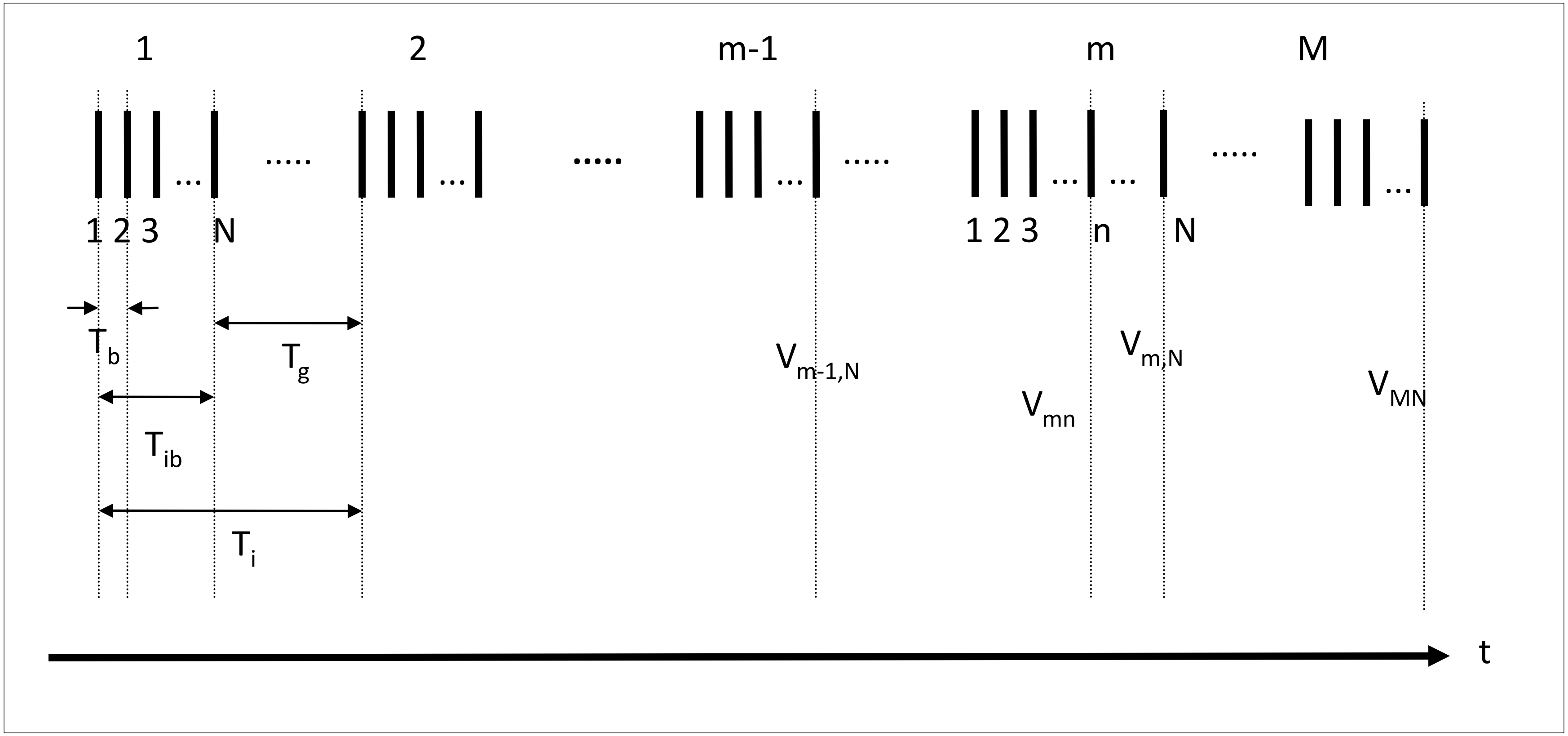
Longitudinal HOM power *estimations* for pulsed beams.rev

W. Weingarten

On longitudinal HOM excitation for pulsed beams (as in high intensity proton drivers) 1/4

