

6.1 Defining IFO working point

The resonant condition of an optical cavity follows from the gain factor:

$$g_{rt} = r_i r_o \exp(i\omega 2L/c)$$

where r_i and r_o are the reflectances of the cavity input and output mirror, respectively.

When talking of the state of a cavity, sometimes some confusion arises from using the terms resonant or anti-resonant. Some people define a cavity as resonant, depending on its length, i.e. equal to an integer number of half wavelengths. Others, instead, define the resonant condition according to the phase gain of the light after a round trip. Here we choose the latter convention.

For us resonant means phase gain $\phi = \text{Arg}[g_{rt}] = 0$. Anti-Resonant means phase gain $\phi = \text{Arg}[g_{rt}] = \pi$.

6.1.1 Arm Cavities and Michelson

- When the light is resonant in the arms, since $r_o \approx +1$, these can be replaced by compound mirrors of reflectivity $\sim +1$:

$$r_{\text{arm}} = -r_i + \frac{t_i^2}{r_i} \frac{g_{rt}}{1 - g_{rt}} = -r_i + \frac{1 - r_i^2}{r_i} \frac{r_i r_o}{1 - r_i r_o} \approx -r_i + 1 + r_i = +1$$

- When not resonant, the arms show reflectivity equal to -1 .
- When resonant, the Michelson has the reflectivity of the arm cavities, i.e $+/-1$, depending if these are resonant or not.
- For a carrier resonant in the arms, the Michelson-arms compound mirror has reflectance $+1$. For frequencies non resonant in the arms, it has reflectance -1 .
- The Michelson compound mirror has reflectance and transmittance identical on both sides. When it is locked, that is the microscopic offset of its arms is zero, its scattering matrix looks like this:

$$S = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}.$$

That is not in contradiction with the requirement of energy conservation since the transmissivities have zero amplitude, but non-zero arguments.

6.1.2 Tuning the PRC

The carrier, and both sidebands have to be resonant in the coupled cavity PRC-Arms. For a carrier that is resonating in the arms, that means that it has to be anti-resonant in the PRC alone.

$$g_{rt} = r_{prm} r_{\text{arm}}(\omega_0 + \Omega) \exp[i(\omega_0 + \Omega) 2L_{prc}/c]$$

- **carrier:** $r_{\text{arm}}(\omega_0) = +1$; $\exp(i\omega_0 2L_{\text{prc}}/c) = 1$
- **sidebands:** $r_{\text{arm}}(\omega_0 + \Omega) = -1$; $\exp[i(\omega_0 + \Omega) 2L_{\text{prc}}/c] = -1$

For these conditions to be satisfied, the cavity length has to be

$$L_{\text{prc}} = \left(n + \frac{1}{2}\right) \frac{c}{2f_1}.$$

For the 40m Upgrade $n = 0$.

6.1.3 Tuning the SRC

In a RSE signal extraction scheme with dual recycling and DC readout, the carrier has to be anti-resonant, the f_2 sideband has to be resonant and f_1 has to be non-resonant.

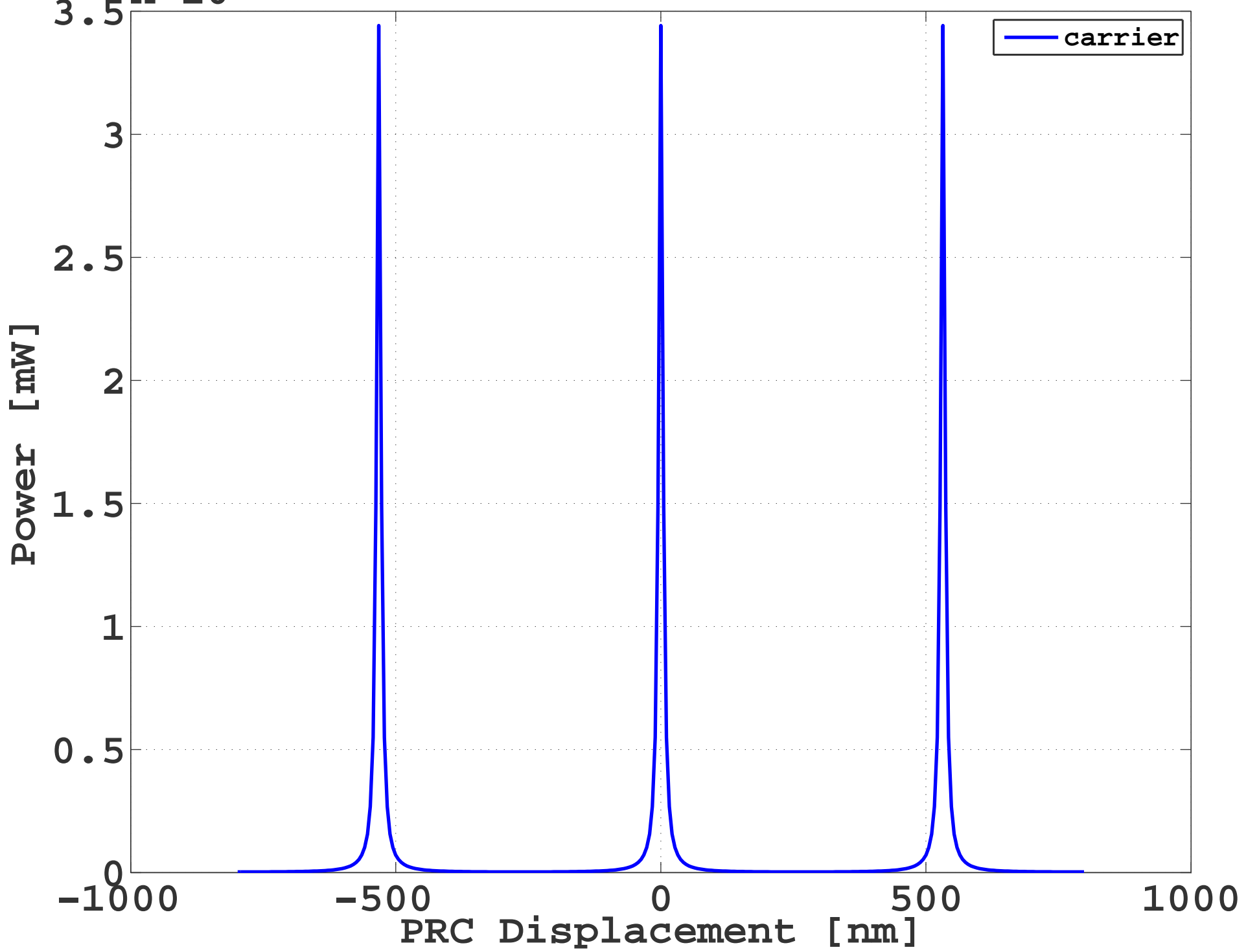
- **carrier:** $g_{\text{rt}}(\omega_0) = +r_{\text{prm}} \exp(i\omega_0 2L_{\text{src}}/c) = -1$
- **sidebands:** $g_{\text{rt}}(\omega_0 + \Omega_2) = -r_{\text{srm}} \exp[i(\omega_0 + \Omega_2) 2L_{\text{src}}/c] = -1$

