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Design and optimisation of a vibrating wing insect-size air vehicle

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1-Context

State of the art:

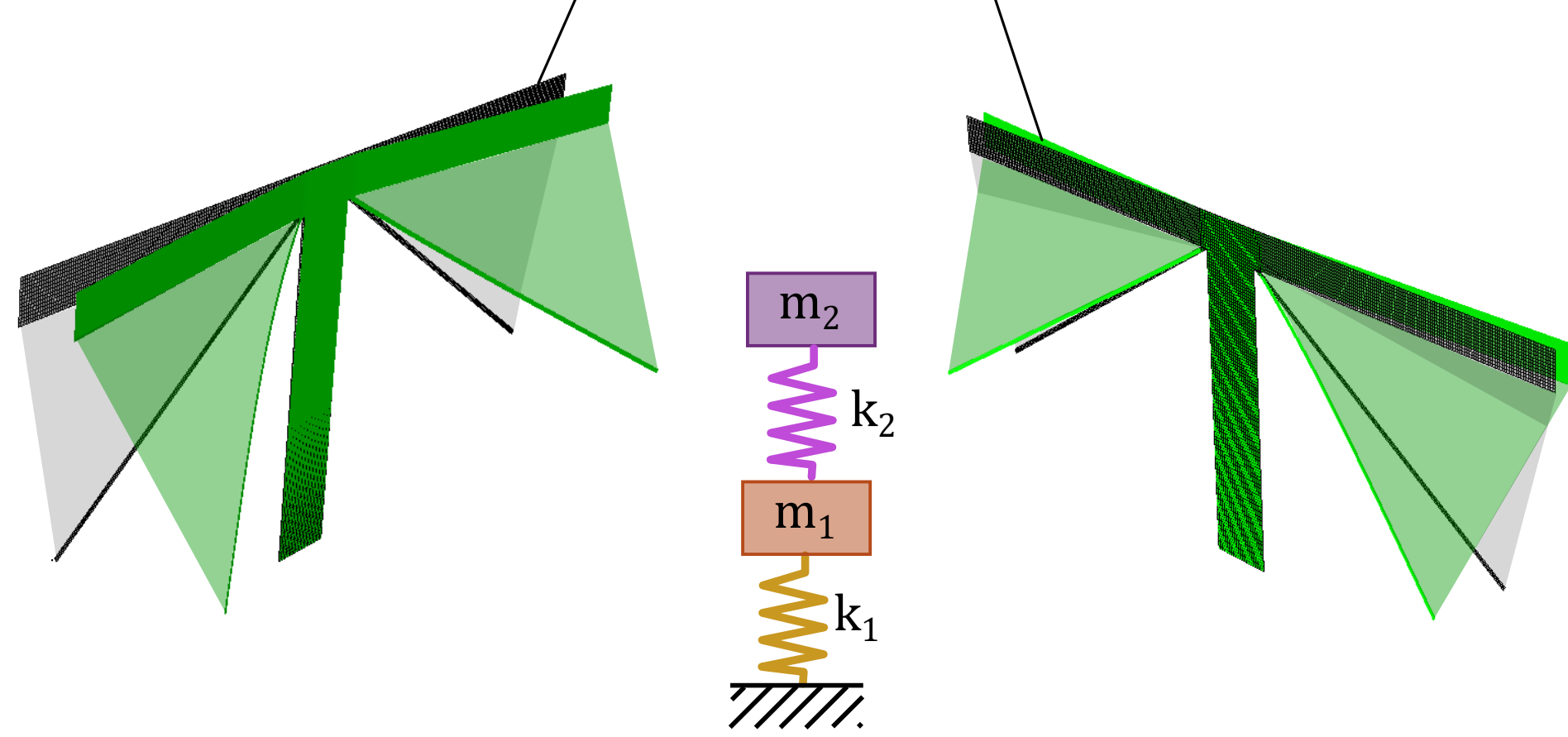
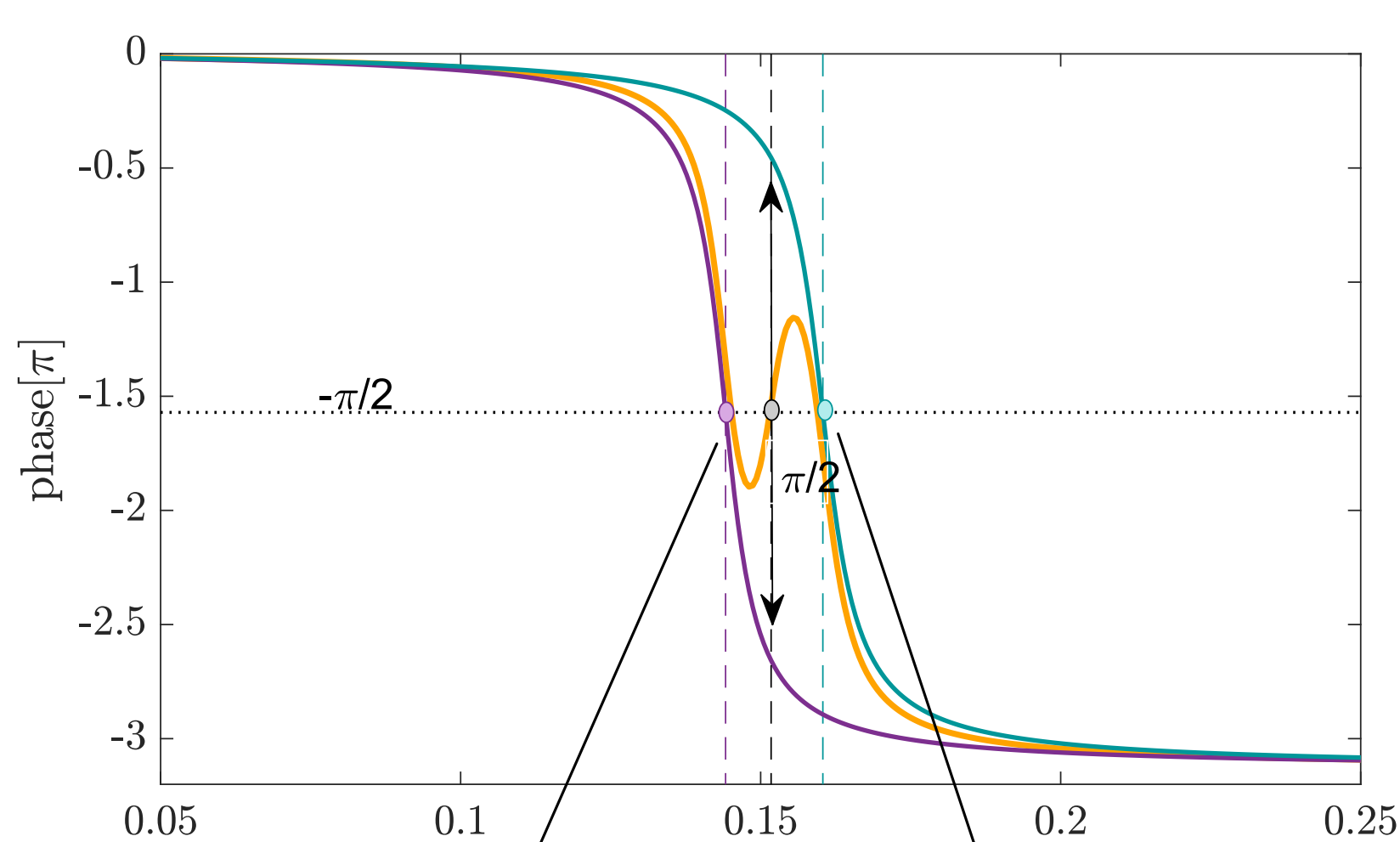
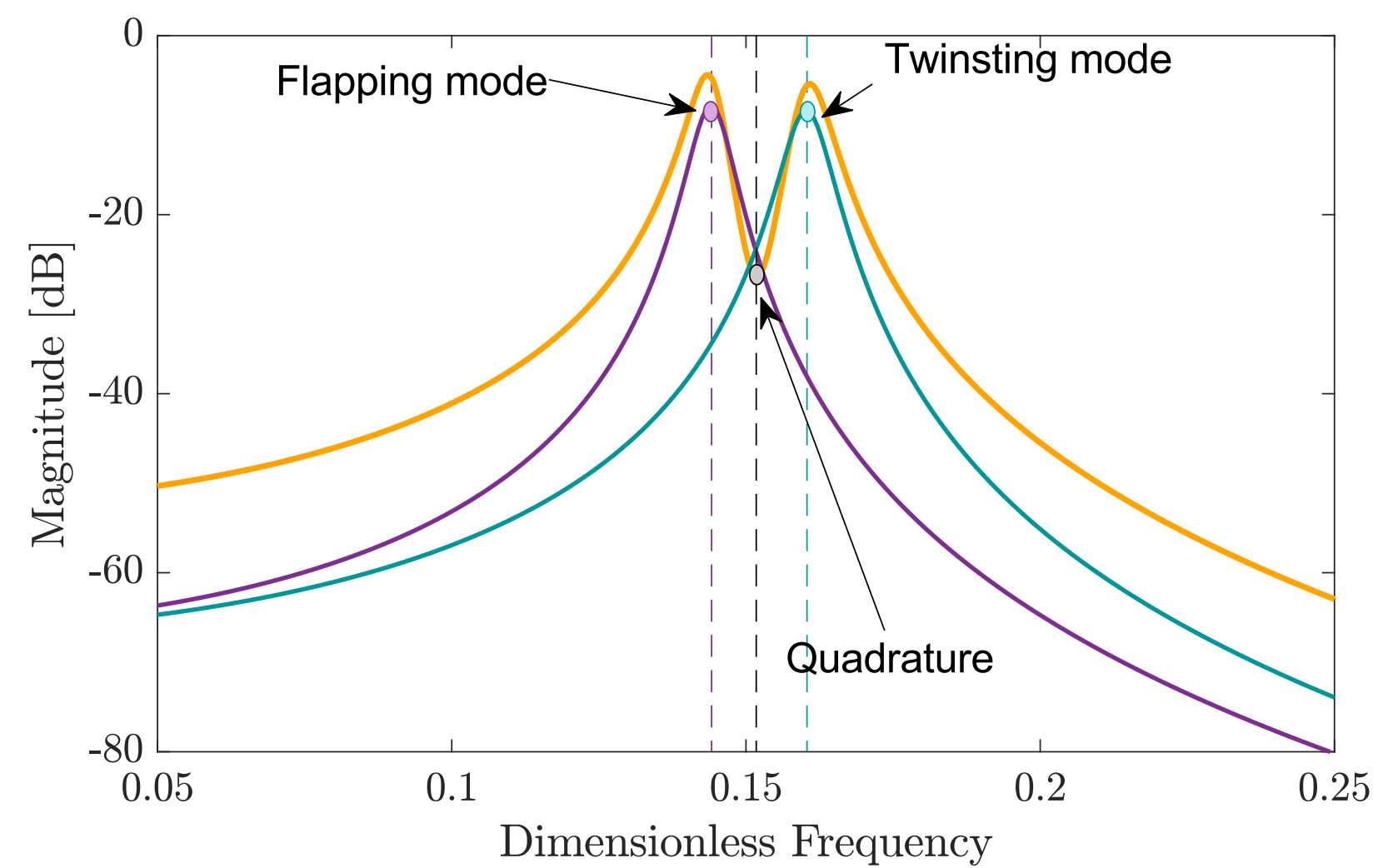
- Only 2 projects have succeeded in taking off a NAV with a mass of 100 mg: Shanghai [Zou 2018] and Harvard [Wood 2019].
- They are both based on passive twisting to imitate insect flight.