CW beam: $$V = V_q \sum_{n'=0}^{\infty} e^{-n' p T_b} = \frac{V_q}{1 - e^{-pT_b}}$$



On longitudinal HOM excitation for pulsed beams (as in high intensity proton drivers) 2/4

$$m(t) = \frac{t}{T_i} + 1\,(\text{truncated})$$

$$t^* = t - [m(t) - 1] \cdot T_i$$

$$p = 2 \cdot \pi \cdot f \cdot i + \frac{1}{T_d}$$

$$n(t) = \frac{t}{T_b} + 1 \;\; (\text{truncated}) \text{ if } t^* \le (N\text{-}1) \cdot T_b \text{ or } = N \text{ otherwise}$$

$$T_d = \frac{Q_L}{\pi \cdot f}$$

$$T_g = T_i - T_{ib} = T_i - (N - 1) \cdot T_b$$

$$Q_L = \frac{1}{\frac{1}{Q_0} + \frac{1}{Q_{ex}}}$$

$$V_q = \pi \cdot f \cdot \frac{R}{Q} \cdot q$$

On longitudinal HOM excitation for pulsed beams (as in high intensity proton drivers) 3/4

$$V_{mn} = V_{m-1,N} \cdot e^{-pT_g} \cdot e^{-(n-1)pT_b} + V_q \cdot e^{-(n-1)pT_b} + V_q \cdot e^{-(n-2)pT_b} + \ldots + V_q =$$

$$= V_{m-1,N} \cdot e^{-pT_i} \cdot e^{+(N-n)pT_b} + V_q \cdot e^{-(n-1)pT_b} + V_q \cdot e^{-(n-2)pT_b} + \ldots + V_q \Rightarrow$$

$$V_{mn} = V_q \cdot \left[\frac{1-e^{-(m-1)pT_i}}{1-e^{-pT_i}} \cdot \frac{1-e^{-NpT_b}}{1-e^{-pT_b}} \cdot e^{-p[T_i-(N-n)T_b]} + \frac{1-e^{-npT_b}}{1-e^{-pT_b}} \right]$$

$$V_{mn}(t) = V_{mn} \cdot e^{-p(t-t_{mn})}; \quad t_{mn} = [m(t)-1] \cdot T_i + [n(t)-1] \cdot T_b$$

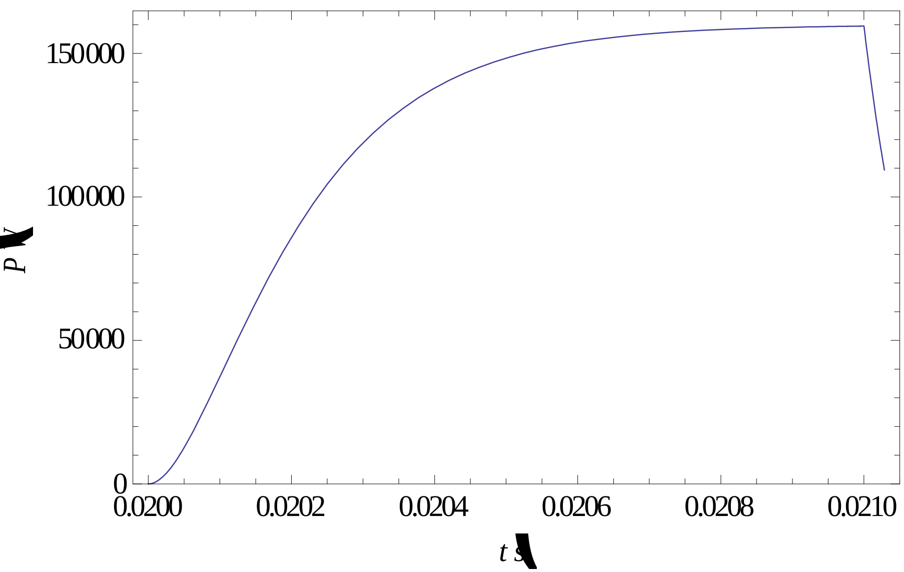
$$P_{HOM}(t) = \frac{V_{mn}(t) \cdot V_{mn}^*(t)}{\frac{R}{Q} \cdot Q_L} \qquad P_{rad}(t) = \frac{P_{HOM}(t)}{1+\frac{Q_{ext}}{Q_0}} \qquad P_c(t) = \frac{P_{HOM}(t)}{1+\frac{Q_0}{Q_{ext}}}$$

