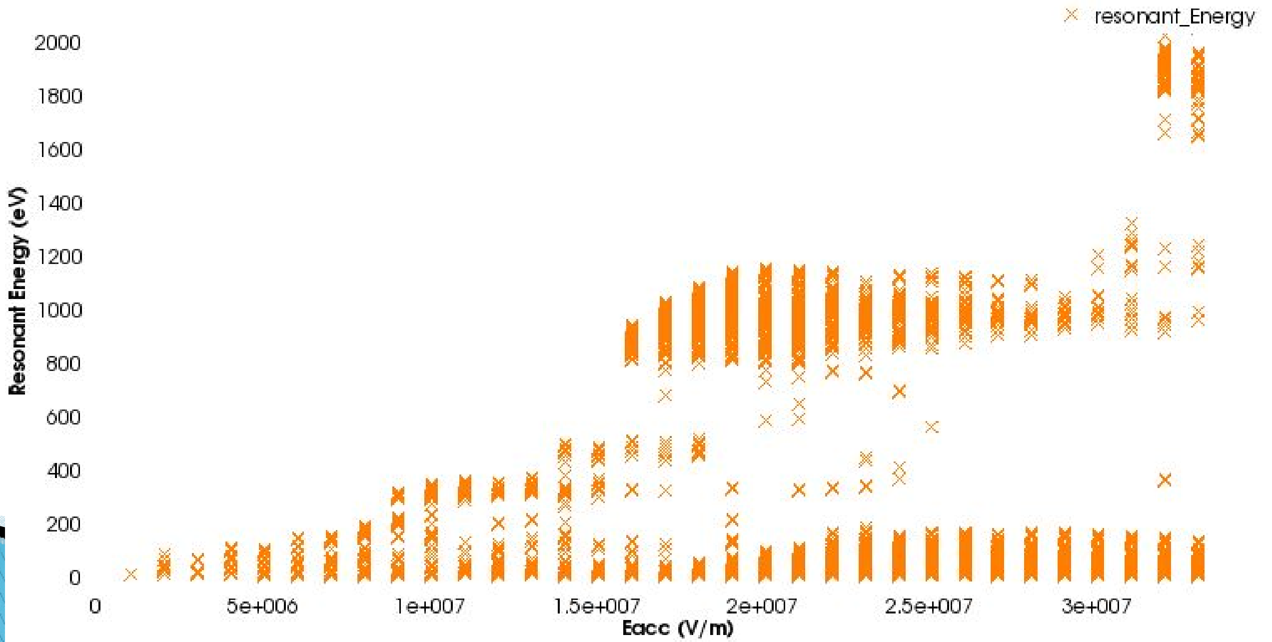


R=5mm stick

What will happen on the MP after tuning device assembled?



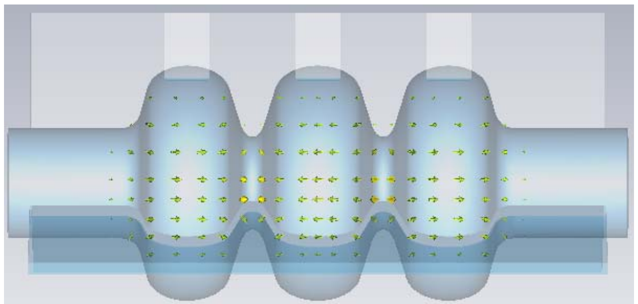


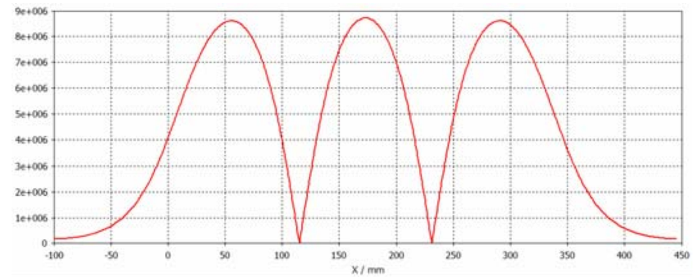


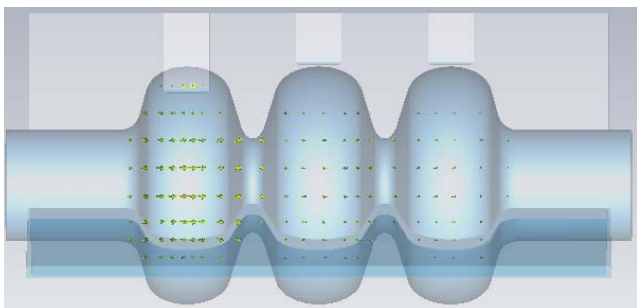
Field flatness (1)

