HOM damping with an enlarged beam tube for HEPS 166.6 MHz SC cavities

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Abstract

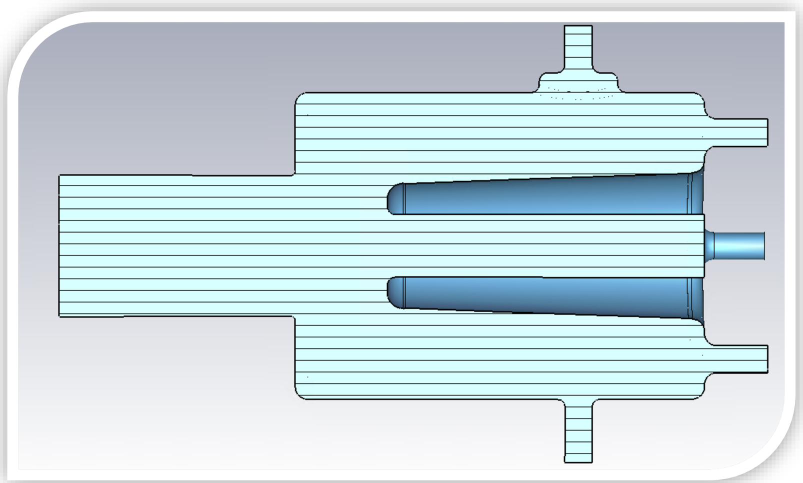
The 166.6 MHz superconducting cavities have been proposed for the High Energy Photon Source (HEPS) storage ring, which is initiated by the Institute of High Energy Physics in Beijing. Their higher order modes (HOMs) have to be damped sufficiently in order to limit coupled-bunch instabilities and parasitic mode losses. In order to keep the beam stable, the impedance budget and the HOM damping requirement are given. As one HOM damping option, an enlarged beam tube allows HOMs to propagate and subsequently be absorbed by downstream HOM dampers installed on the inner surface of the beam tube. And the conventional coaxial HOM coupler, which will be mounted on the big beam tube, is planned to extract the HOM power below the cut-off frequency of the beam pipe.

1. HEPS-TF project

parameter	value
Circumference	1300m
Beam energy(E0)	6GeV
Beam current(Ib)	200mA
Total energy loss per turn	2.5MV
Beam power	500kW

High Energy Photon Source (HEPS) is a 6 GeV kilometer-scale light source, and the main beam parameters are listed in Table. Prior to its official construction, a test facility namely HEPS-TF has been approved in 2016 to R&D and prototype key technologies and components. A 166.6 MHz RF system has been chosen to be the fundamental RF system for the HEPS storage ring to accommodate the newly proposed novel injection scheme. Due to the low RF frequency and high beam current, higher order modes (HOM) damping becomes one of the key challenges of the 166.6 MHz SC cavities.

2. The HOMs and their DAMPING REQUIREMENTs

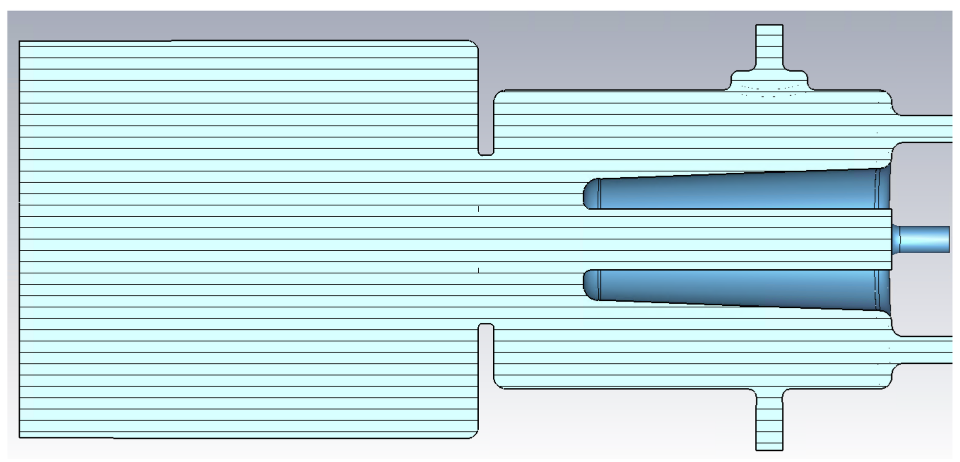


The figure shows the RF model of the recently designed 166.6 MHz cavity namely PoP cavity.