Insect flight [Dickinson 1999]

- It is a complex mechanism that can be reduced to a combination of flapping and twisting modes.
- It generates the larger lift when flapping and twisting are in phase quadrature.

2-Modal Superposition

We are looking for a combination of the flapping and twisting modes that gives maximum amplitude to the quadrature.



Dimensionless motion equations (2 degree of freedom):

$$\ddot{x}_1 + 2\xi_1 \dot{x}_1 + (1 + \mu\bar{\omega}^2)\bar{x}_1 - \mu\bar{\omega}^2 \bar{x}_2 = \cos(\bar{\Omega}t), \quad (1)$$

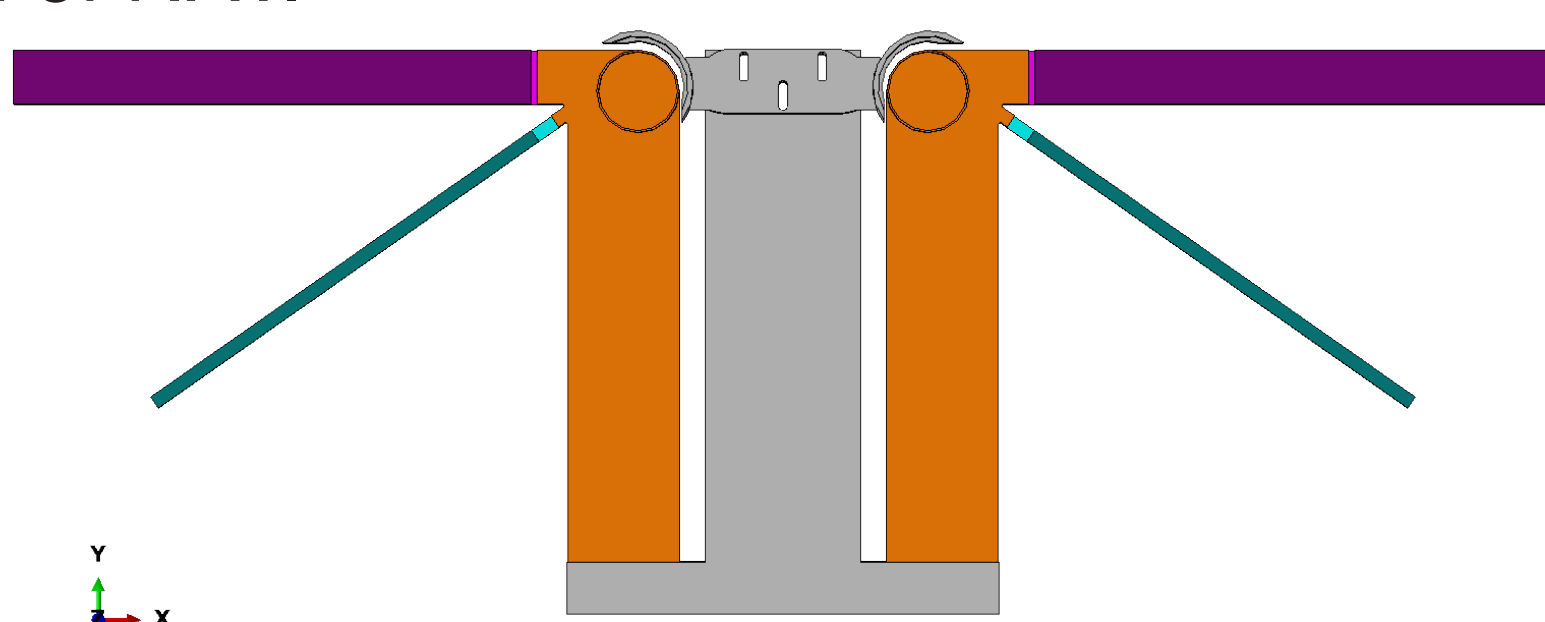
$$\ddot{x}_2 + 2\xi_2 \dot{x}_2 + \bar{\omega}^2(\bar{x}_2 - \bar{x}_1) = 0, \quad (2)$$

Criteria:

- two resonances close together and at the same amplitude
- anti-resonance with a not too low amplitude
- ratio between the amplitude of the leading edge and the magnet of $\approx \frac{1}{6}$

