A range of assumptions are possible here, and the operating frequency of your filter and the insertion loss will depend on your assumptions, but the overall form of the solution should be similar to this.

\[ K_{beam} = \frac{12EI}{L^2} = \frac{EWH^3}{L^3} \]

\[ E = 160 \text{ GPa} \quad W = 5 \text{ mm} \quad H = 2 \text{ mm} \]
\[ L = 5 \text{ mm} \quad K_{beam} = 5.12 \times 10^4 \text{ N/m} \]

The mass density \( \rho = 2331 \text{ kg/m}^3 \)
\[ m = 2331 (LWH) = 2331 (20 \times 40 \times 5) \times 10^{-18} \]
\[ m = 9.324 \times 10^{-12} \text{ kg} \]
\[ \omega_n = \sqrt{\frac{k}{m}} = \sqrt{\frac{4K_{beam}}{m}} = 1.48 \times 10^8 \text{ rad/s} \]

(This is without the spring part of the squeeze-film or air bearings effect.)

Now look at the squeeze-film effects:

Squeeze number \( \sigma = \frac{12n}{\rho_{film}} \left( \frac{W}{h_0} \right)^2 \)
\[ n = 1.86 \times 10^{-5} \text{ N/m}^2 \]
\[ \rho_{film} = 1.013 \times 10^5 \text{ N/m}^2 \]
\[ \sigma = 1.30 \times 10^4 \]

\[ k = \sqrt{\frac{E}{h_0}} = 80 \]
\[ h_0 = 25 \text{ nm} \quad \omega = 1.48 \times 10^8 \text{ rad/s} \]

The "spring" part of the squeeze force (the in-phase component) corresponds to \( \omega_n \). \( \alpha = \frac{E}{h_0} \) and \( E \) is the displacement, so the in-phase force \( \alpha \) is a spring constant from the air bearing.
\[ W_{1,\infty} = \alpha W L \text{Patm} \left( W_{1,0} \right) \]

\[ k_{\text{bearing}} = \frac{W_{1,0}}{E} = \frac{W L \text{Patm}}{h_0} \left[ 1 - \frac{\sinh k}{k} + \frac{\sinh k}{k} \frac{1}{(\cosh k + \cos k)} \right] = \frac{W L \text{Patm}}{h_0} \left( 1 - \frac{1}{k} \right) \]

\[ k_{\text{-bearing}} = 800 \text{ N/m} \]

Now, this must be added to the original spring constant of 4.512 x 10^4 to yield 2.06 x 10^5 ( \approx k_{\text{total}} \) )

the new \( W_n \) is then \( \sqrt{\frac{k_{\text{total}}}{m}} = 1.48 \times 10^8 \) (less than 1% change)

So no need to iterate with the new \( k_{\text{total}} \).

For the damping, \( W_{2,\infty} = \alpha W L \text{Patm} \frac{\sinh k - \sinh k}{k (\cosh k + \cos k)} = \frac{\alpha W L \text{Patm}}{k} \)

\[ W_{2,\infty} = \text{Cbearing} \times W_n \]

so \( \text{Cbearing} = \frac{W L \text{Patm}}{h_0 W_n k} = 6.78 \times 10^{-8} \text{ N.s/m} \)

\[ S = \frac{\text{Cbearing}}{2V_{\text{in, n}}} = 2.45 \times 10^{-5} \]

\( Q = \frac{1}{2S} = 2.04 \times 10^4 \)

**Finally, note that the small spacing corrections probably apply but will not be used here.**

Next find the operating point
\[ J_0 = 25 \text{ nN.m} = 2.5 \times 10^{-8} \text{ m} \]
\[ Q_0 = \frac{\frac{EA}{J_0}}{V_{in, 0}} = \frac{(8.85 \times 10^{-12})(5 \times 40 \times 10^{-12})}{2.5 \times 10^{-8}} = 2.12 \times 10^{-13} \]

\[ Z_{EB} = \frac{CEB}{J_0} = \frac{(8.85 \times 10^{-12})(5 \times 40 \times 10^{-12})}{2.5 \times 10^{-8}} = 7.08 \times 10^{-14} \]
\[ Z_{ms} = C_{ms} = \frac{1}{4 k_{beam} \left(1 - \frac{Q_o^2}{4 k_{beam} F_0}\right)} \quad \text{for one actuator or}\]
\[ C_{ms} = \frac{1}{4 k_{beam} \left(1 - \frac{2 Q_o^2}{4 k_{beam} F_0}\right)} = 4.93 \times 10^{-6} \quad \text{F} \]

(K_{effective} = 2.027 \times 10^5 \text{ instead of } 2.048 \times 10^5 \text{ because of spring softening } )

\[ \phi = \frac{Q_o}{F_0} = 8.50 \times 10^{-6} \]

\[ \frac{1}{\phi} = 1.18 \times 10^5 \]

Simulation results:

Peak frequency 23.4745 MHz
Peak current = 650 mA
Half power points at 450/\sqrt{2} = 460 mA at 22.4735 MHz and 22.4754 MHz

Bandwidth \( k \) = 1.9 \times 10^{-3} \text{ MHz} = 1.9 kHz

\[ P_{out, \ max} = I^2 R = (450 \times 10^{-6})^2 (300) = 1.27 \times 10^{-4} \text{ W} \]

\[ P_{ideal} = \frac{1}{1200} = 8.33 \times 10^{-4} \text{ W} \]

Insertion loss = \( 10 \log_{10} \left( \frac{1.27}{8.33} \right) = -8.2 \text{ dB} \)

(Not great, not too bad)

Recalculate at \( \frac{1}{2} \) atmosphere, \( K_{effective} = 2.028 \times 10^5 \)

(\text{Current}) = 2.15 \times 10^{-9} \text{ m/s}

\( C_{ms} = 4.93 \times 10^{-6} \) (very small change)

With these changes,

\[ P_{out, \ max} = I^2 R = (1.59 \times 10^{-3})^2 (300) = 7.58 \times 10^{-4} \text{ W} \]

Insertion loss = -0.41 dB (very good!)
Note: 100k resistors prevent floating nodes.
Note: 100k resistors prevent floating nodes.