

Absorption of Wake Fields from Accelerating Cavities in Re-Entrant Cavity BPM

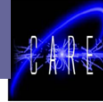
dapnia



saclay

Re-entrant Cavity BPM

XFEL
X-Ray Free-Electron Laser



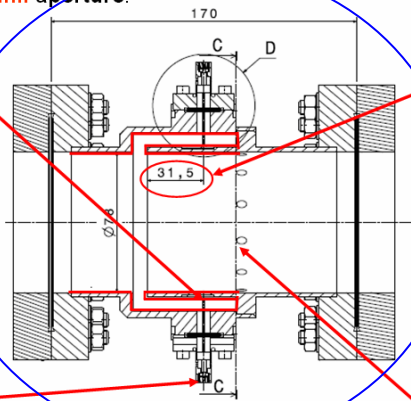
- It is arranged around the beam tube and forms a coaxial line which is short circuited at one end.

- The cavity is fabricated with stainless steel as compact as possible :

170 mm length (minimized to satisfy the constraints imposed by the cryomodule)

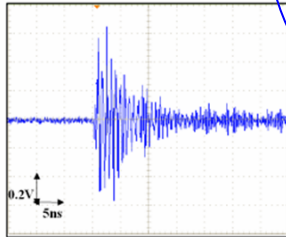
78 mm aperture.

Cu-Be RF contacts welded in the inner cylinder of the cavity to ensure electrical conduction.



Feedthroughs are positioned in the re-entrant part to reduce the magnetic loop coupling and separate the main RF modes (monopole and dipole)

Cryogenic tests in N₂ : OK



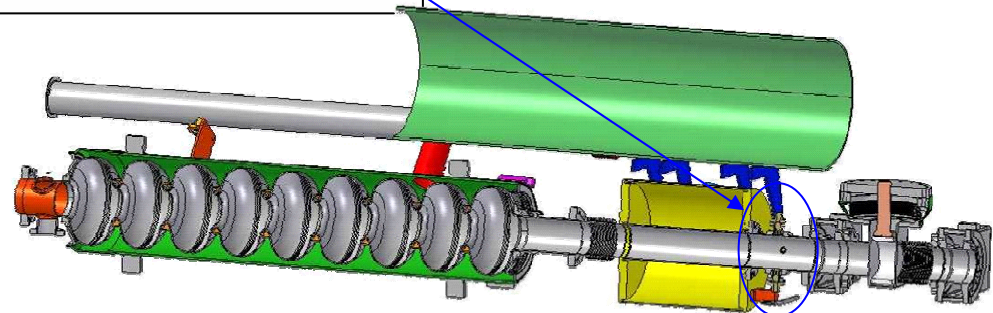
Signal from one pickup

Twelve holes of 5 mm diameter drilled at the end of the re-entrant part for a more effective cleaning (Tests performed at DESY).