For these conditions to be satisfied, the cavity length has to be

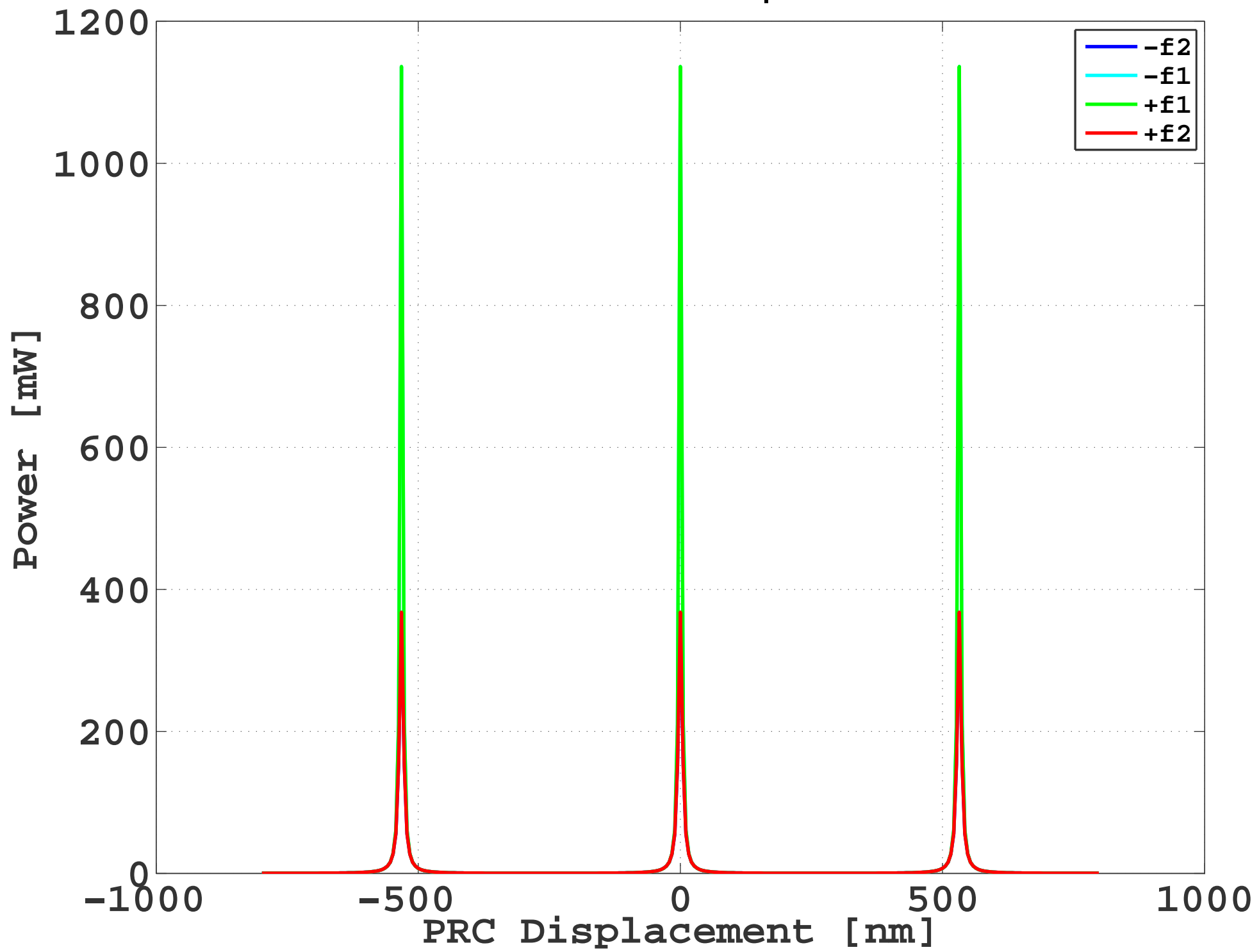
$$L_{\text{src}} = n \frac{c}{2f_2}.$$

For the 40m Upgrade $n = 2$.

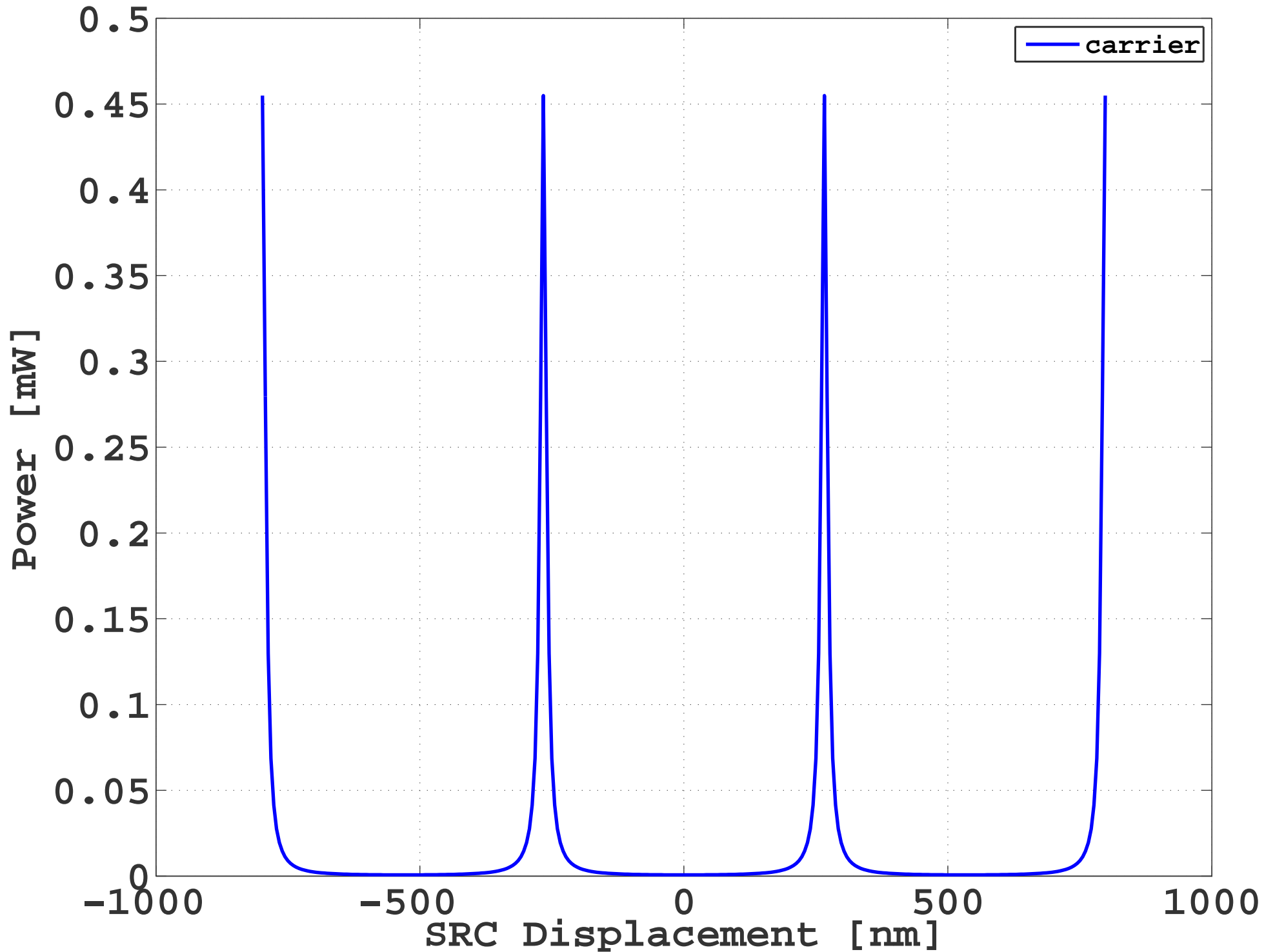
PRCI₄ Intra-Cavity Power | SRMoff = 180 deg



