Redesign of the End Group in the 3.9 GHz LCLS-II Cavity*

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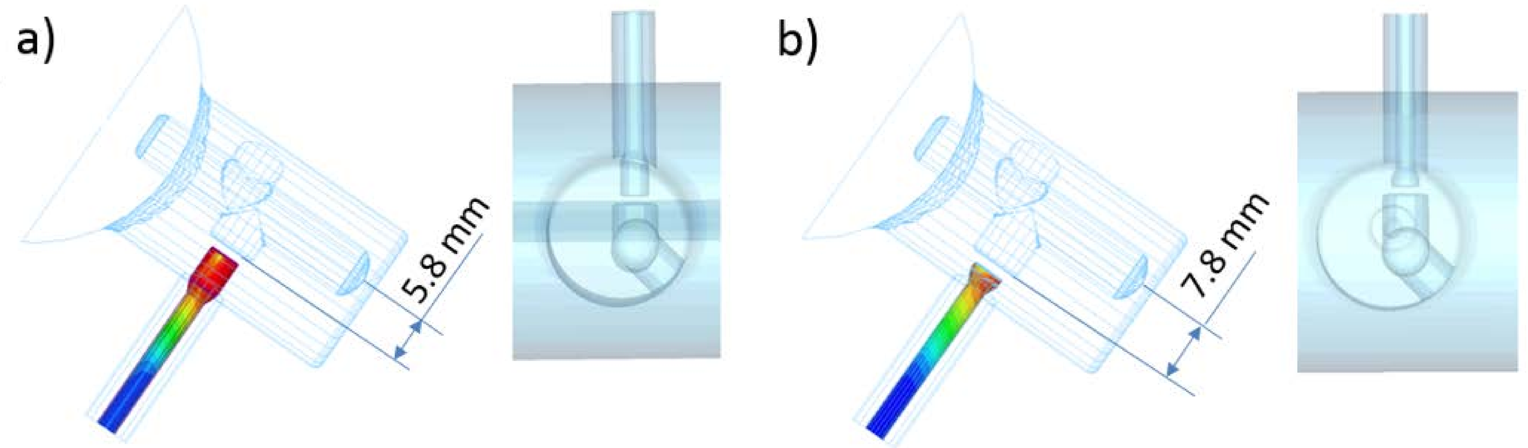
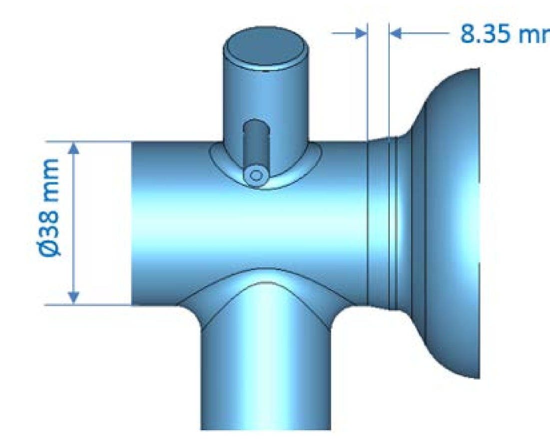
Introduction

A continuous operation regime of the 3.9 GHz LCSL-II accelerating structure at the maximum gradient of 14.9 MV/m sets an extra caution on possible overheating of HOM couplers feedthroughs. The HOM feedthrough coupling antenna is made of a solid Niobium, which does not produce significant amount of RF losses until its temperature is keeping below critical, but it may initiate a thermal runaway process and end up by a cavity quench due to a leak of an operating mode or a resonant excitation of the cavity HOM spectrum. In order to avoid such a scenario, one has to minimize the antenna RF heating by using smaller antenna tip and increasing the size of the f-part snag.