On longitudinal HOM excitation for pulsed beams (as in high intensity proton drivers) 4/4

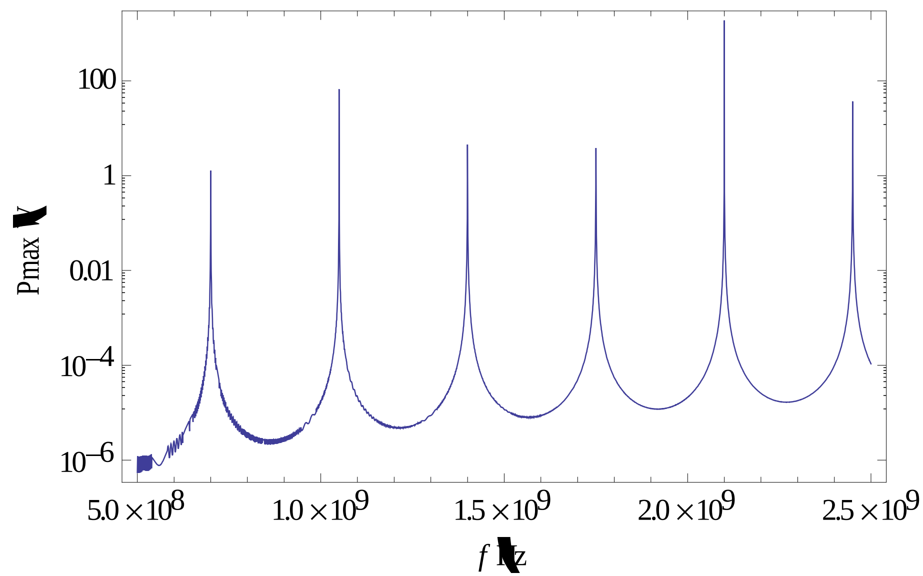
I = 40 mA; pulse length 1 ms, R/Q = 100 Ω ;