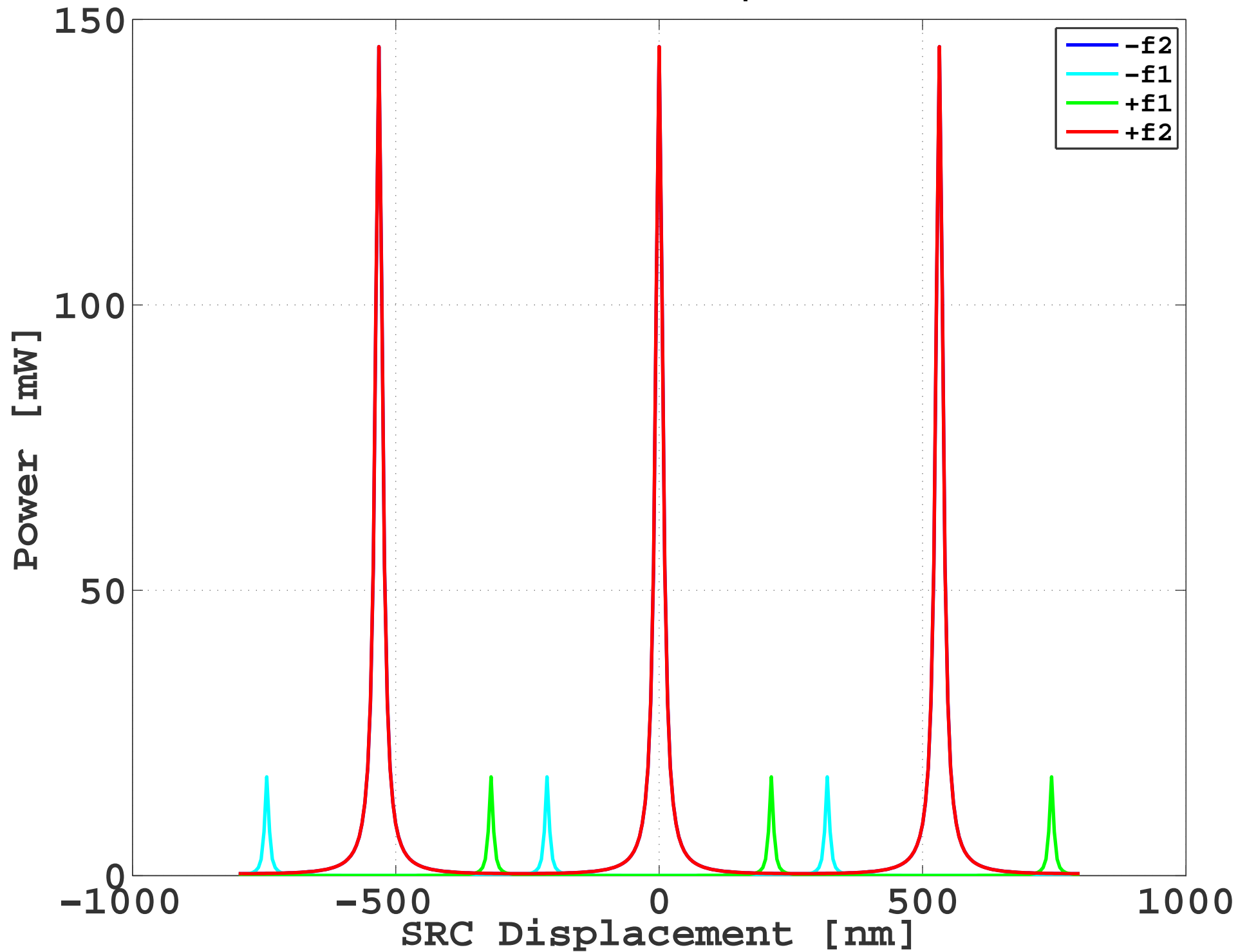
PRCL Intra-Cavity Power | SRMoff = 180 deg



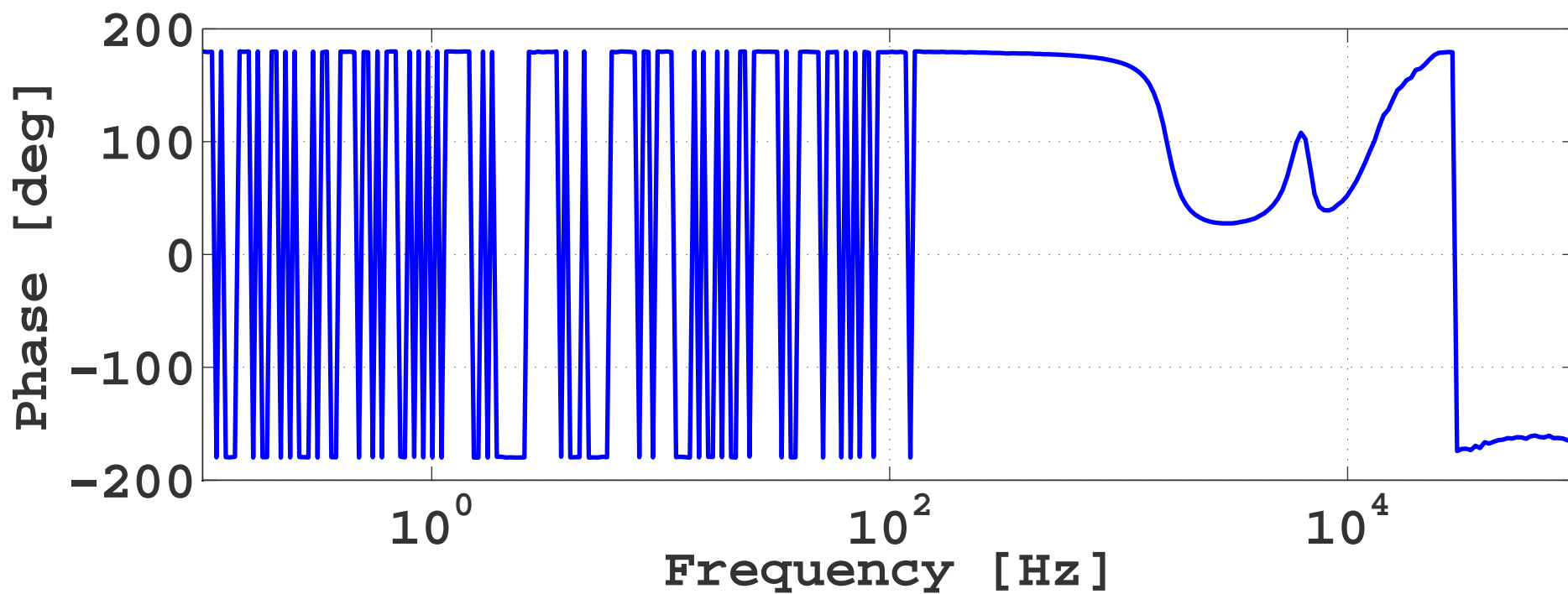
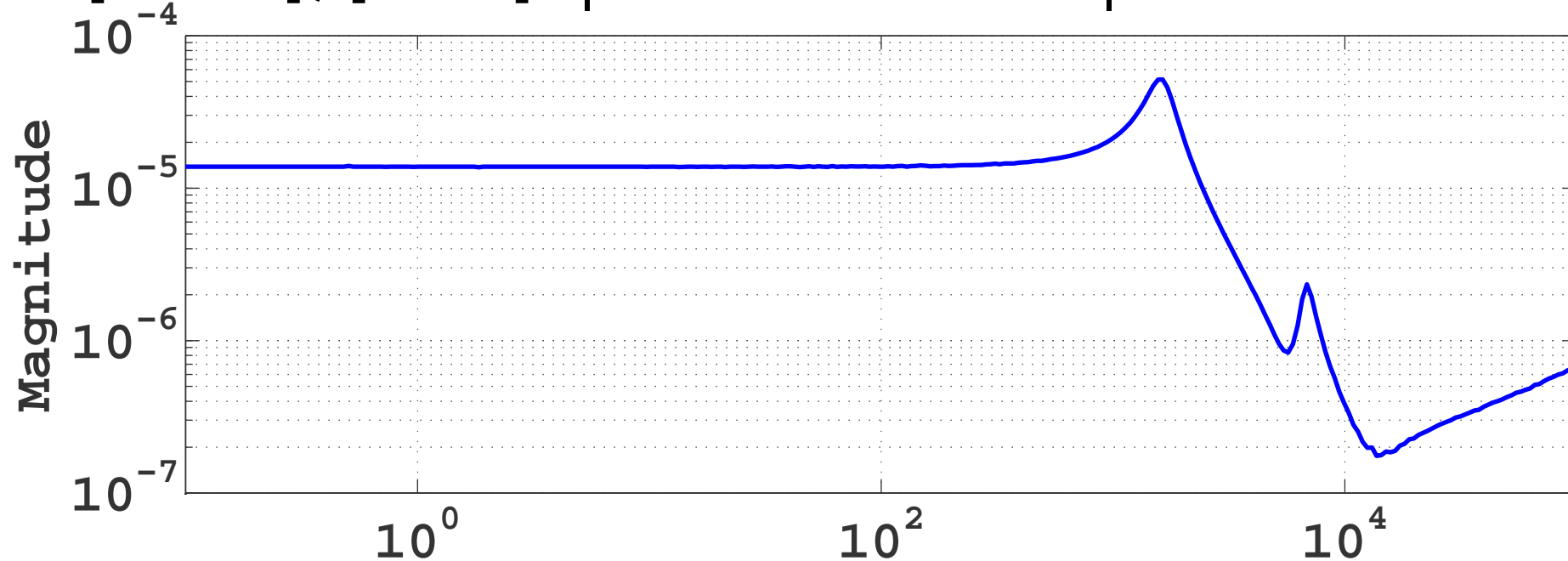
SRCL Intra-Cavity Power | SRMoff = 180 deg