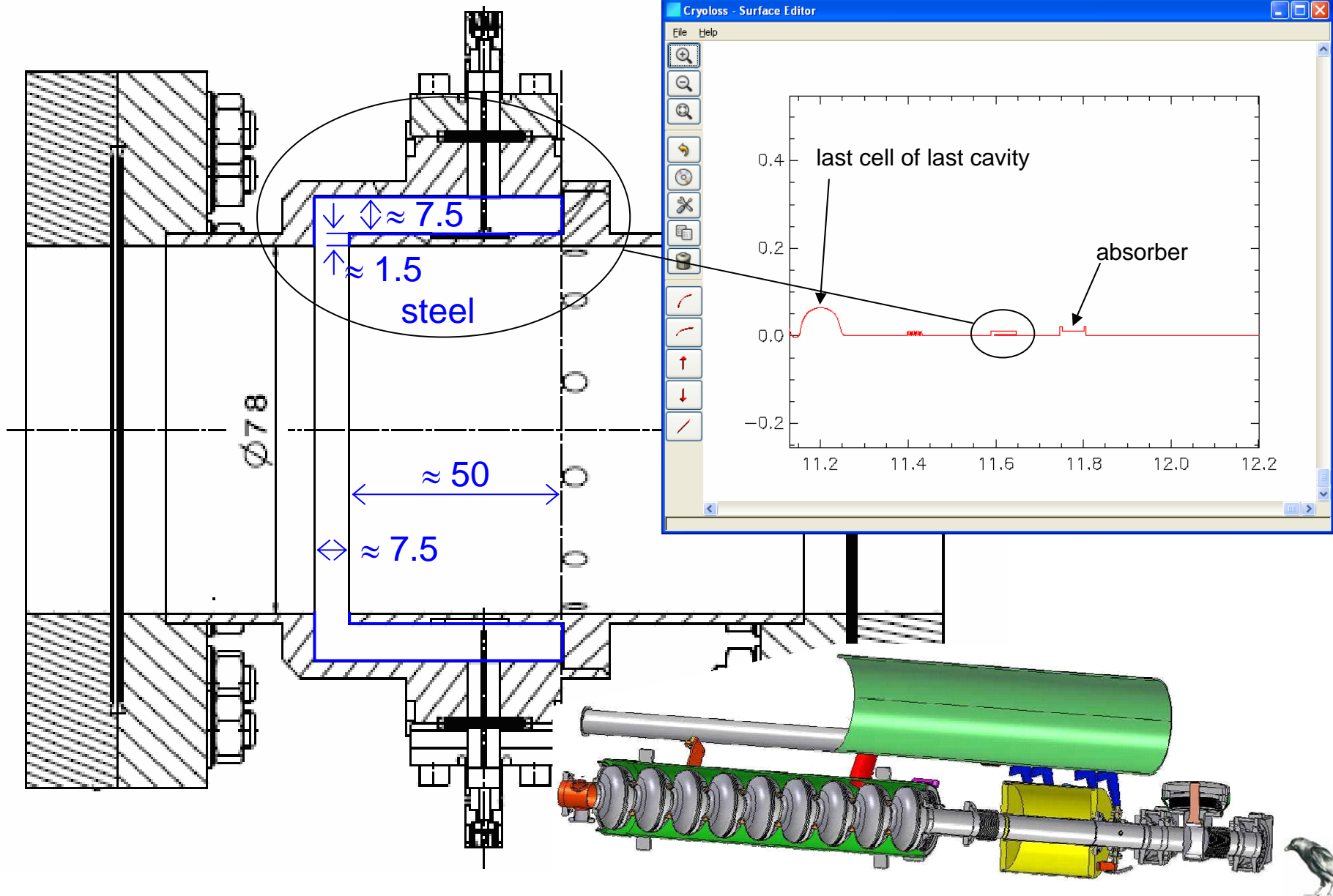
Claire Simon

XFEL BPM Workshop

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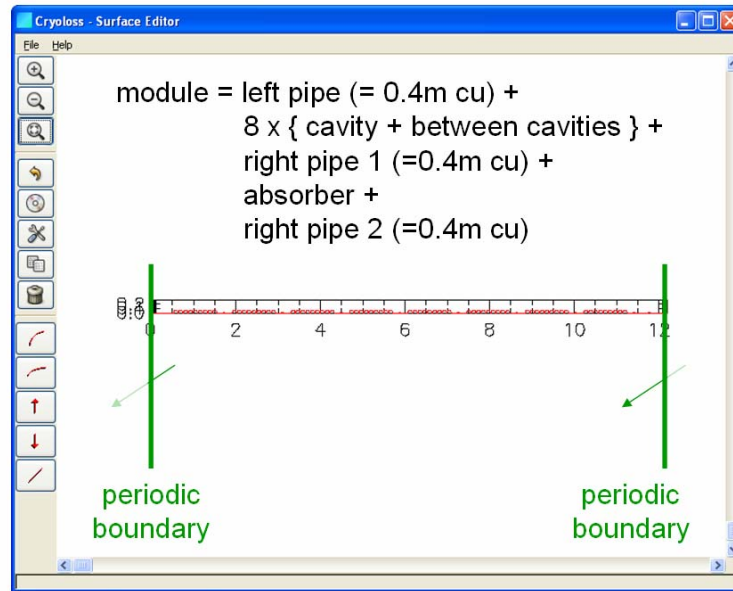
geometry used for cryoloss



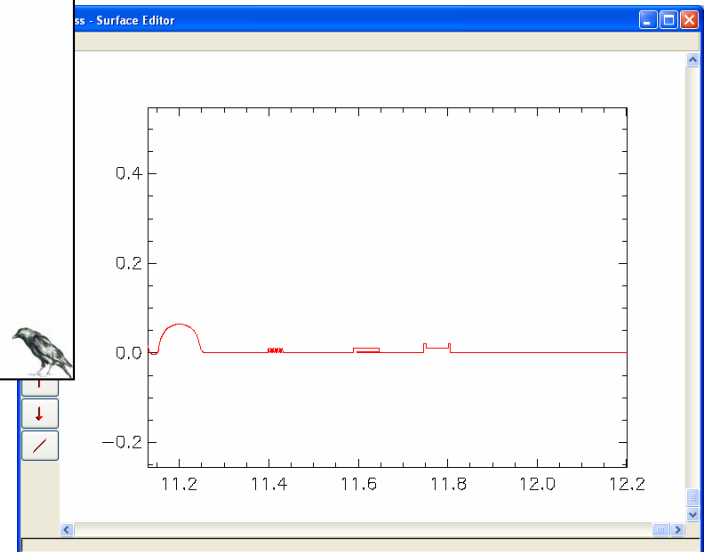
geometry used for cryoloss

3. Module Models XFEL – surface geometry

"module_bellows_geo2.cav"