Rep. rate 50 Hz; f_{HOM} = 2.1 GHz; $Q_0 = 10^{10}$

Power built-up/decay during pulse of 1 ms



Maximum power vs. frequency showing principal Fourier components of beam

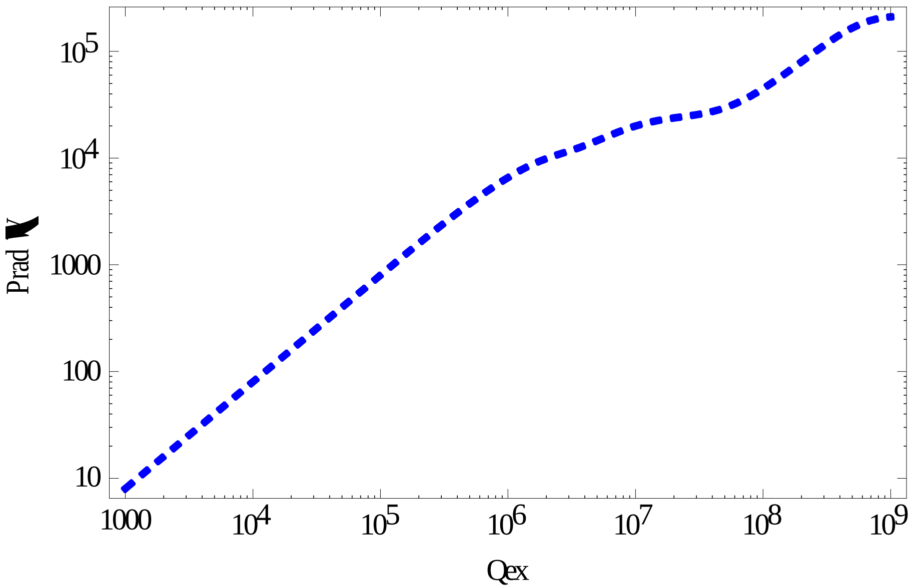


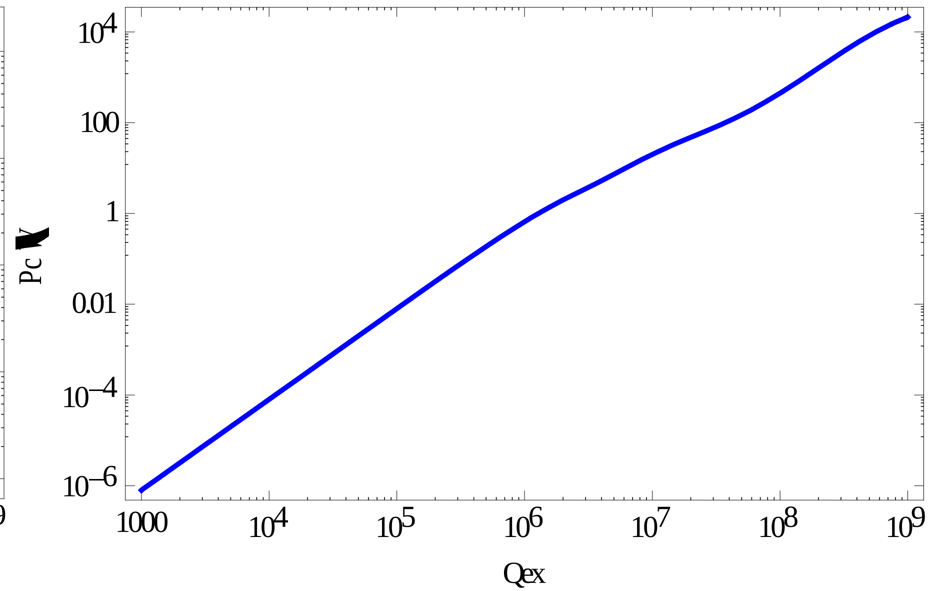
Power dumped by beam into a HOM 1/4

f (HOM) precisely on beam spectral line

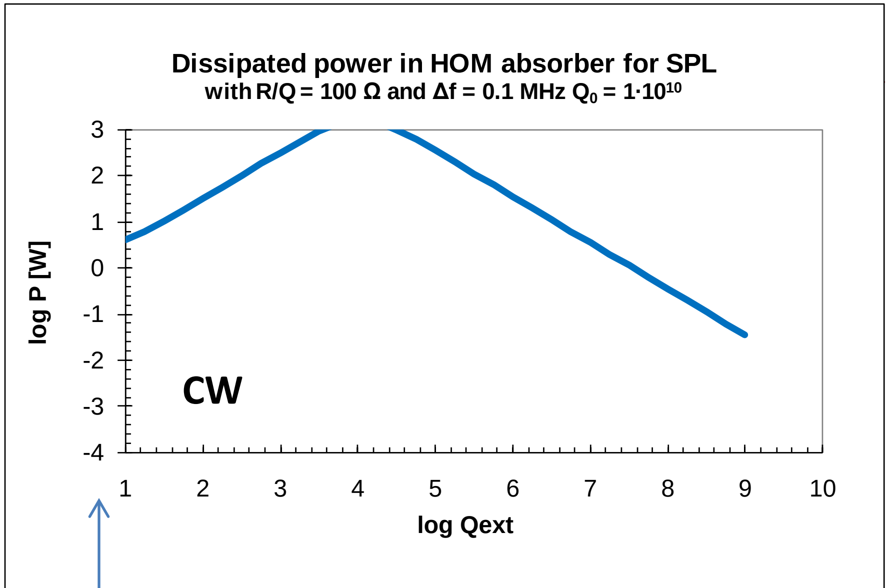
I = 40 mA; pulse length 1 ms, R/Q = 100 Ω ;