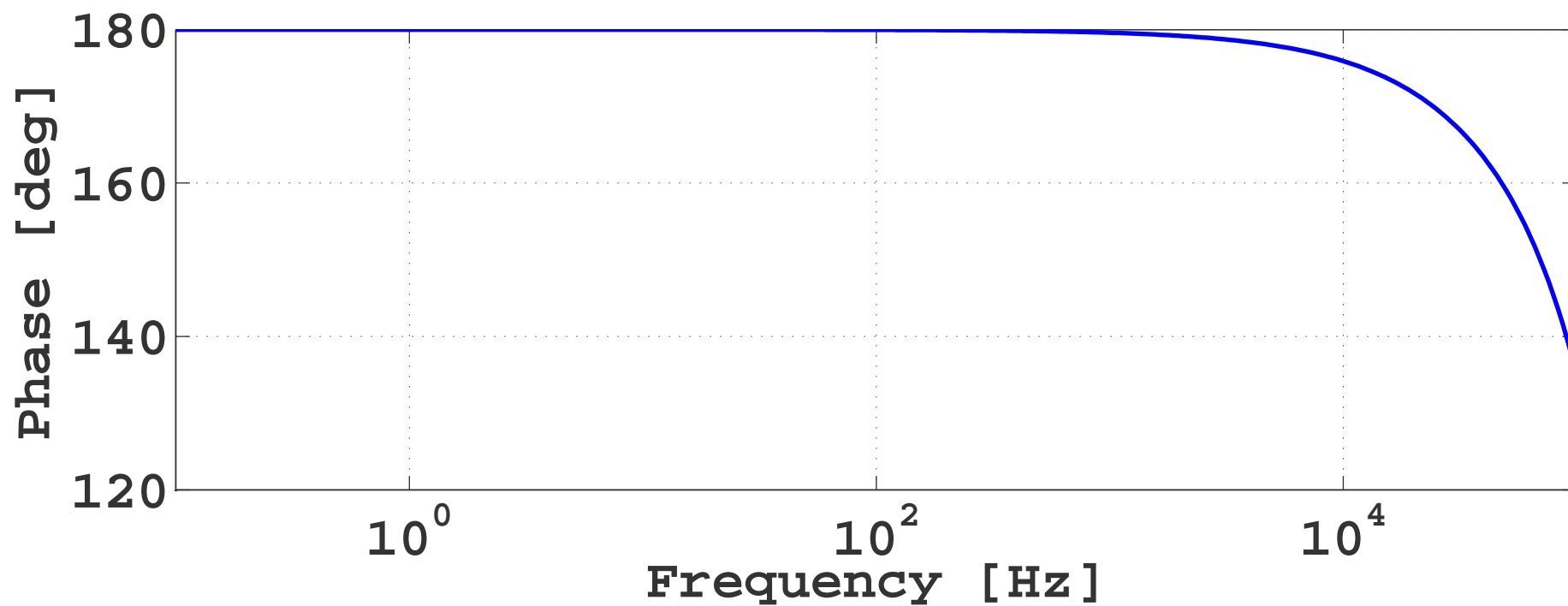
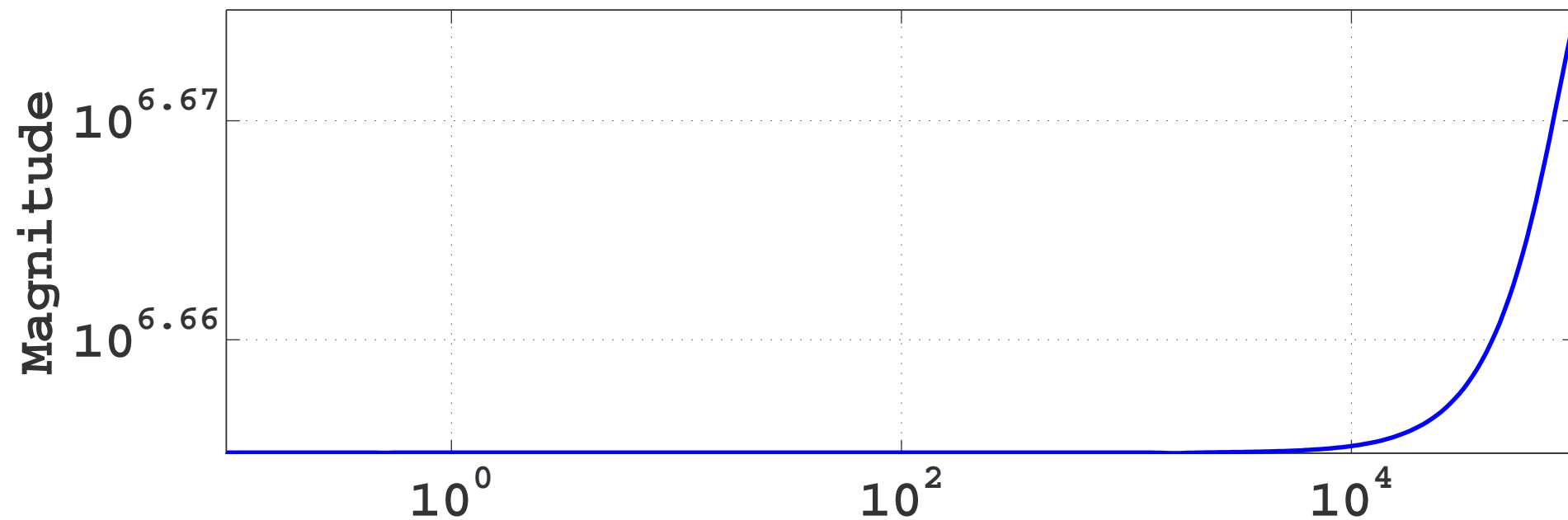
SRCL Intra-Cavity Power | SRMoff = 180 deg