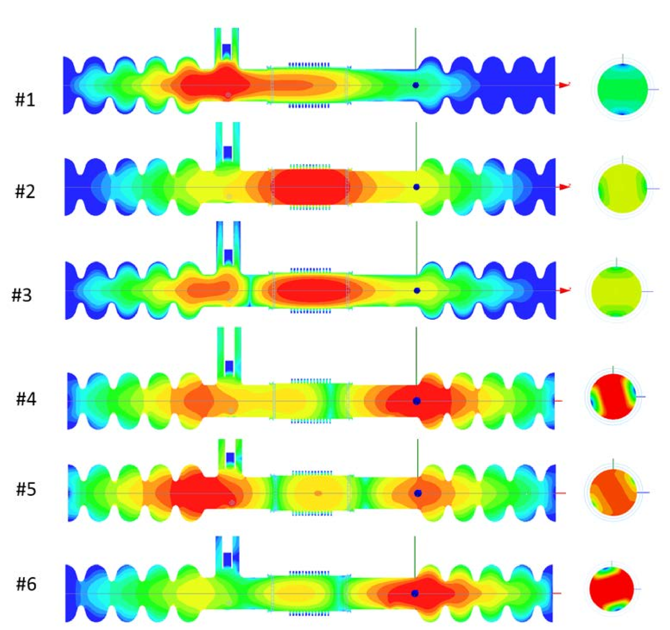
Modifications of the HOM coupler for the 3.9 GHz cavity:
a) XFEL design and b) LCLS-II design.



New design of the 3.9 GHz cavity End Group

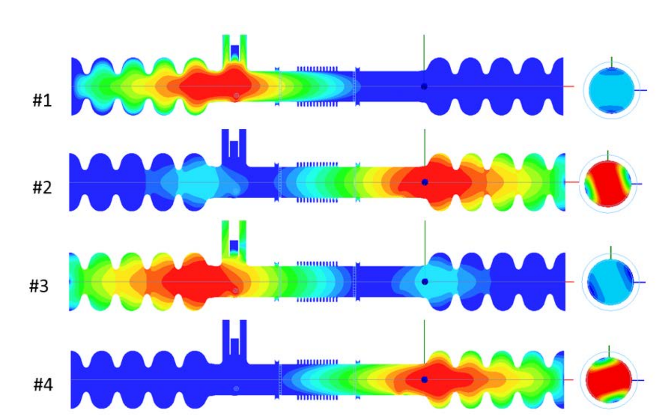
- **In the tuned HOM coupler, the feedthrough antenna with new tip has a higher local G-factor of 1.7x10^9, comparing to the 3.2x10^8 G-factor of the original design.**
- **It is equivalent to a reduction by a factor of five of associated surface RF losses, which makes new HOM coupler suitable for the CW operation**

Dipole HOMs Spectrum in the End Group



Dipole HOMs of the XFEL 3.9 GHz Cavity

#	Freq. [GHz]	Q_{ext}	$(R/Q)_x$ [Ω/mm²]	$(R/Q)_y$ [Ω/mm²]
1	3.992	3.6e4	0.06	0.26
2	4.047	8.0e4	0.02	5e-3
3	4.059	2.5e5	5e-3	0.34
4	4.136	5.9e3	1.0	0.96
5	4.135	4.9e3	7.3	3.0
6	4.150	3.3e5	1.2	1.6