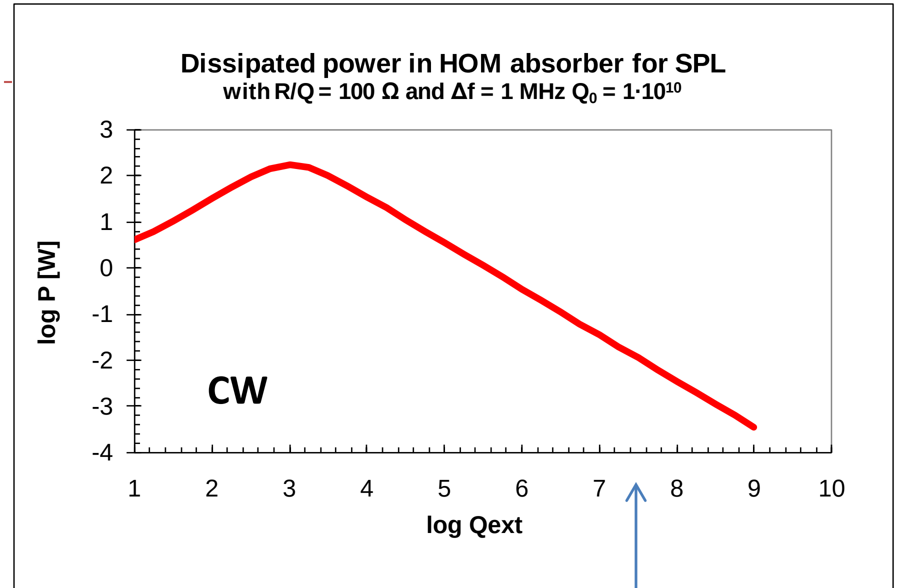
Rep. rate 50 Hz; f_{HOM} = 2.1 GHz; $Q_0 = 10^{10}$