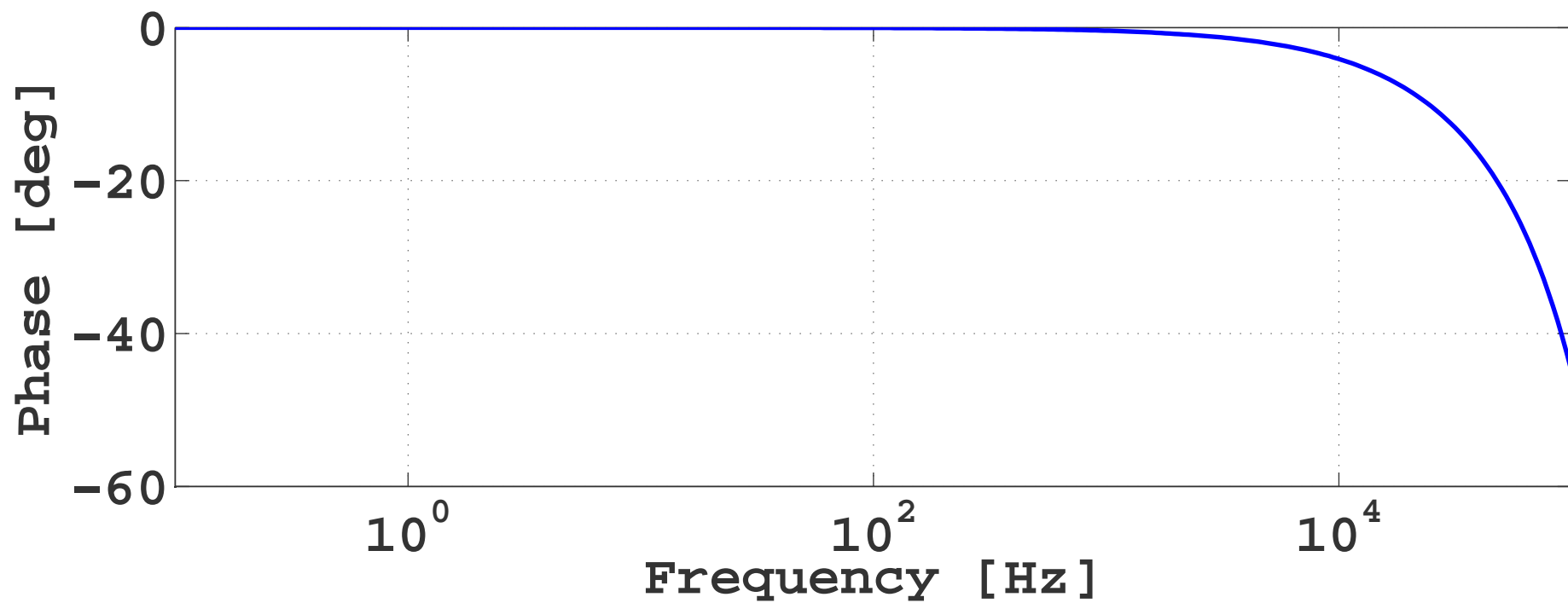
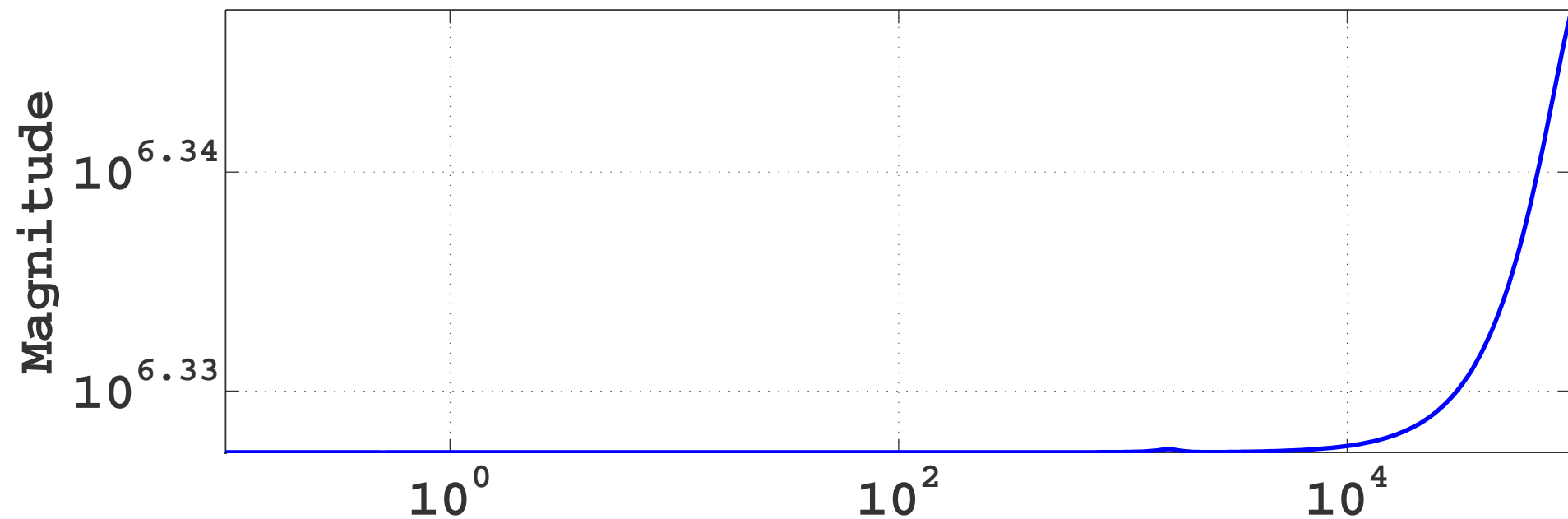
[AS DC]/[DARM] | DARMoff = 0 m | SRMoff = 180 deg



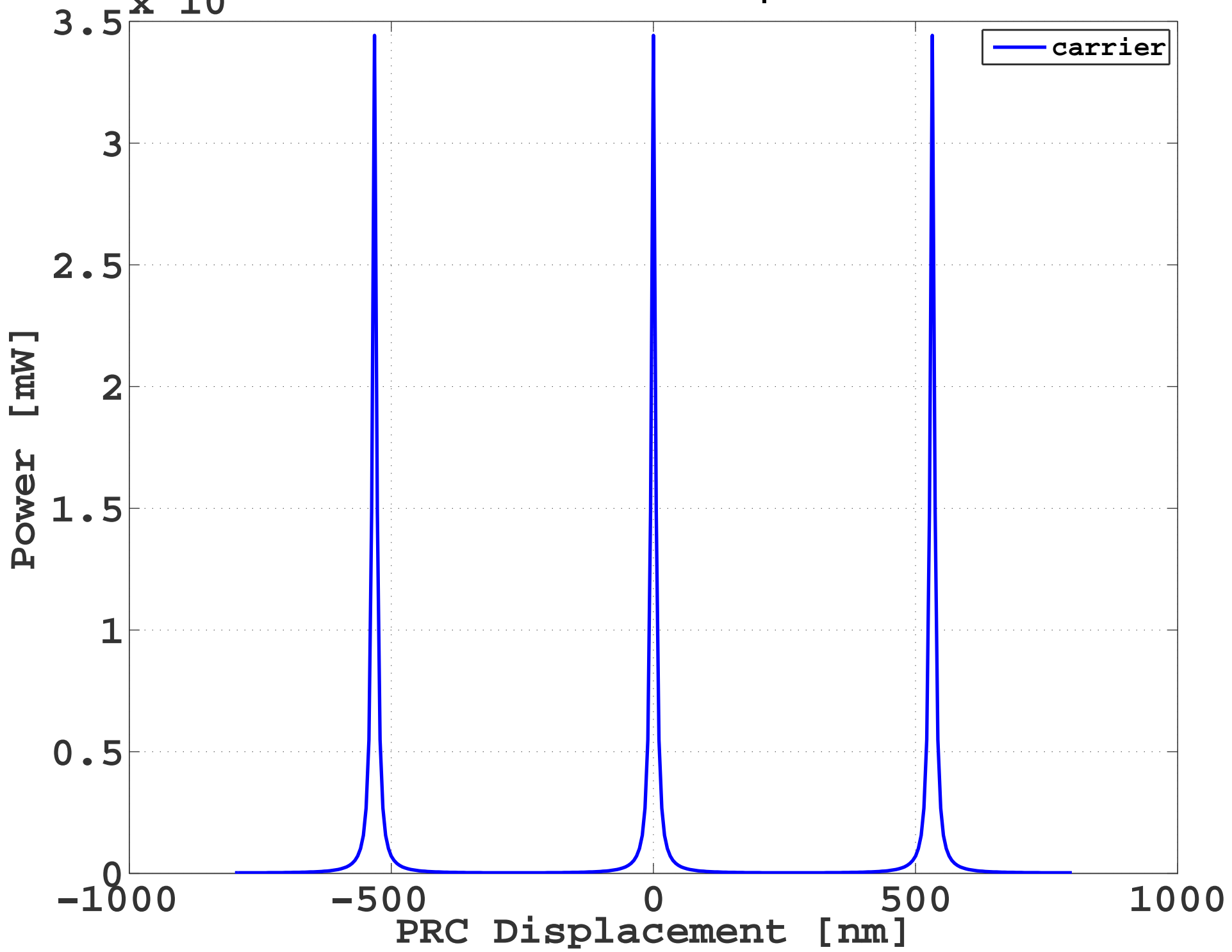
[AS I2]/[DARM] | DARMoff = 0 m | SRMoff = 180 deg