mode	freq/MHz	R/Q	$k_{\|\|}(V/pC)$	$P_{HOM}^{avg}(W)$	$R^{th}/k\Omega$	Q_L^{th}
M1	166. 844	136. 42				
M2	464. 474	71. 685	0. 0523	53. 347	81	2. 26e3
M3	700. 233	49. 078	0. 054	55. 0617	53	2. 16e3
M4	920. 795	8. 37	0. 012	12. 3483	41	1. 1e4
M5	1194. 658	6. 55	0. 012	12. 5373	31	9. 6e3

modes	freq/MHz	R/Q(Ω/cm^2)	R/Q($k\Omega/m$)	$R^{th}/k\Omega$	Q_L^{th}/x/y
D1-1	431. 9	0. 32	0. 36	381	2. 1e3
D1-2	432. 98	0. 42	0. 46	381	1. 6e3
D2-1	643. 063	0. 57	0. 42	381	1. 8e3
D2-2	644. 854	0. 64	0. 47	381	1. 6e3
D3-1	874. 476	0. 85	0. 46	381	1. 6e3
D3-2	874. 992	0. 92	0. 50	381	1. 5e3
D4-1	1012. 701	1. 146	0. 24	381	3. 2e3
D4-2	1013. 597	1. 159	0. 24	381	3. 2e3

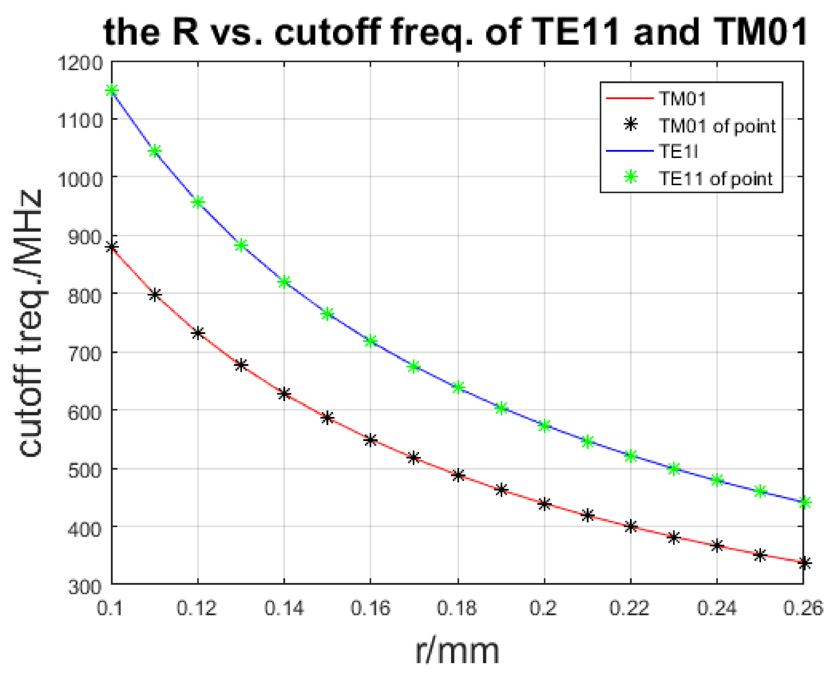
3. The enlarged tube HOM coupler



The enlarged tube itself is a high-pass filter.