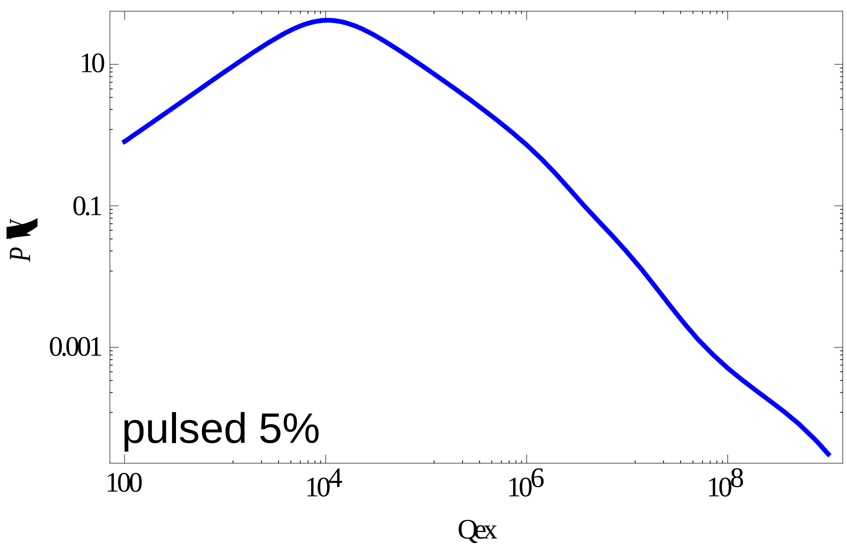


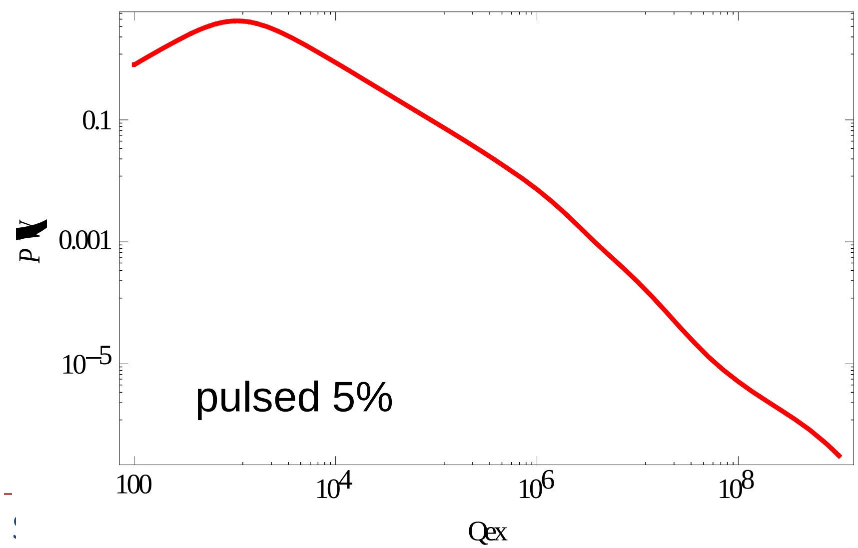
Power dumped by beam into a HOM 2/4 comparison between CW and pulsed beam





from presentation "Beam tube damping *estimations* for SPL cavity " of 8 March 2010