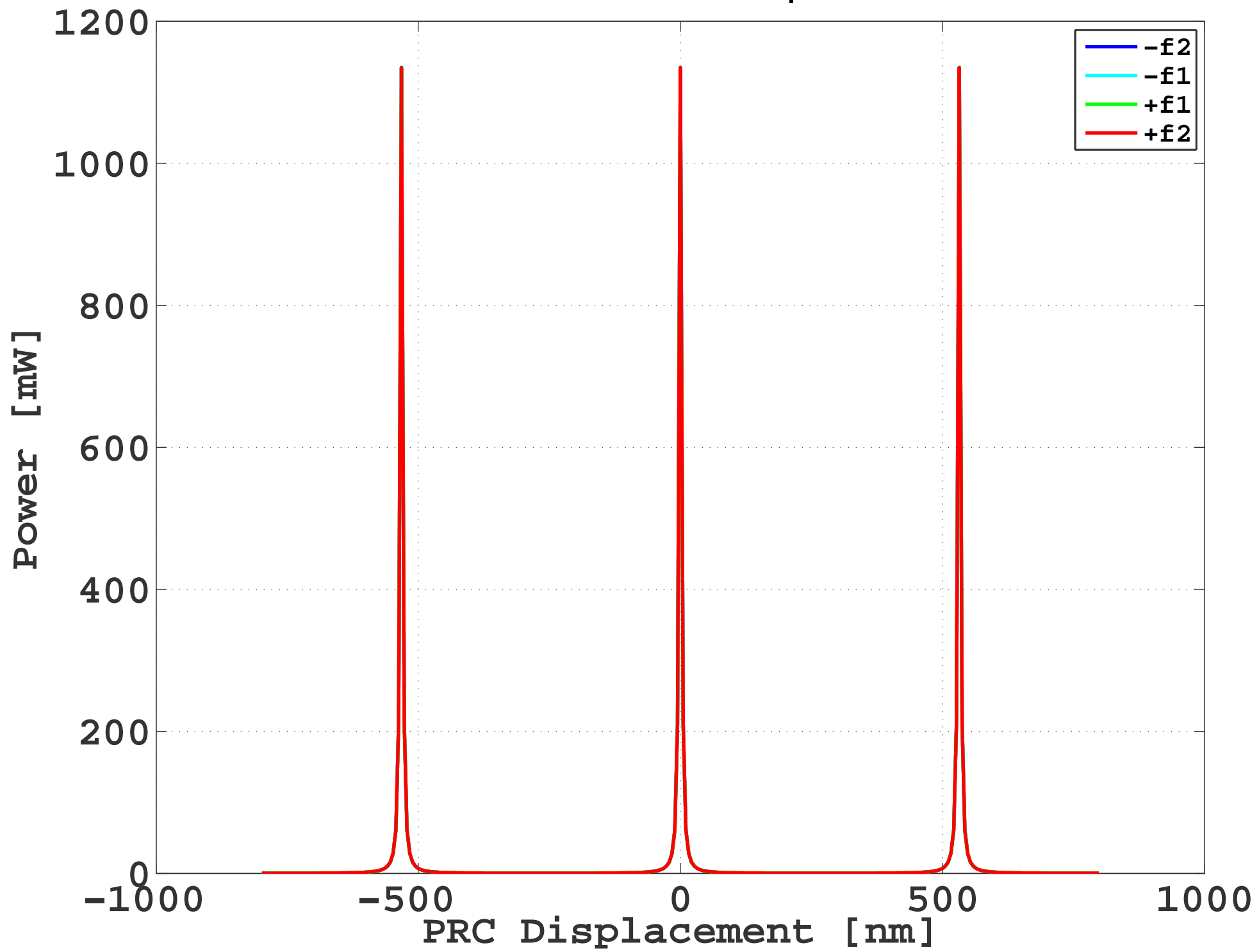
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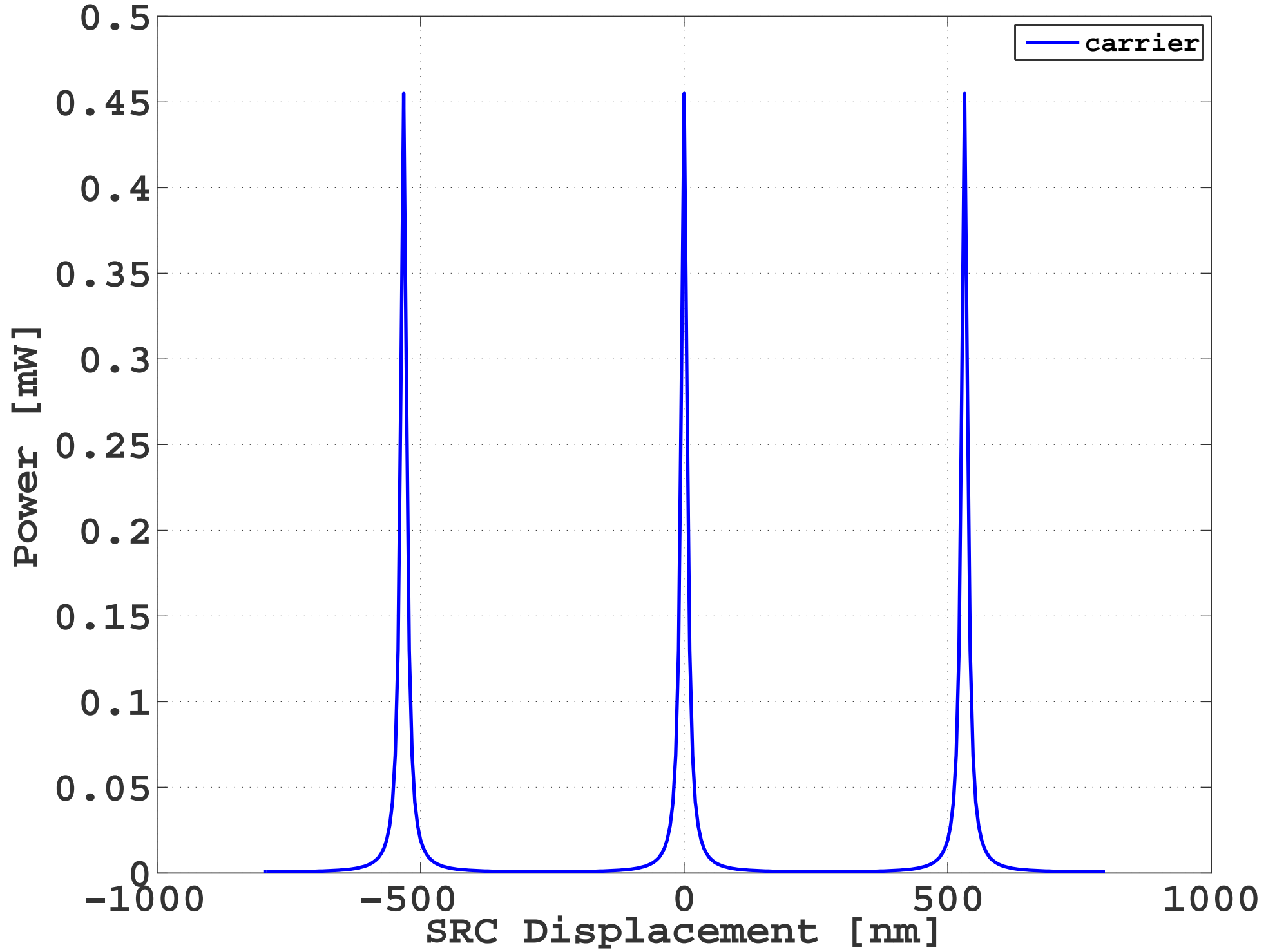
PRCL Intra-Cavity Power | SRMoff = 0 deg



