Support-Q Optimisation of a Trapped Mode Beam Resonator

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Introduction: The introduction of a disorder into a finite periodic oscillatory system induces the presence of a 'trapped mode': a mode in which the displacement field is localised to the region of the disorder. One class of resonator that can exhibit these modes are trapped mode beam resonators (TMBRs). These present a way to tune support loss to a minimal value, thus are a good potential candidate for a high-Q geometry. Presented here is an initial investigation into Q optimisation of a TMBR and in particular the parameters affecting the support-Q (Q_{SUPP}).

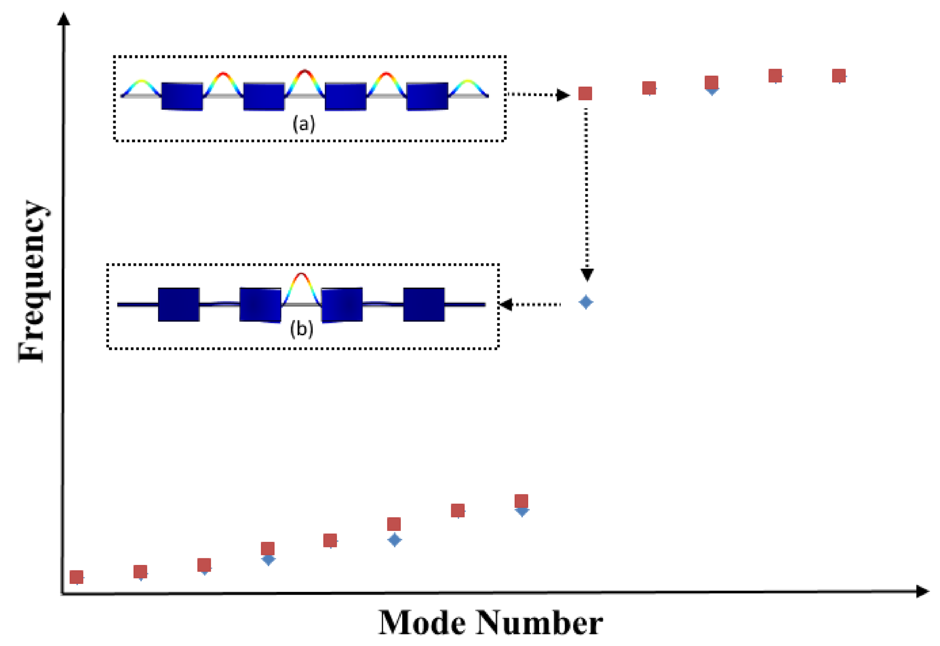

Figure 1. *Dispersion plot showing frequency shift of 9th mode (a) into the stop-band forming the 'trapped mode', (b).*

Computational Methods: Parametric sweeps were used in coupled resonator (Eigenfrequency) and substrate (Frequency domain) studies. These were used in combination with analytical calculations [1] to determine the Q_{SUPP} [2].

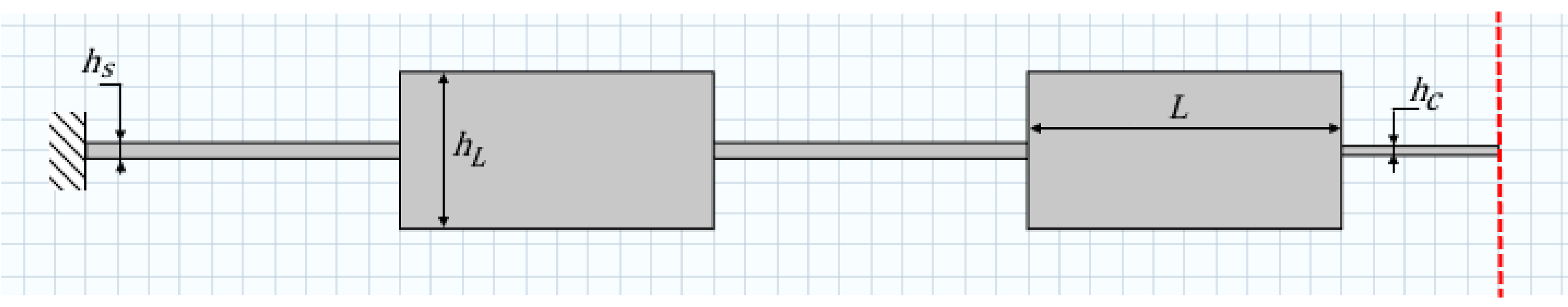

Figure 2. *Tuning parameters of the resonator model. The dashed red line denotes the symmetry boundary.*

The parameters of interest for tuning Q_{SUPP} (fig.2) were the thickness ratio, $m_r = \frac{h_L}{h_S}$, and the disorder ratio, $\delta K = \left(\frac{h_C}{h_S}\right)^3$.