= infinite string of cold modules !



periodic string of modules

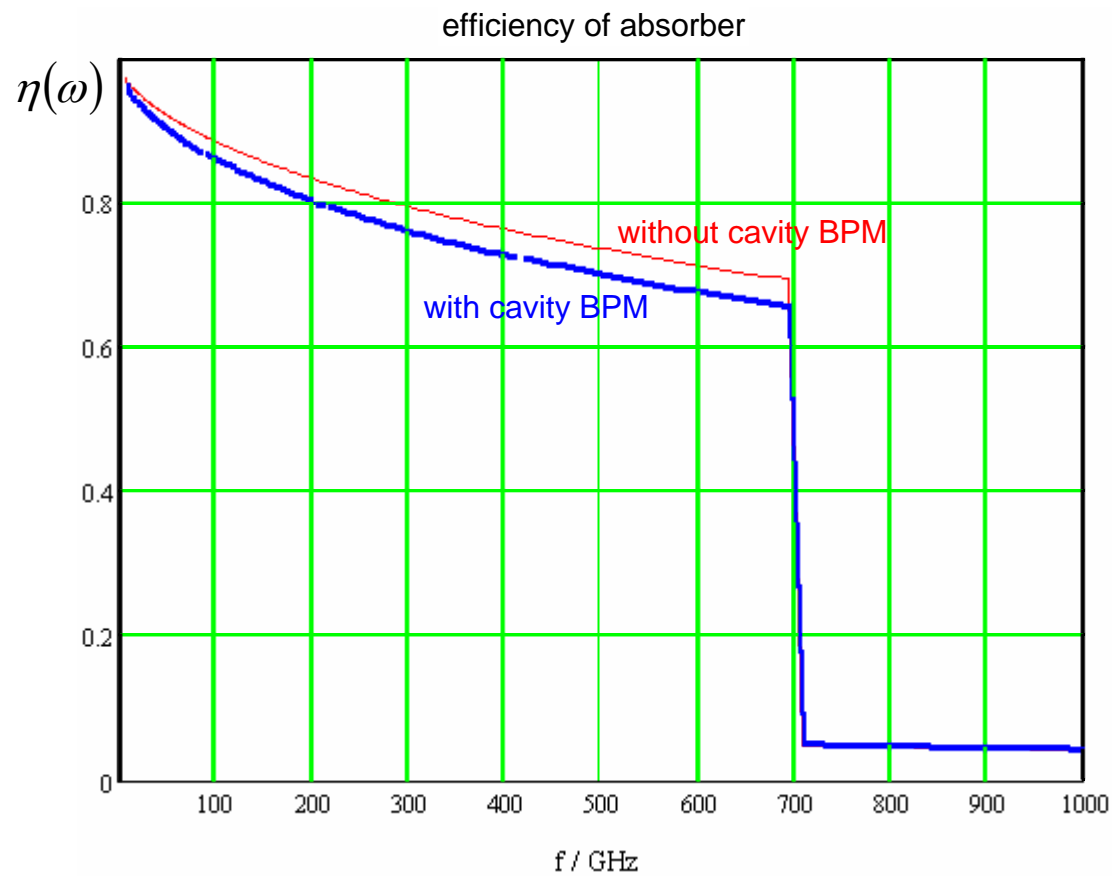
see geometry description in:

http://www.desy.de/xfel-beam/data/talks/talks/dohlus_-_cryo_calc_20071112.pdf



absorber 1
perfect cu

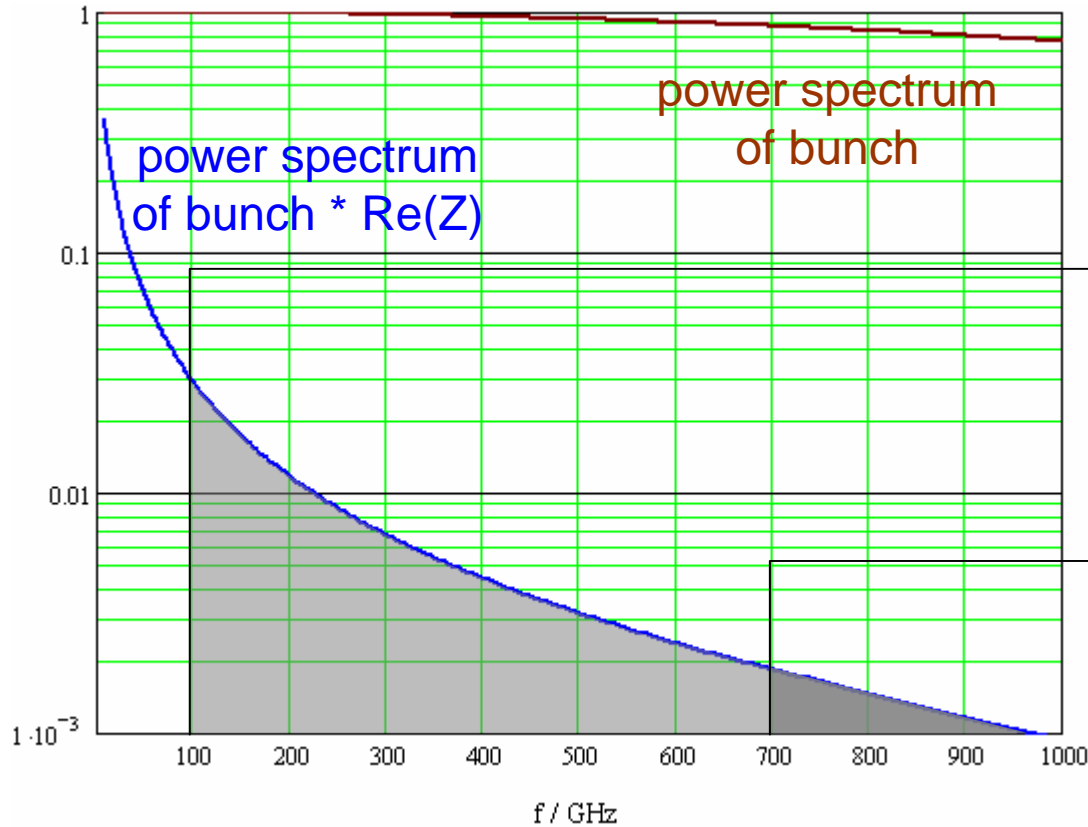
cryoloss results XFEL



absorber 1
perfect cu

total absorber efficiency

bunch length = 25 μm



$$\frac{\int_{100\text{GHz} \cdot 2\pi}^{\infty} P^{(\sigma)} \text{Re}\{Z\} d\omega}{\int_0^{\infty} P^{(\sigma)} \text{Re}\{Z\} d\omega} \approx 0.258$$

$$\frac{\int_0^{\infty} P^{(\sigma)} \text{Re}\{Z\} d\omega}{\int_0^{\infty} P^{(\sigma)} \text{Re}\{Z\} d\omega} \approx 0.046$$

total absorber efficiency without cavity BPM: = 83.1 %

total absorber efficiency with cavity BPM: = 80.9 %

with $\eta_{\text{abs}}(\omega) = 0$ for $\omega > 700\text{GHz} \cdot 2\pi$



2.2% additional losses in in re-entrant cavity BPM

	10x3000 bunches / sec	30x3000 bunches / sec
single bunch losses =	4.6 W	13.8 W
losses per cavity BPM =	0.1 W	0.3 W
best-case-2K-cryo-load = (per module with C-BPM)	0.9 W	2.6 W

single passage losses due to re-entrant cavity BPM

10x3000 bunches / sec	30x3000 bunches / sec
0.04 W	0.12 W

a large part of these losses goes to the HOM absorber



estimated 2004, 3250 bunches, 10Hz

$$P_{\text{single_passage_750GHz}} := \frac{k_{750\text{GHz}}(\sigma_{\text{bu}} \cdot q_b)^2}{T_{\text{bs}}} \cdot L_{\text{active}} \cdot \eta_{\text{bu_duty}}$$

$$P_{\text{single_passage_750GHz}} = 0.214$$

d) Power to HOM Absorber (estimated efficiency = 0.75)

$$i_{\text{hom_abs}} := 1 \quad \text{(1: yes there is an absorber, 0: no)}$$

$$\eta_{\text{hom_abs}} := 0.75 \cdot i_{\text{hom_abs}} \quad \text{(no design so far: efficiency is speculative)}$$

$$P_{\text{to_hom_absorber}} := \eta_{\text{hom_abs}} \cdot (P_{\text{single_passage_5GHz}} - P_{\text{single_passage_750GHz}})$$