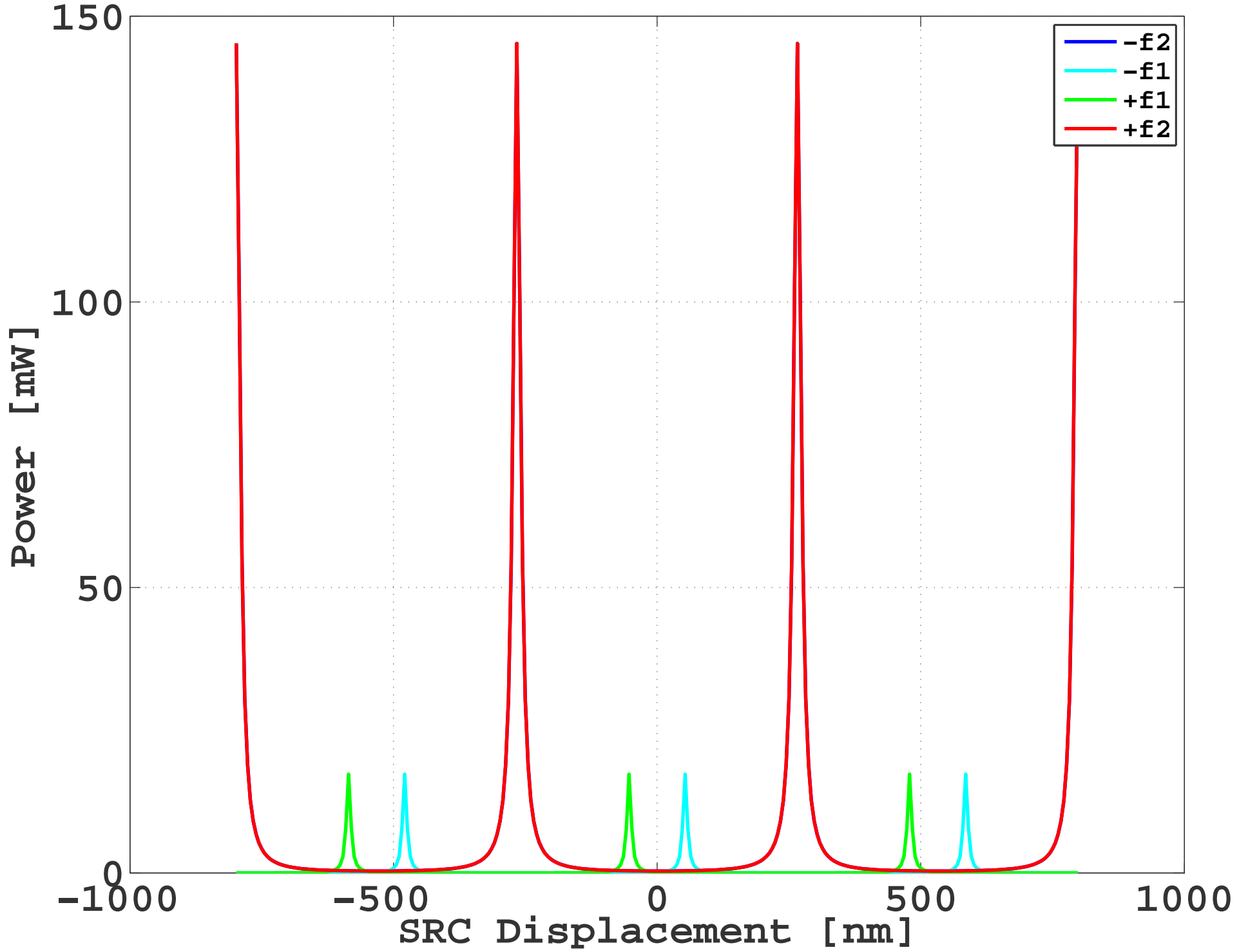
PRCL Intra-Cavity Power | SRMoff = 0 deg



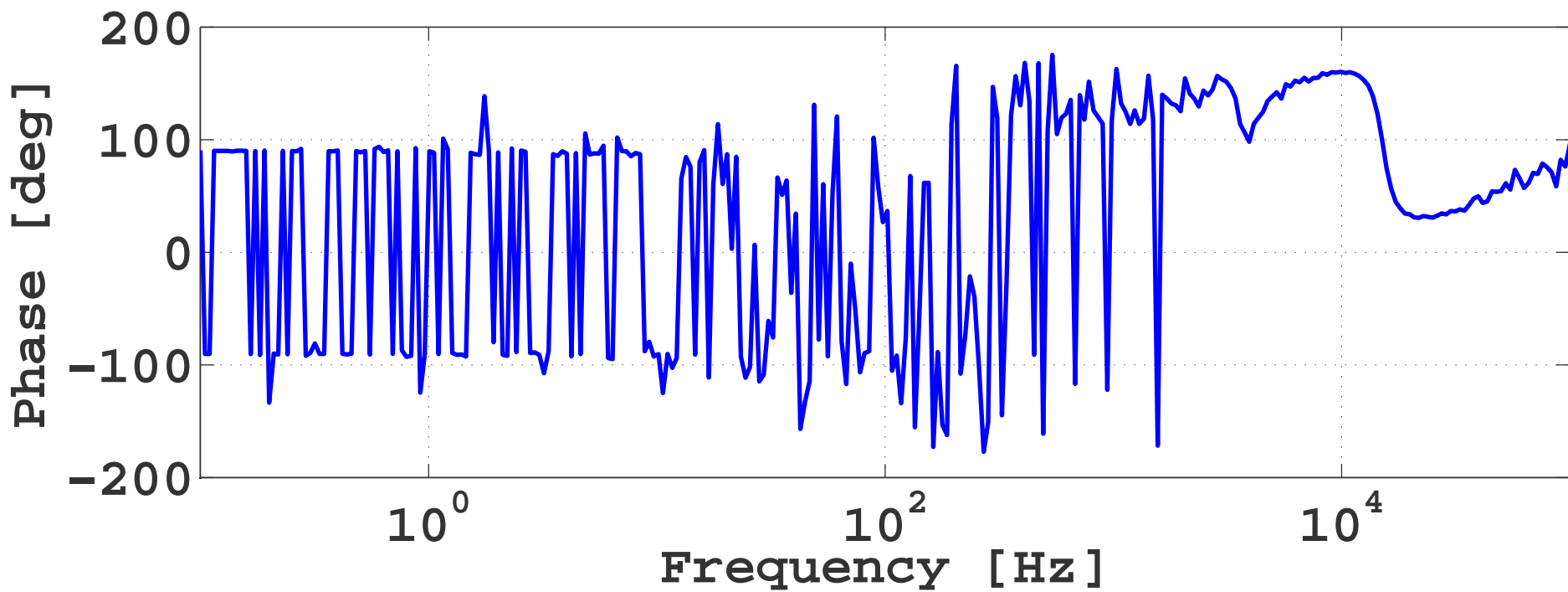
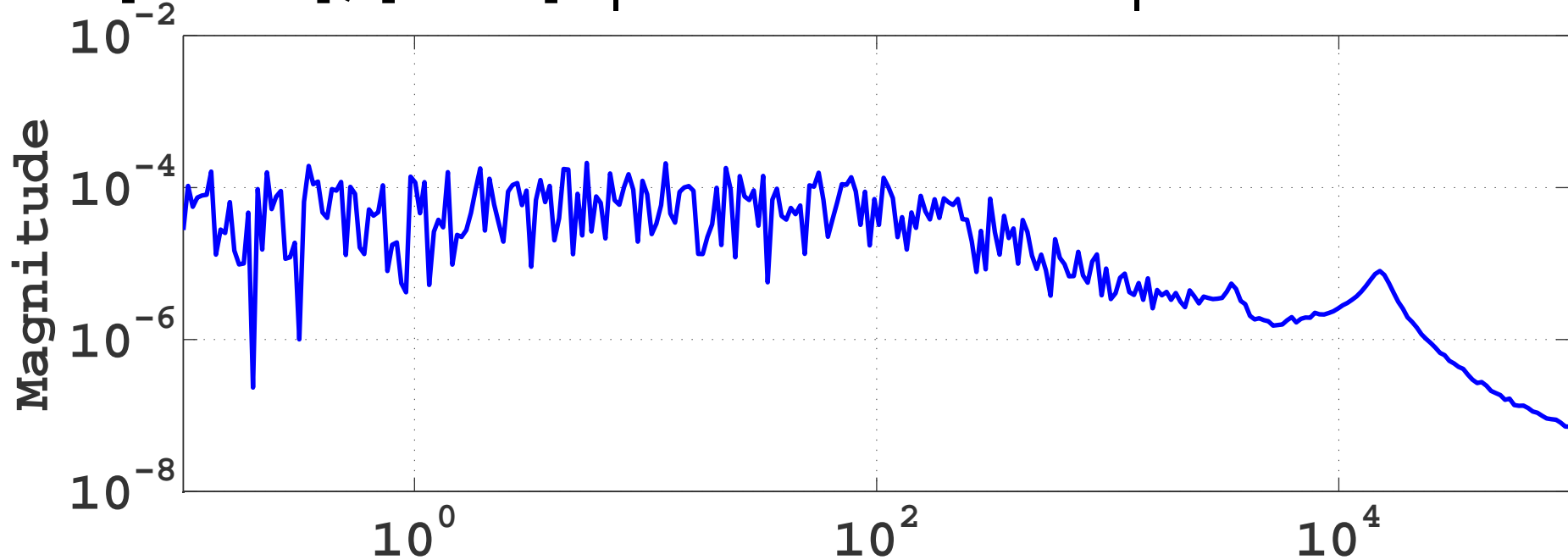
SRCL Intra-Cavity Power | SRMoff = 0 deg