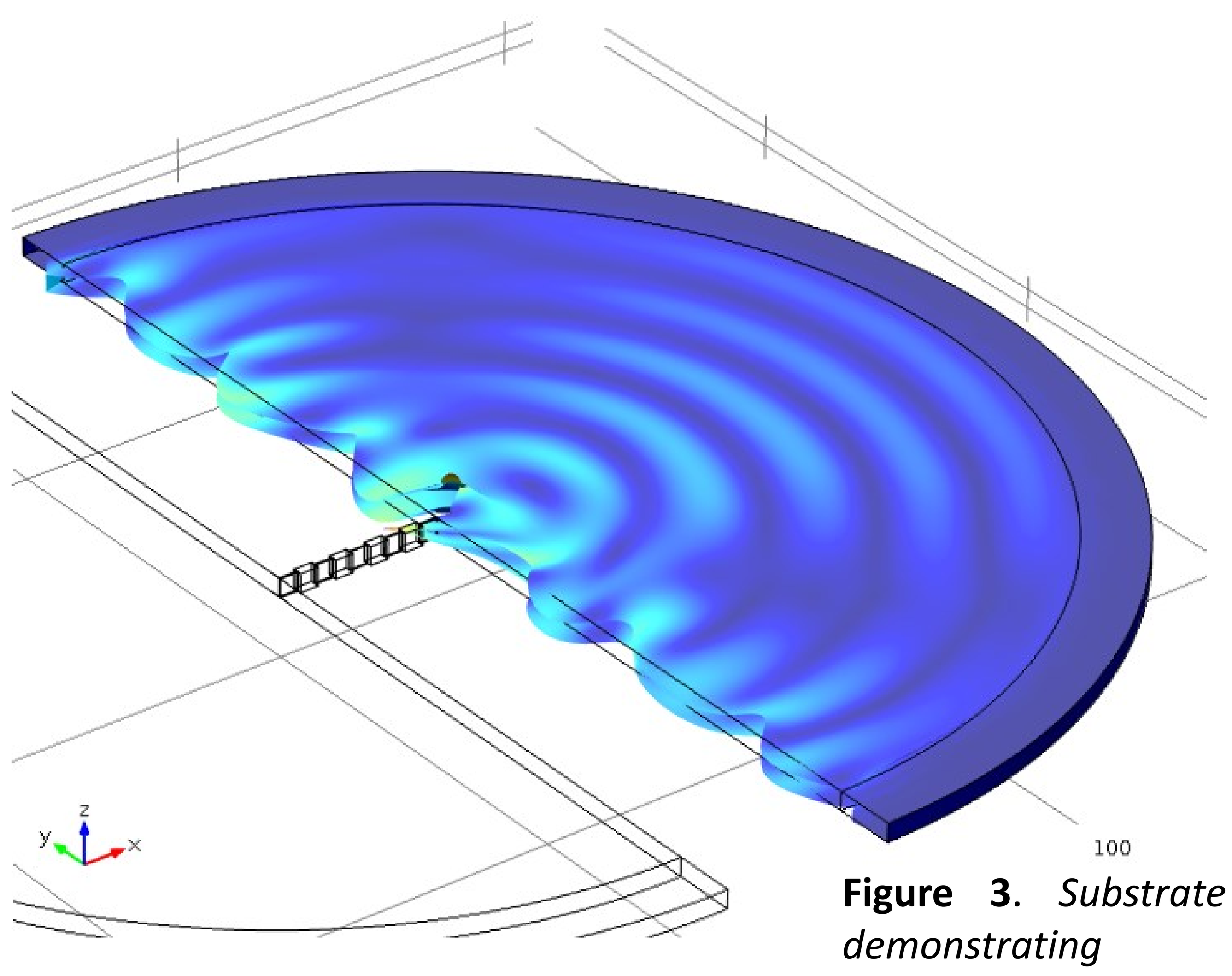

Figure 3. *Substrate model demonstrating energy radiation from the TMBR towards the PML. This absorbing boundary condition replicates the assumption that the substrate is sufficiently big that no reflections occur.*