$$P_{\text{hom_nc_walls}} := (1 - \eta_{\text{hom_abs}}) \cdot (P_{\text{single_passage_5GHz}} - P_{\text{single_passage_750GHz}})$$

$$P_{\text{to_hom_absorber}} = 2.806$$

$$P_{\text{hom_nc_walls}} = 0.935$$

e) Thermal Isolation of HOM Absorber

(no design so far: numbers are just an example)

$$P_{2\text{K_hom_abs}} := (0.150 + 0 \cdot P_{\text{to_hom_absorber}}) \cdot i_{\text{hom_abs}}$$

$$P_{4\text{K_hom_abs}} := (1.5 + 0 \cdot P_{\text{to_hom_absorber}}) \cdot i_{\text{hom_abs}}$$

$$P_{70\text{K_hom_abs}} := (0 + 0 \cdot P_{\text{to_hom_absorber}}) \cdot i_{\text{hom_abs}}$$

6.4. Single Passage HOM-Losses other Components

$$P_{2\text{K_single_other}} := 0$$

$$P_{4\text{K_single_other}} := 0$$

$$P_{70\text{K_single_other}} := 0$$

only losses below 750 GHz, including 10% safety margin (for resonant losses etc.)
 new cryoloss calculation:
 abs 1, high-rrr-copper: $\eta=83.4\%$
 abs 2, high-rrr-copper: $\eta=81.7\%$
 complete frequency range, but 4.6% losses to 2K above 700 GHz
 abs 1, high-rrr-copper: $\eta=83.4\%$
 abs 2, high-rrr-copper: $\eta=81.7\%$

therefore efficiency to ~750 GHz:
 abs 1, ... : $83.4\% / (1 - 0.046) \approx 87\%$
 abs 2, ... : $81.7\% / (1 - 0.046) \approx 85\%$

for high-rrr-copper there is still the 10% safety margin

abs 1 (eps=15, tan $\delta=0.2$)
 abs 2 (eps=40, tan $\delta=0.7$)



estimated 2004, 3250 bunches, 10Hz

7. Summary

7.1. Losses at 2K

$$\begin{aligned} P_{Q0_module} &= 6.004 & P_{2K} &:= P_{Q0_module} \\ P_{all_couplers_2k} &= 0.38 & P_{2K} &:= P_{2K} + P_{all_couplers_2k} \\ P_{2K_res_hom} &= 0 & P_{2K} &:= P_{2K} + P_{2K_res_hom} \\ P_{2K_res_other} &= 0 & P_{2K} &:= P_{2K} + P_{2K_res_other} \\ P_{single_passage_750GHz} &= 0.214 & P_{2K} &:= P_{2K} + P_{single_passage_750GHz} \\ (1) P_{hom_nc_walls} &= 0.935 & P_{2K} &:= P_{2K} + P_{hom_nc_walls} \\ (2) P_{2K_hom_abs} &= 0.15 & P_{2K} &:= P_{2K} + P_{2K_hom_abs} \\ P_{2K} &= 7.683 \end{aligned}$$

7.2. Losses at 4K

$$\begin{aligned} P_{all_couplers_4k} &= 3.361 & P_{4K} &:= P_{all_couplers_4k} \\ P_{4K_res_hom} &= 0 & P_{4K} &:= P_{4K} + P_{4K_res_hom} \\ P_{4K_res_other} &= 0 & P_{4K} &:= P_{4K} + P_{4K_res_other} \\ P_{4K_hom_abs} &= 1.5 & P_{4K} &:= P_{4K} + P_{4K_hom_abs} \\ P_{4K} &= 4.861 \end{aligned}$$

7.3. Losses at 70K

$$\begin{aligned} P_{all_couplers_70k} &= 32.722 & P_{70K} &:= P_{all_couplers_70k} \\ P_{70K_res_hom} &= 0 & P_{70K} &:= P_{70K} + P_{70K_res_hom} \\ P_{70K_res_other} &= 0 & P_{70K} &:= P_{70K} + P_{70K_res_other} \\ P_{70K_hom_abs} &= 0 & P_{70K} &:= P_{70K} + P_{70K_hom_abs} \\ P_{70K} &= 32.722 \end{aligned}$$

(1) geschätzter Wirkungsgrad 75%

(2) statische Verluste, thermische Isolation des HOM absorber
2008: 135mW für Bellows +
4x25mW für Stützen
= (0.15+0.085)W

zusätzliche 2K Verluste:
re-entrant cavity BPM: 0.1W @ 10Hz
0.3W @ 10Hz
pro Module mit diesem Monitor Typ