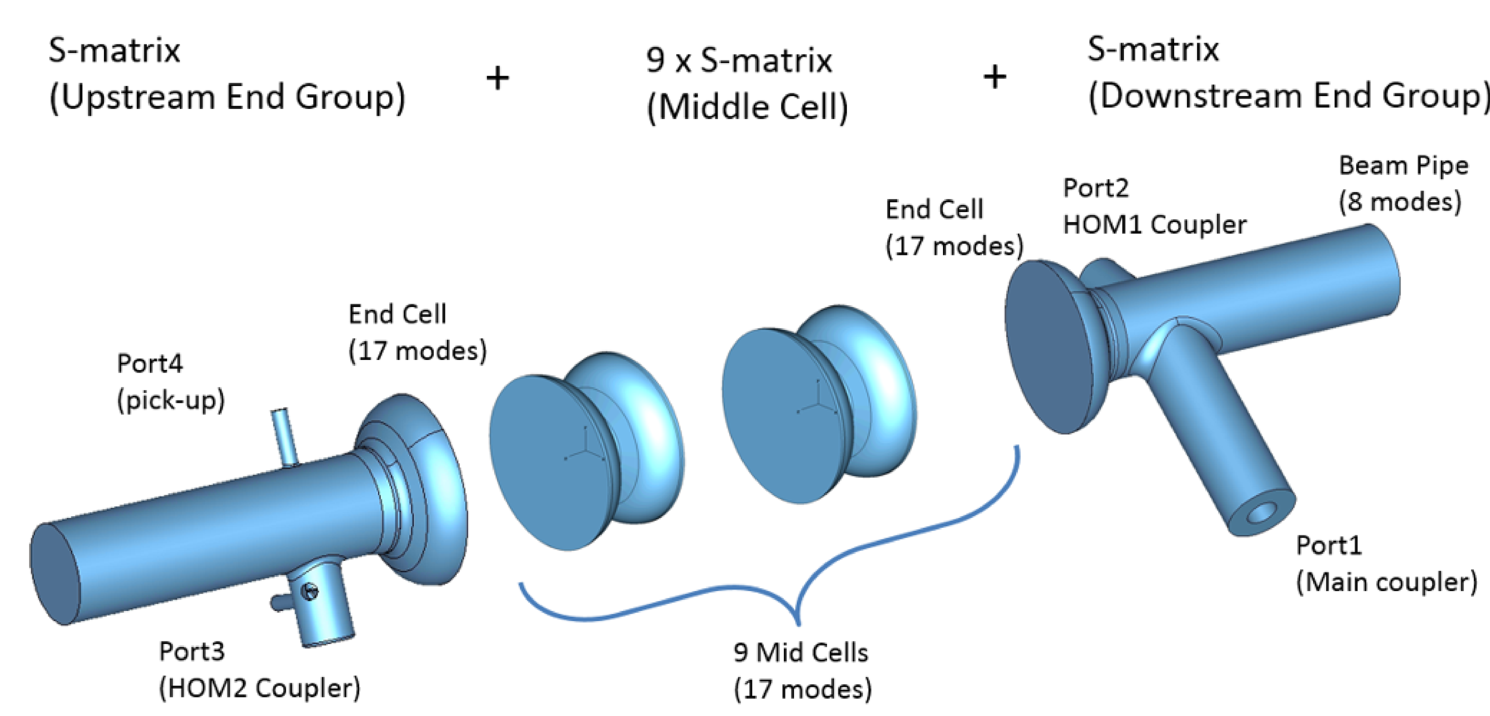


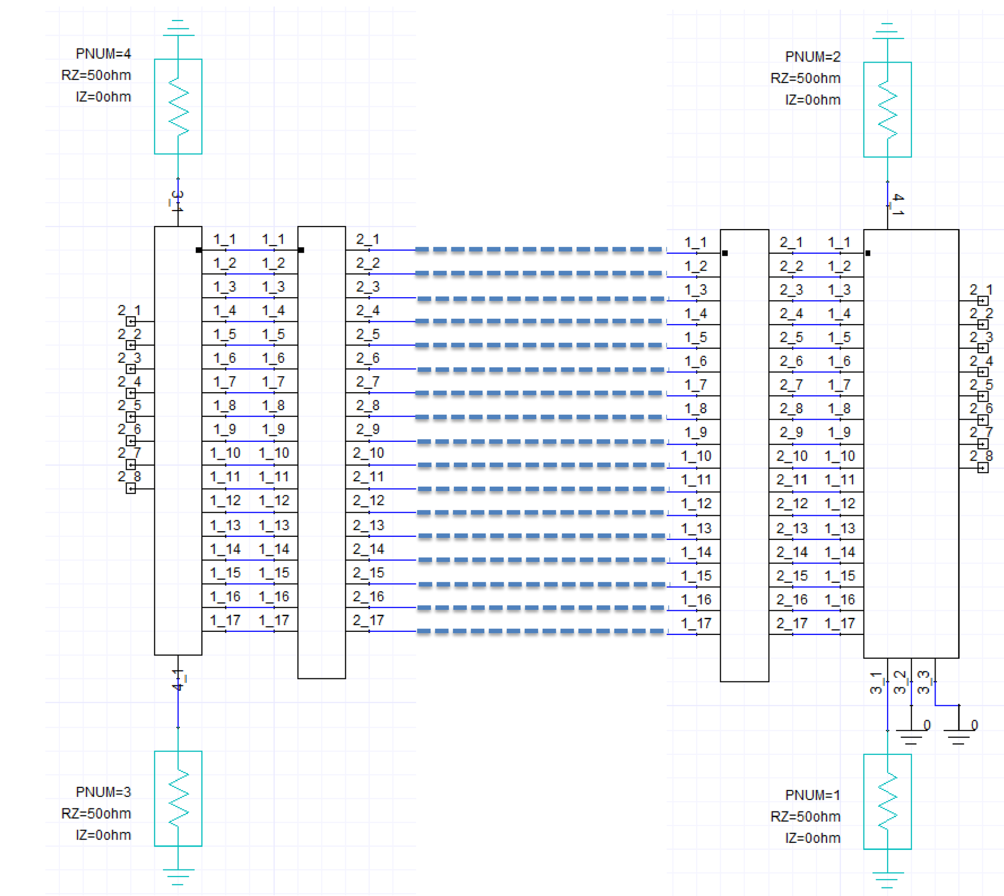
Dipole HOMs of the LCLS-II 3.9 GHz Cavity

#	Freq. [GHz]	Q_{ext}	$(R/Q)_x$ [Ω/mm²]	$(R/Q)_y$ [Ω/mm²]
1	3.992	3.6e4	0.06	0.26
2	4.047	8.0e4	0.02	5e-3
3	4.059	2.5e5	5e-3	0.34
4	4.136	5.9e3	1.0	0.96

- **It is difficult to tune the notch filter in a close proximity of dipole HOMs**
- **Number of nearby dipole HOMs is reduced to four in the LCLS-II 3.9 GHz cavity**
- **The frequency of the closest dipole mode is shifted up by 100 MHz comparing to the original XFEL design.**