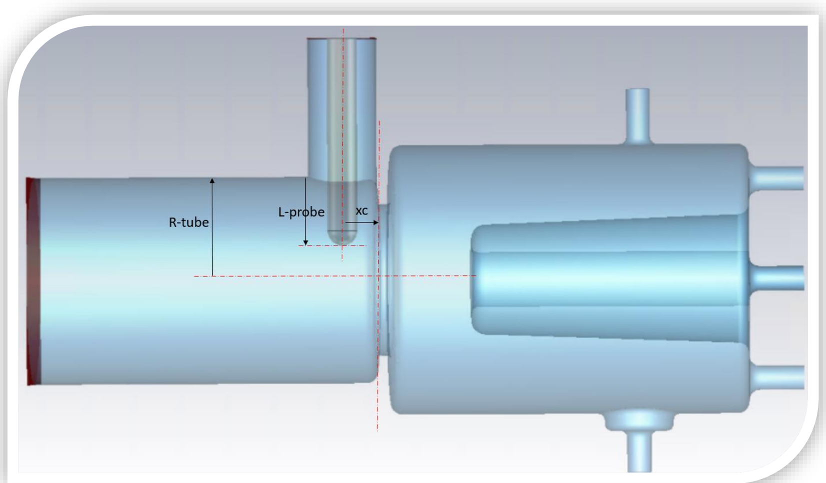
$$TM01:\ f_c = 3e8 \cdot \frac{2.405}{2\pi \cdot R}$$

$$TE11:\ f_c = 3e8 \cdot \frac{1.841}{2\pi \cdot R}$$



Damping all HOMs from enlarged tube, the radius of the tube needs at less 260mm.

4. Combined the big tube with the coaxial HOM coupler

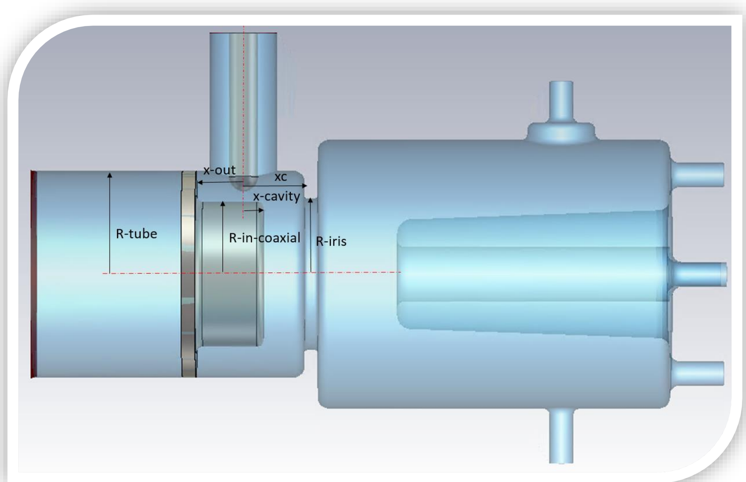


R-tube	150	*L-tube*	500
xc	50	*L-probe*	100
R-coaxial	50	*L-coaxial*	200
R-iris	110	*L-iris*	20

M1	Qe1	M2	Qe2
167. 2326	2. 1e4	466. 197	1890
D1	Qe1	D2	Qe2
429. 3	1489	632	32
M3	Qe3		
704. 9	997		

Combined with the notch filter, the structure could achieve the design target. However, the probe is long this disturbing the beam current.

5. The within coaxial HOM coupler



R-tube	150	*L-tube*	500
xc	95	*L-probe*	30
R-in-Coaxial	82	*x-out*	80
R-iris	110	*L-iris*	20
d	20	*x-cavity*	30

M1	Qe1	M2.1	Qe2.1
167. 23	1. 5e9	452. 49	413
D1	Qe1	D2	Qe2
429. 75	6e4	628. 46	913
M2.2	Qe2.2	M3	Q3
472. 32	849	709	1. 5e4

The fundamental mode has the perfect value, which has been inhibited deeply. And the next monopole mode has been transmitted well. But the first dipole has the trouble to transmit.