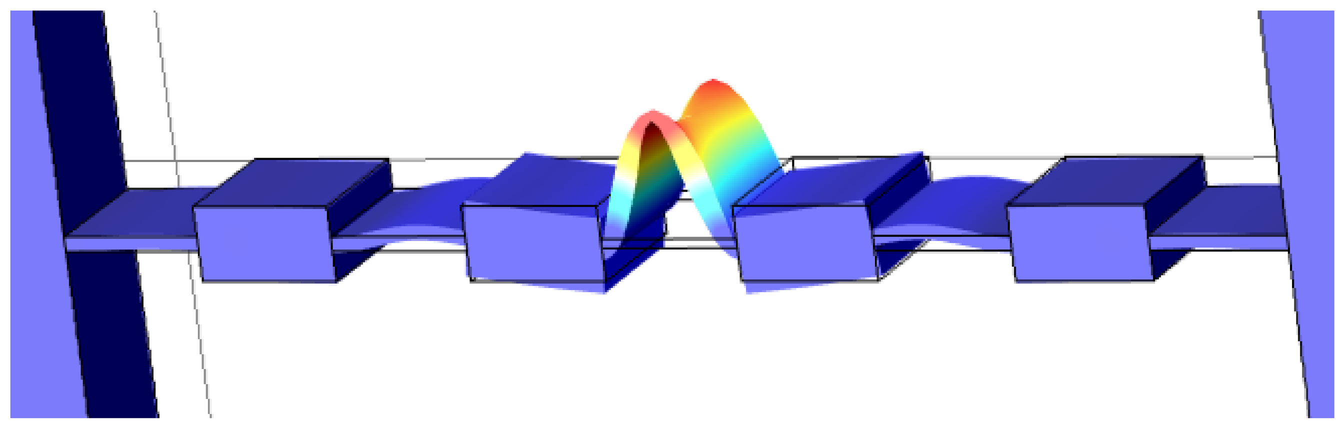

Figure 4. *Resonator model oscillating in a 'trapped mode'.*

Results: The maximum Q_{SUPP} achieved was ~3×10^8, in line with the highest available in the literature. Good qualitative agreement is found with the lumped parameter solution.

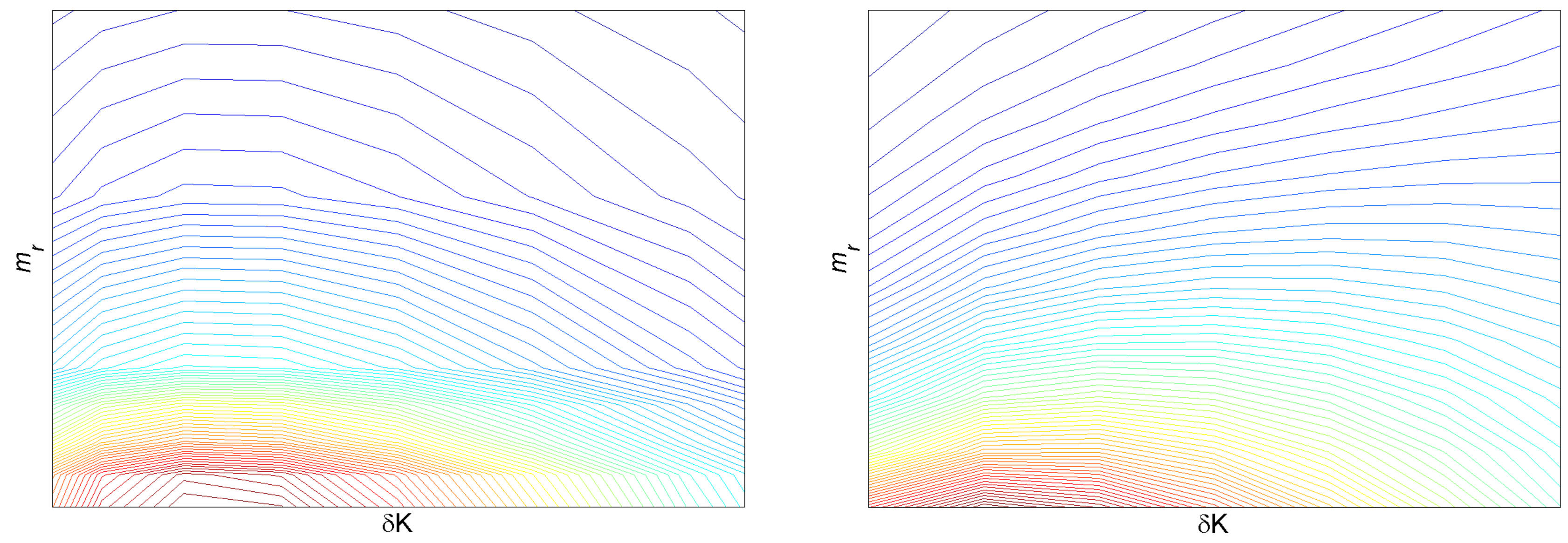

Figure 5. *Comparison COMSOL Multiphysics® solution (left) to the lumped parameter solution (right).*