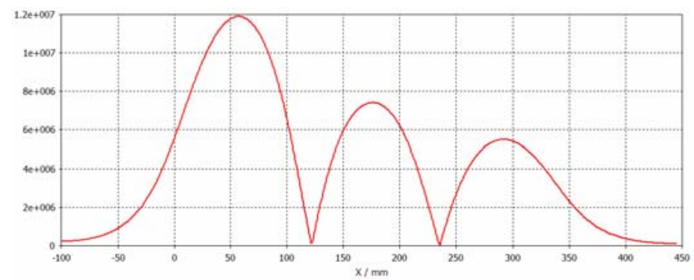
- Use tuning sticks
- Move each sticks in and out separately to tune the field flatness
- Stick with r=5mm can tune ~7% field flatness, so the cavity need pre-flatness tuning or use larger sticks (~50%)

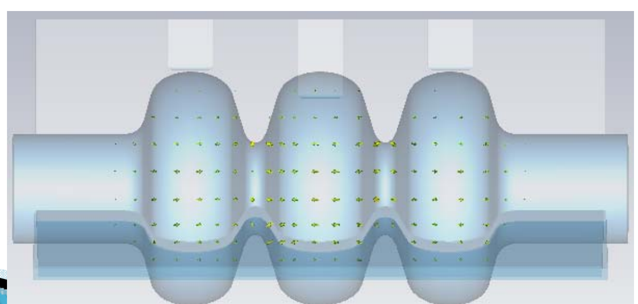
Field flatness (2)

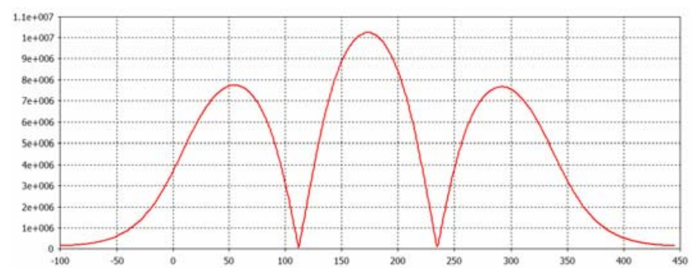




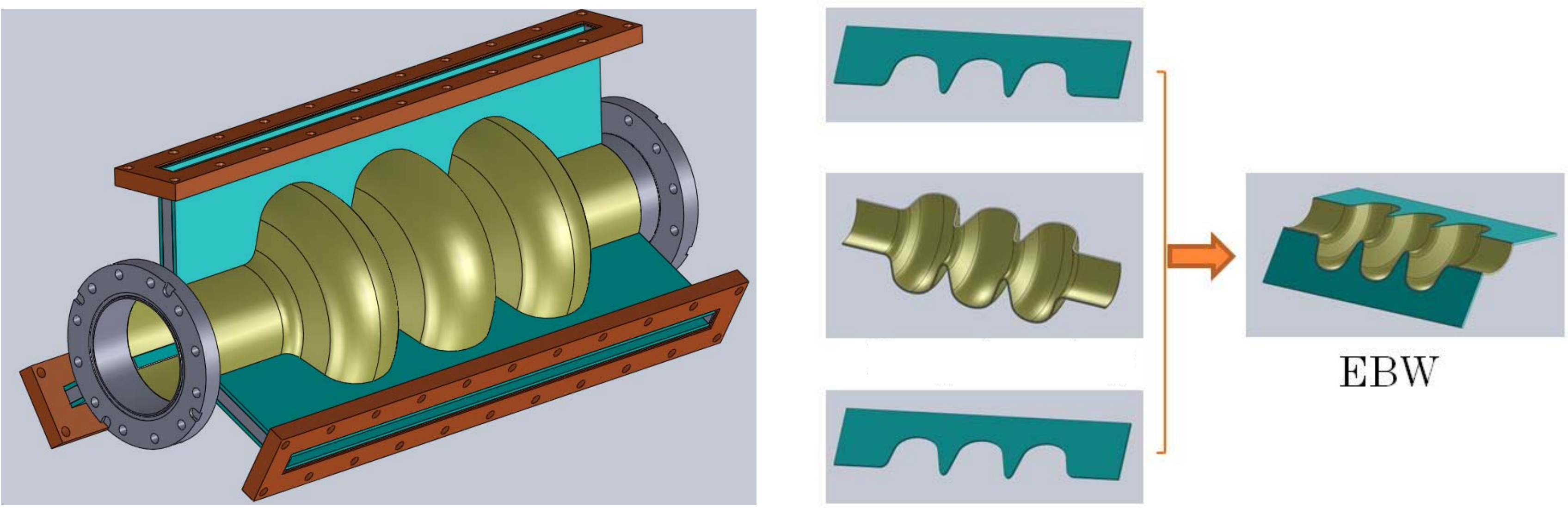








Fabrication prototype



Future work

- Fabricate a 3-cell slotted cavity prototype and tested at 2K(4K).
- Field flatness tuning test
- Frequency tuning test
- MP test
- HOMs absorbing test
- ……

Ackownledgement

We wish to thank the Advanced Computations Department of SLAC for providing the ACE3P code suite and related resources.

Thanks!