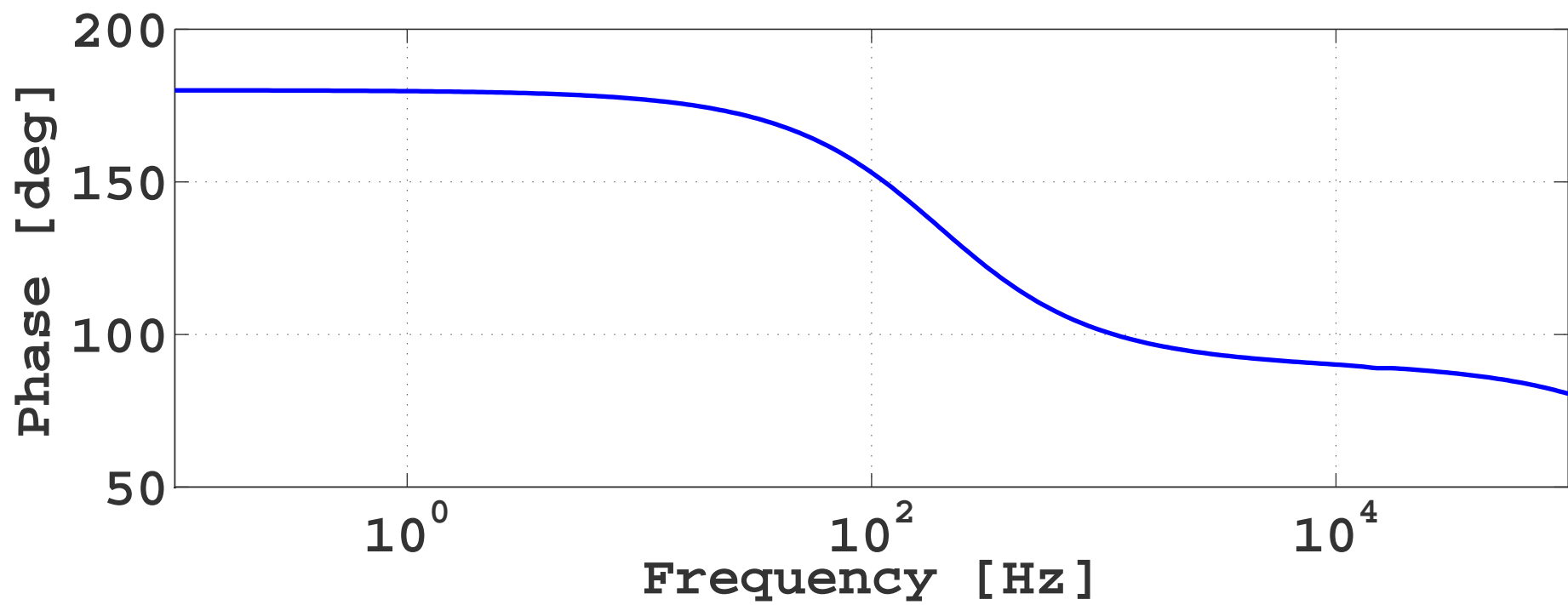
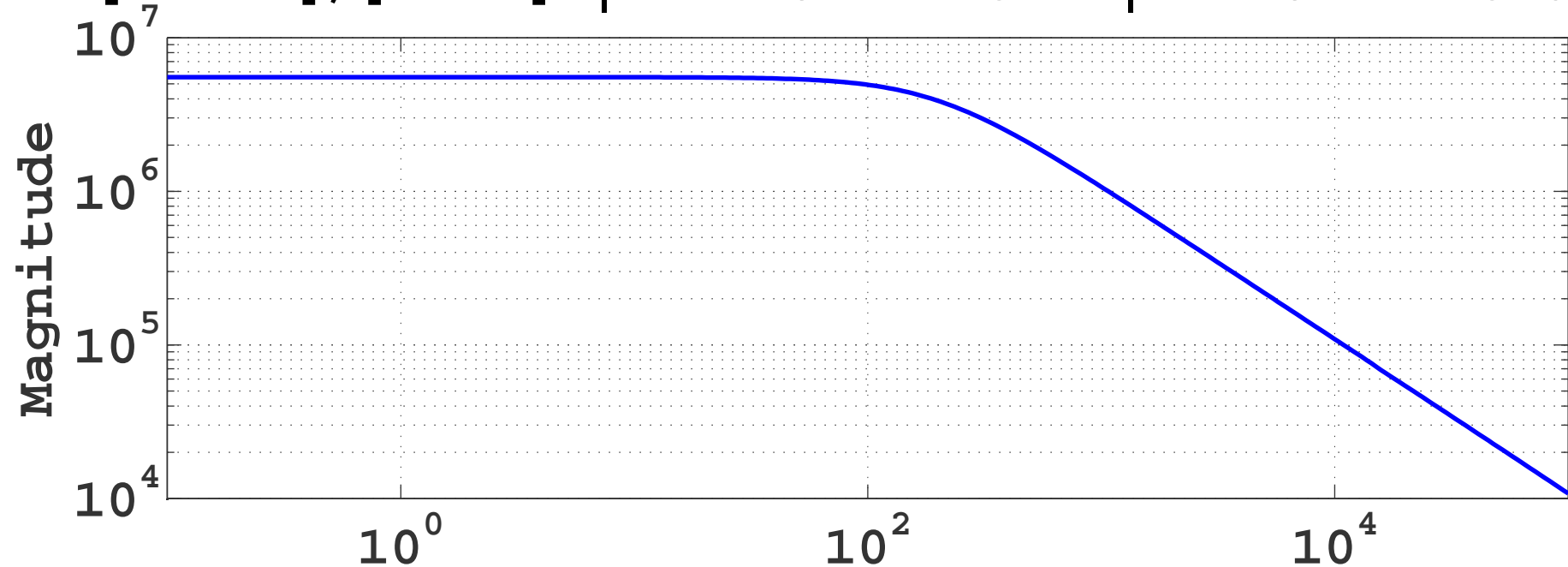
SRCL Intra-Cavity Power | SRMoff = 0 deg



[AS DC]/[DARM] | DARMoff = 0 m | SRMoff = 0 deg



[AS I2]/[DARM] | DARMoff = 0 m | SRMoff = 0 deg



[AS Q2]/[DARM] | DARMoff = 0 m | SRMoff = 0 deg