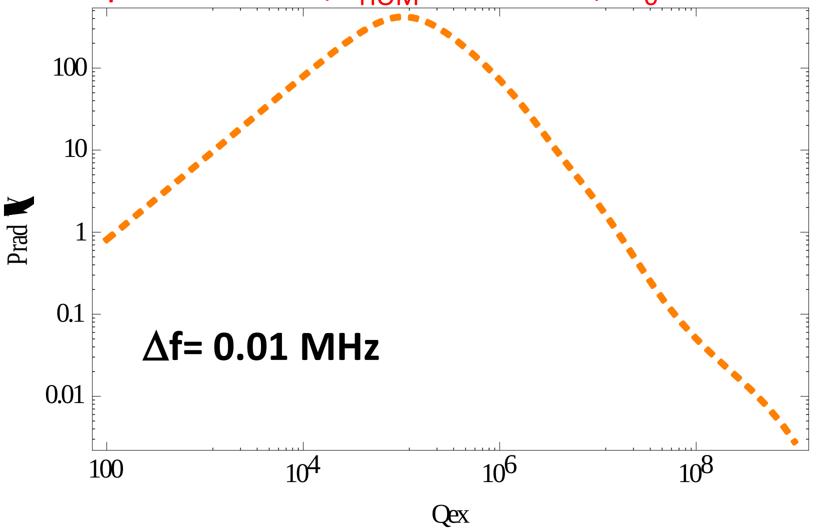


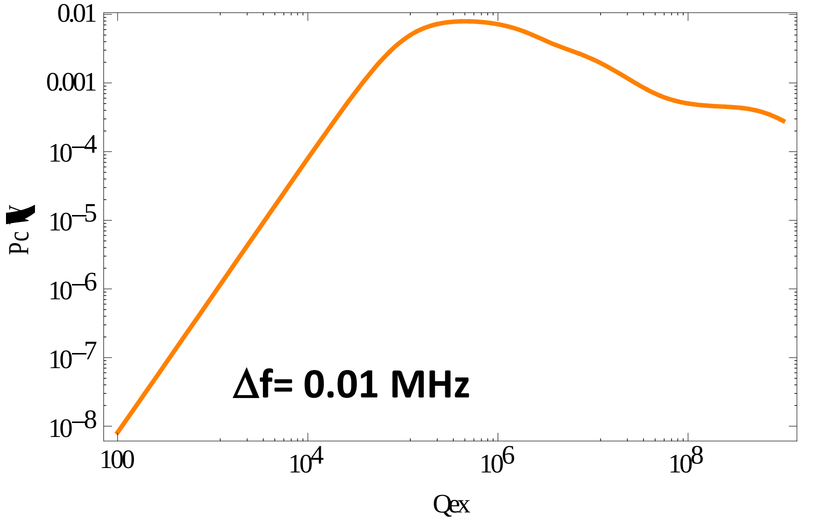


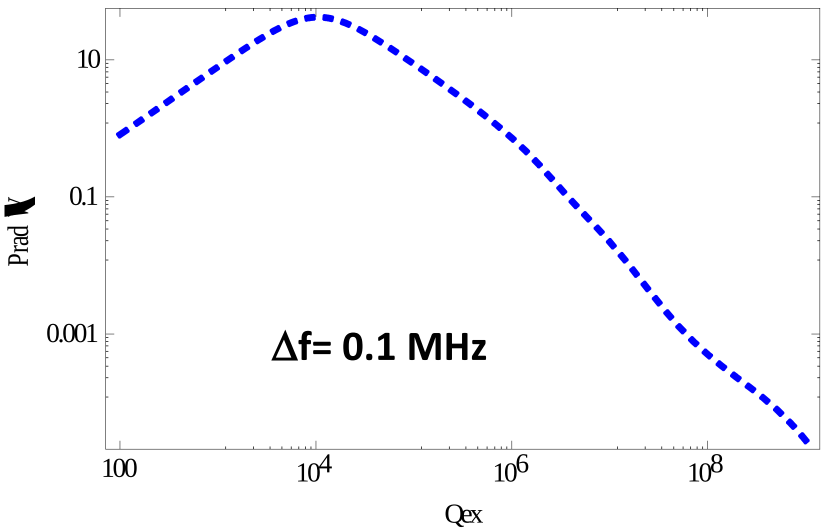
Power dumped by beam into a HOM 3/4
beam spectral line Δf away from resonant frequency of HOM

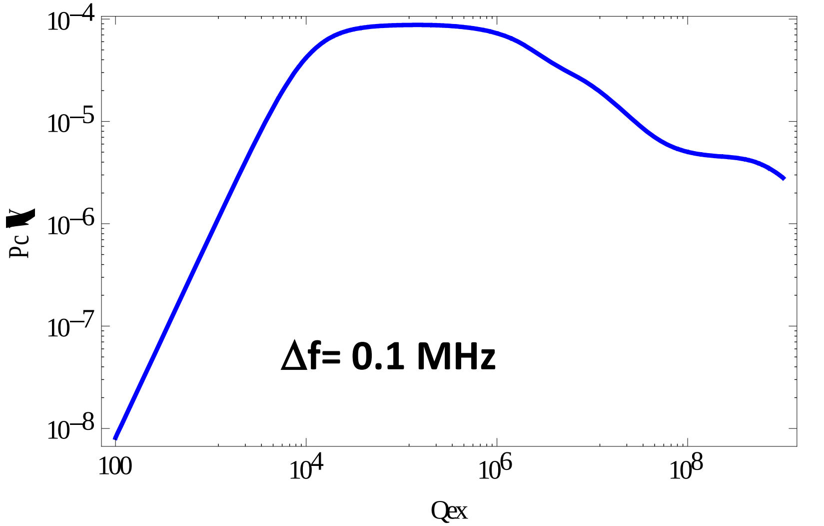
I = 40 mA; pulse length 1 ms, $R/Q = 100\ \Omega$;