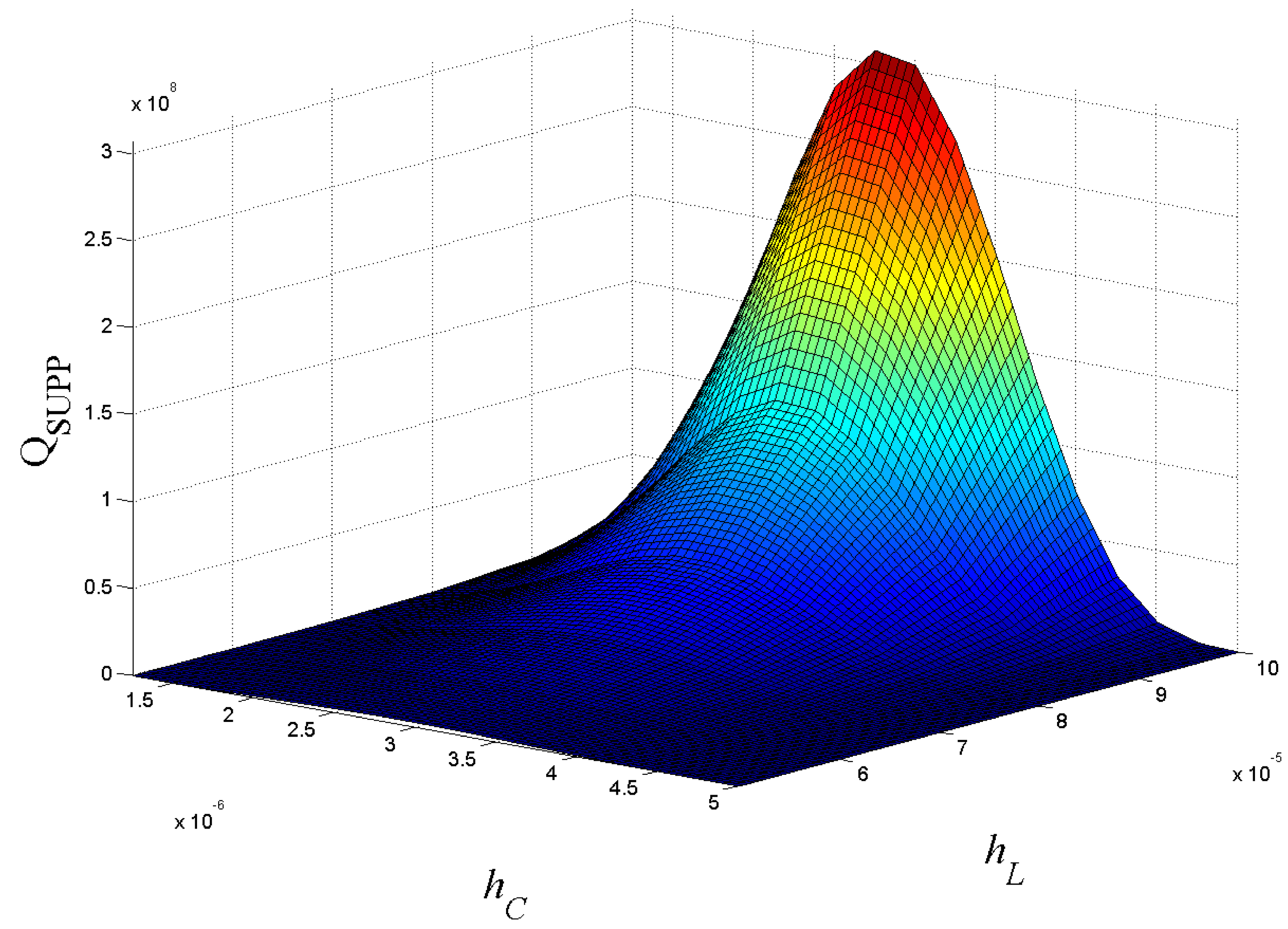

Figure 6. *Q_{SUPP} with varying thickness ratio and size of disorder (with h_s kept constant). It can be seen that an optimal value of disorder ratio is found to be ~0.8. Q_{SUPP} increases exponentially with an increase in the thickness ratio.*

Conclusions: It has been demonstrated that the TMBR can be a suitable choice for high-Q MEMS resonant devices when this geometric configuration may be favourable.

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References:

[1] Z. Hao, A. Erbil, and F. Ayazi, "An analytical model for support loss in micromachined beam resonators with in-plane flexural vibrations," *Sensors Actuators A Phys.*, vol. 109, no. 1–2, pp. 156–164, Dec. 2003.

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Excerpt from the Proceedings of the 2014 COMSOL Conference in Cambridge