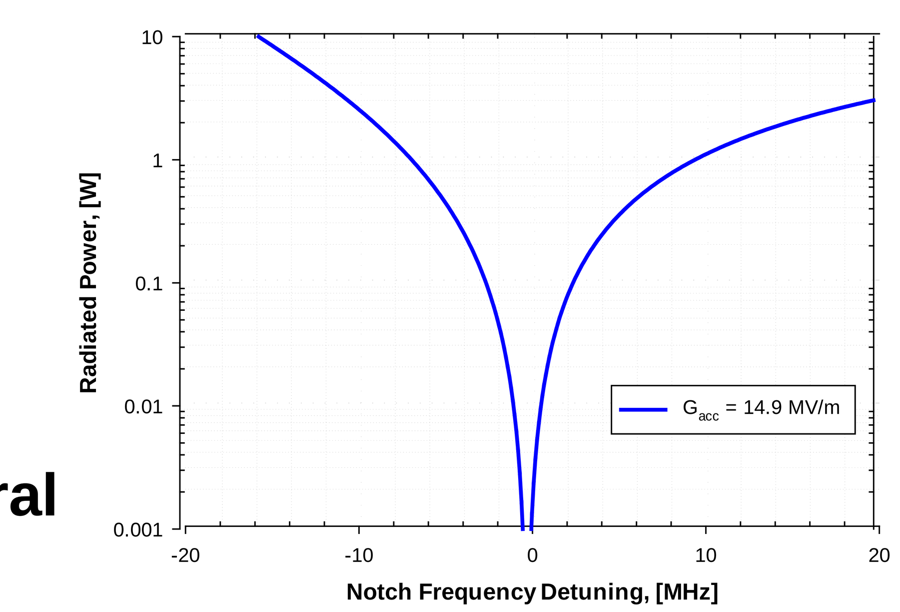
The HOM Coupler Notch Filter Tuning

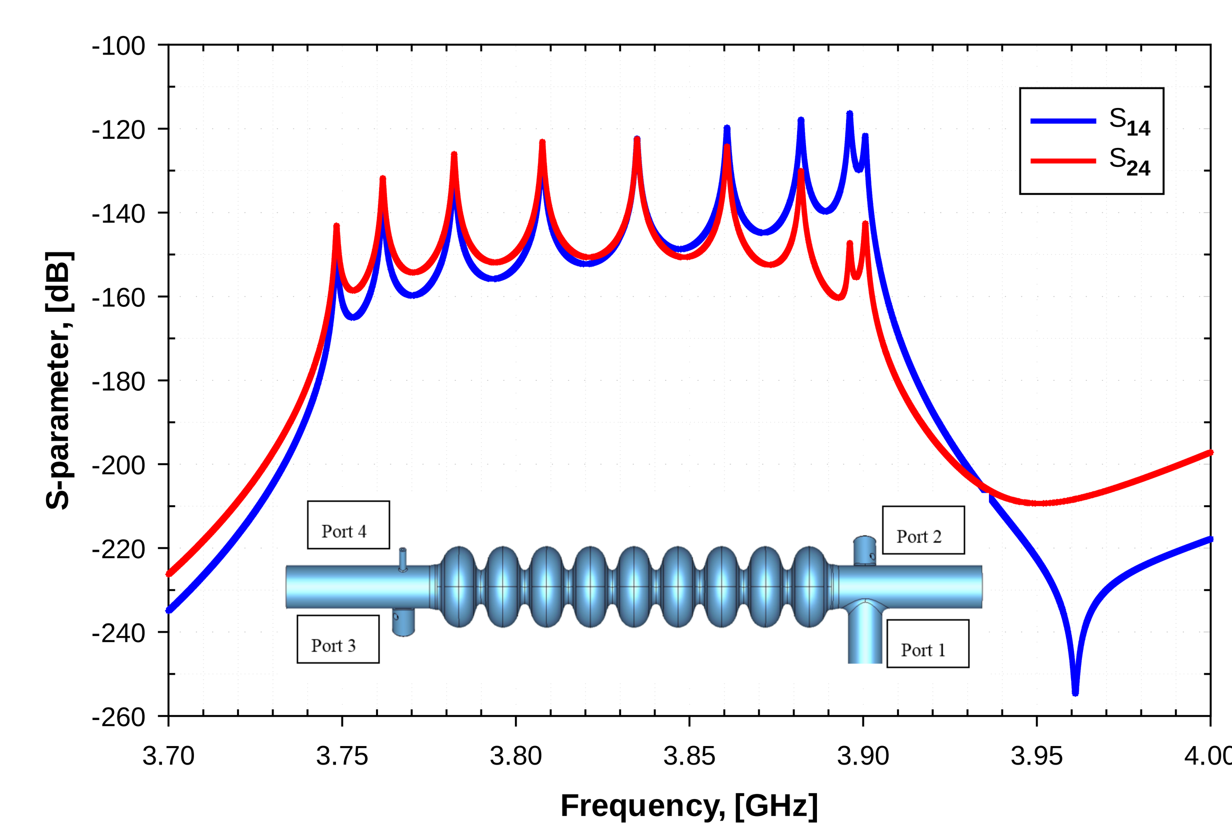




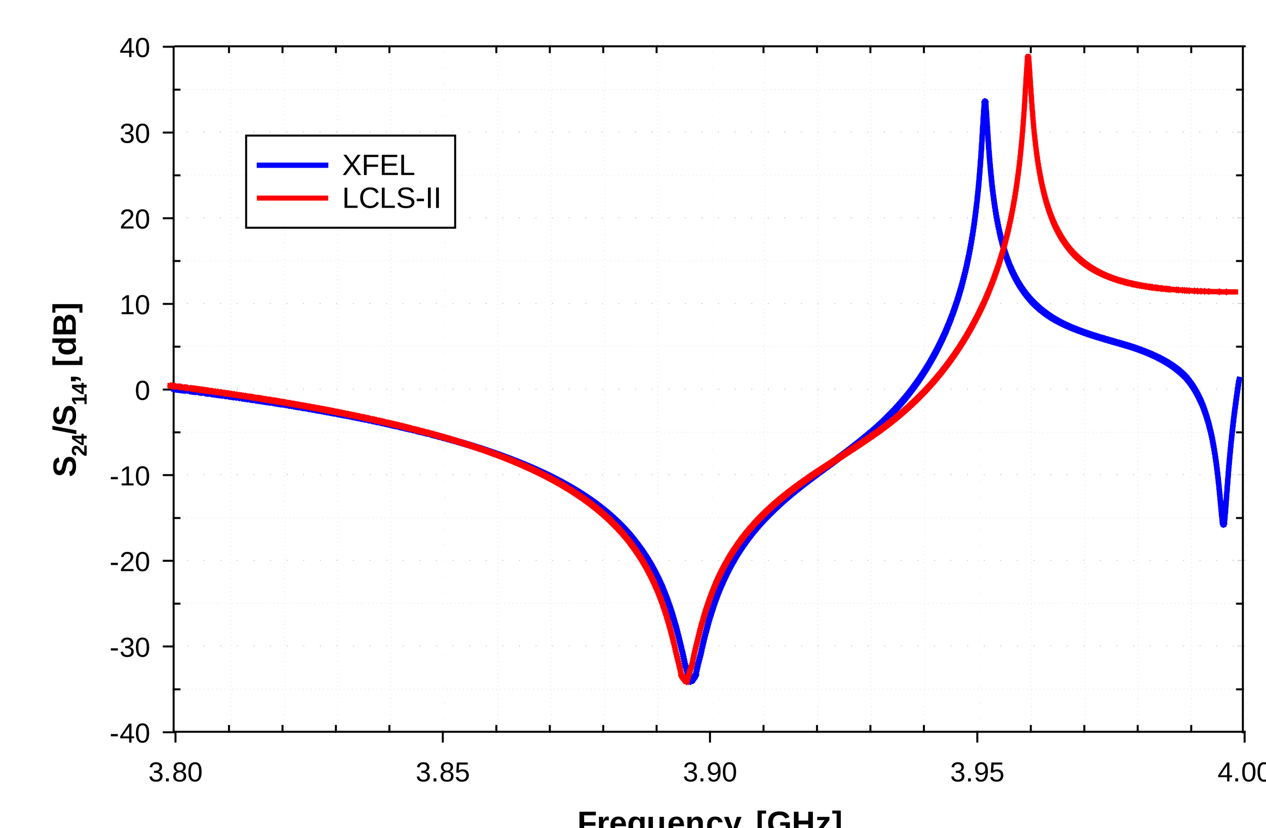
Scheme of S-matrix decomposition of the 3.9 GHz 9-cell cavity (left) and corresponding ANSYS Designer model (right)

- **Detuning of few MHz is observed for the notch filter central frequency in the XFEL 3.9 GHz cryomodule**
- **Up to 1 W average rf power might leak through the single HOM port at 14.9 MV/m gradient.**
- **The HOM port signal (S_{24}) normalized to the cavity transmission signal (S_{14}) reveals the notch filter central frequency**





Signals transmission in the 3.9 GHz cavity



Notch filter passbands.

- **The LCLS-II design with a reduced beam pipe aperture has a less influence of nearby dipole modes and, thus, ensures an easy tuning of the sensitive HOM coupler notch filter.**

Conclusions

The redesign of the 3.9 GHz cavity End Group is completed. Reduced beam pipe aperture simplifies the HOM coupler notch filter tuning, while modifications of the HOM coupler f-part and the antenna reduce RF losses in the HOM feedthrough making it suitable for CW operation of the LCLS-II linac.

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