Rep. rate 50 Hz; $f_{HOM} = 2.1$ GHz; $Q_0 = 10^{10}$

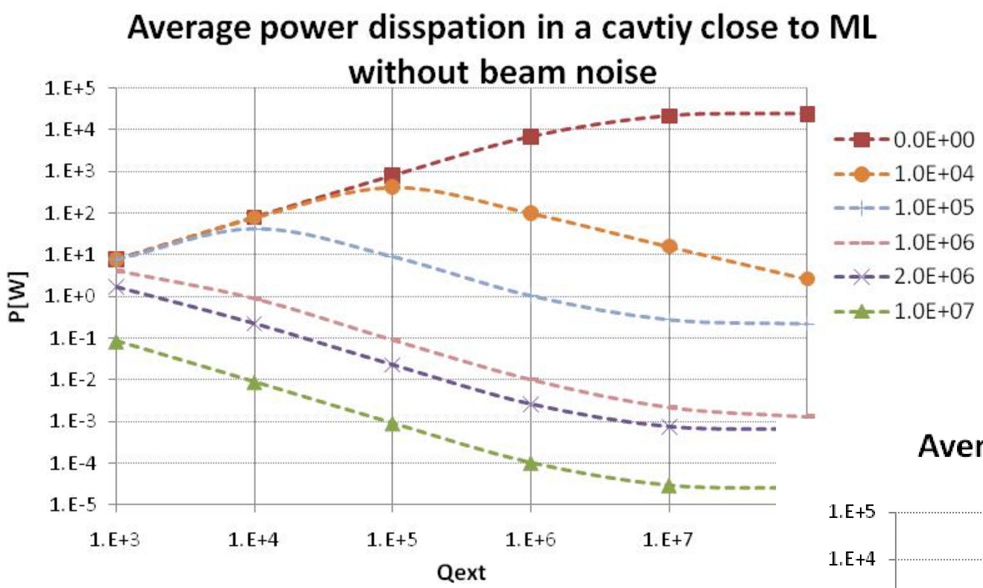


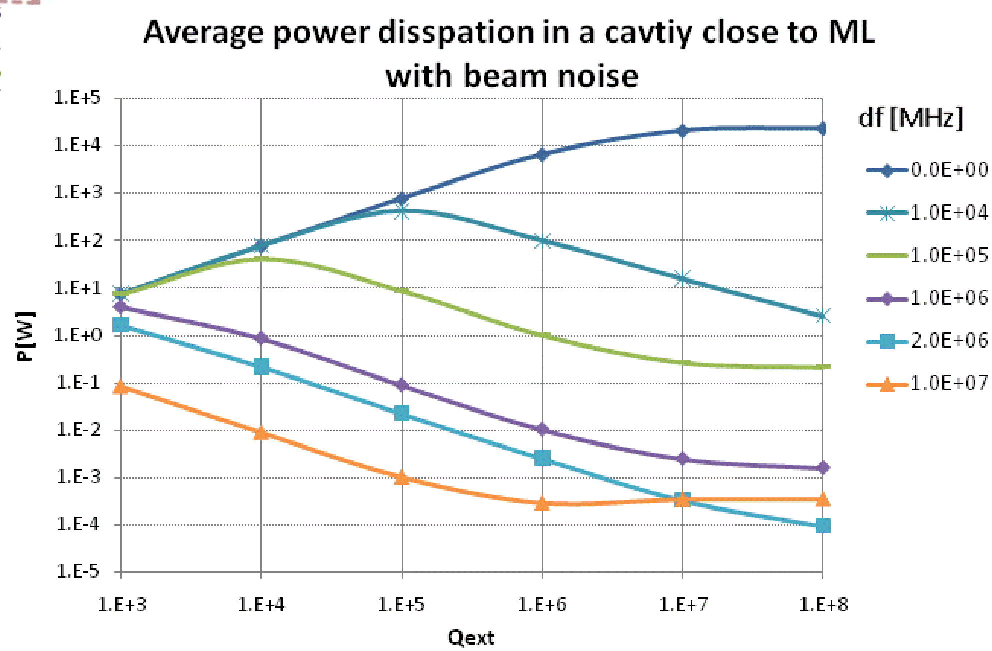






Power dumped by beam into a HOM 4/4
Courtesy M. Schuh





Preliminary conclusion concerning HOM power dumped into the pulsed cavity

I = 40 mA; pulse length 1 ms, R/Q = 100 Ω ;

Rep. rate 50 Hz; f_{HOM} = 2.1 GHz; $Q_0 = 10^{10}$

- The main beam Fourier components (n·352 MHz) contribute significantly to the HOM power, the 50 Hz Fourier component, however, only marginally; to reduce the HOM power below 100 W, the Q-value of the HOM must be $< 10^4$
- Avoiding the main beam Fourier components by the HOM frequencies within 10 kHz reduces the HOM power significantly, with a tendency to become even smaller for larger Q-values ($P < 1$ W @ $Q > 10^7$)

→ The HOM power could possibly be reduced by inelastic detuning or an appropriate design of the cavity (though without changing the fundamental mode frequency) with the aim to keep sufficiently off ALL HOM frequencies from the main Fourier components