7-Future Work

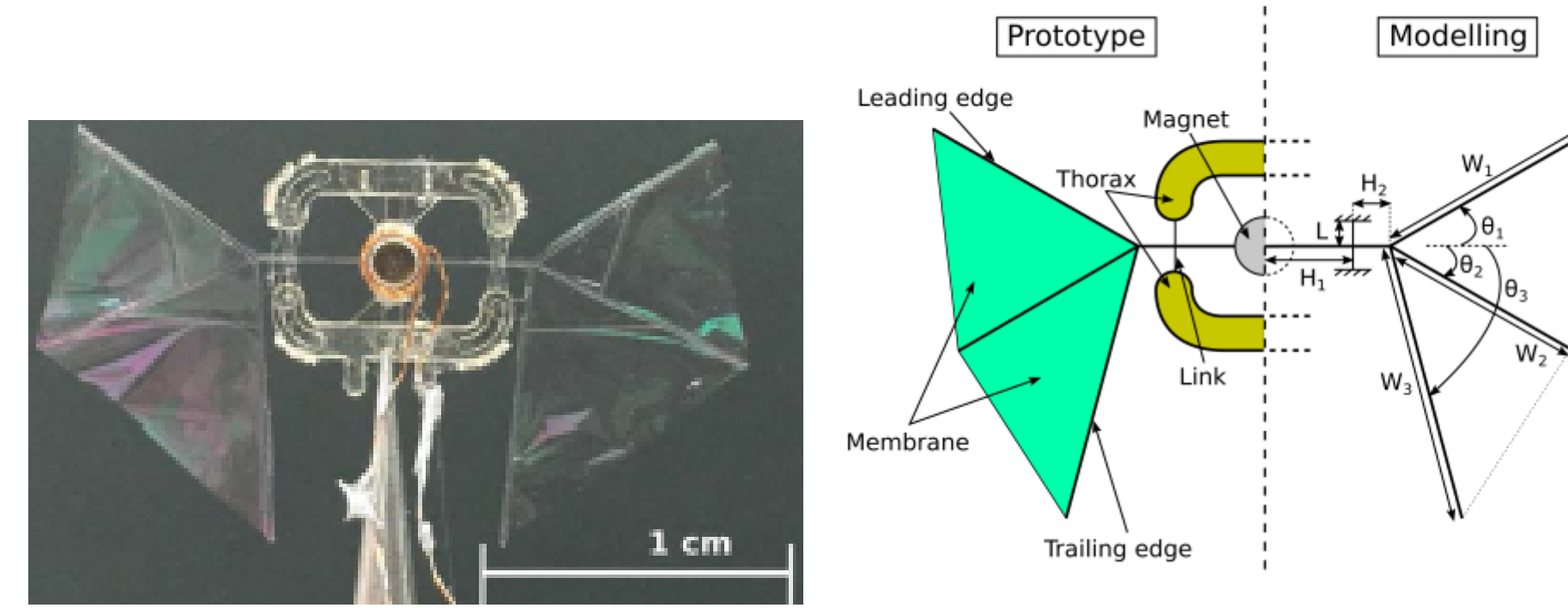
Optimisation, fabrication and testing of a new generation of NAV.



2-The Generations

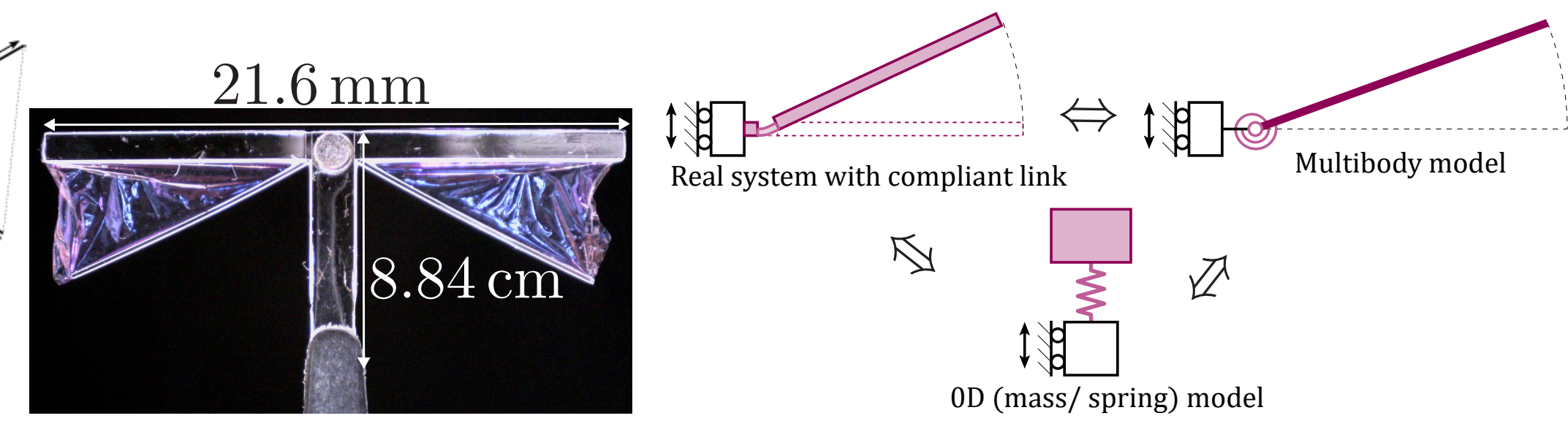
Previous work [Faux 2019]:

- Structure with fully flexible wings
- Optimised by an of Euler-Bernoulli beam model



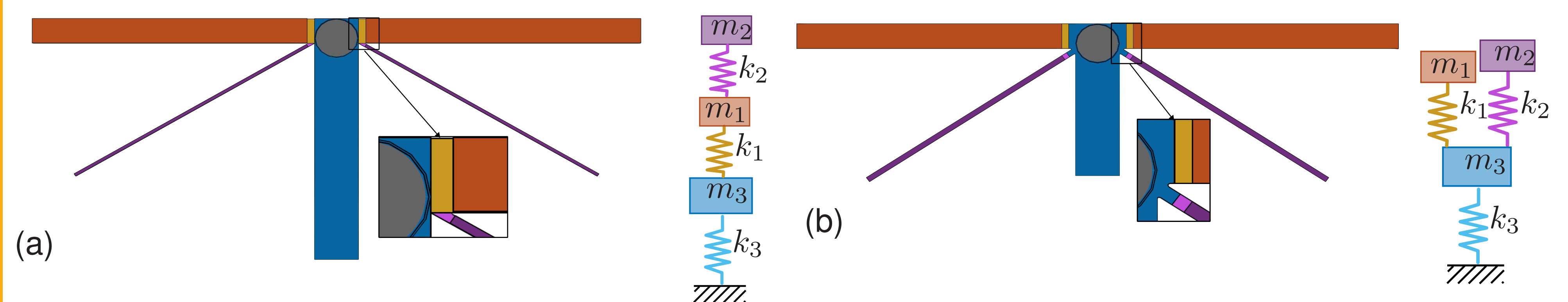
Actual Work [Colin 2021]:

- Structure with compliant links and rigid bodies
- Optimised by equivalence with a 0D model

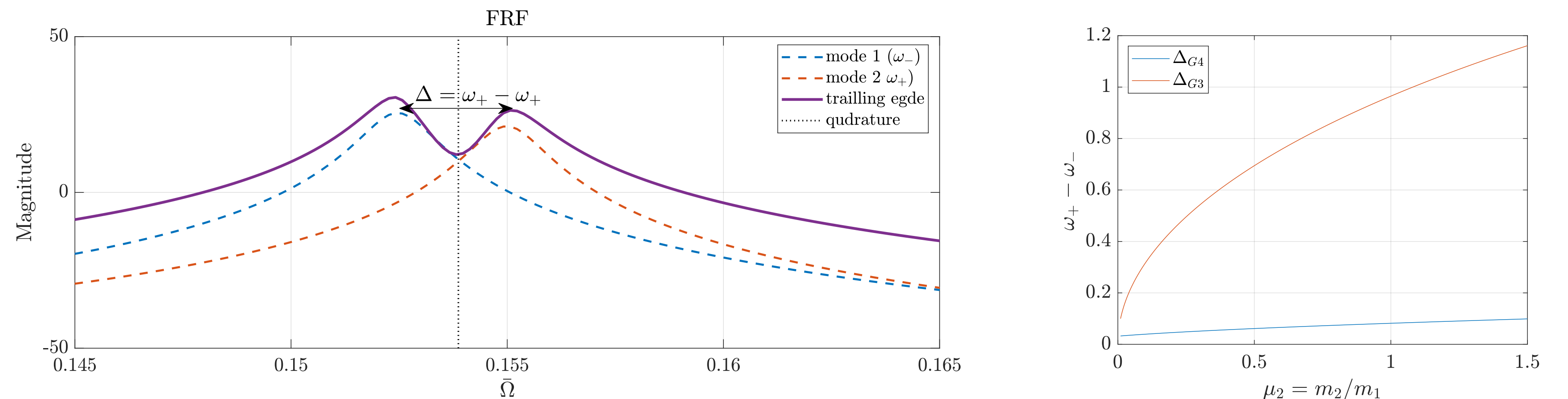


4-NAV Architectures

Two NAV architectures and their simplified models:

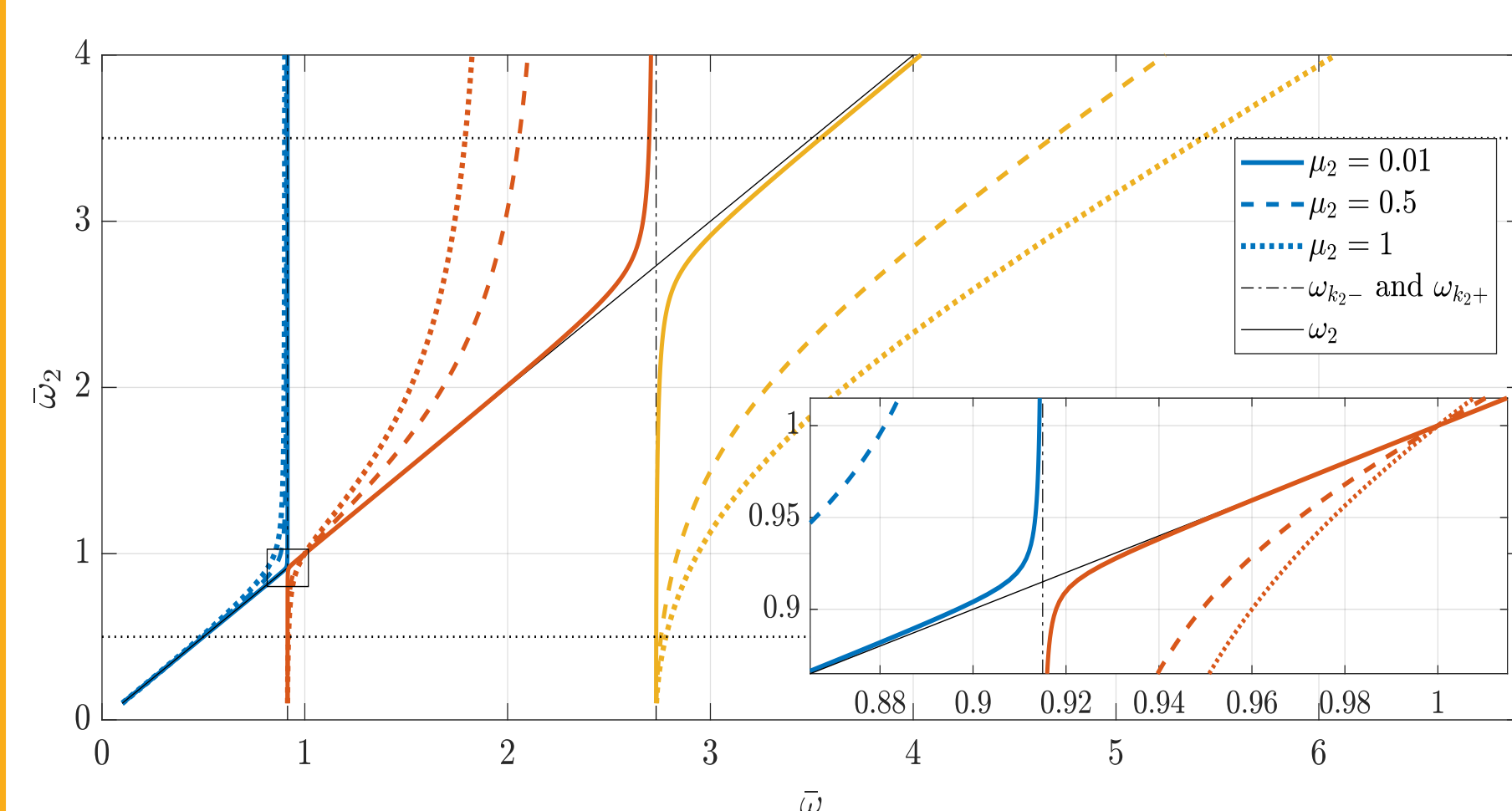


Frequency difference for the two geometries:



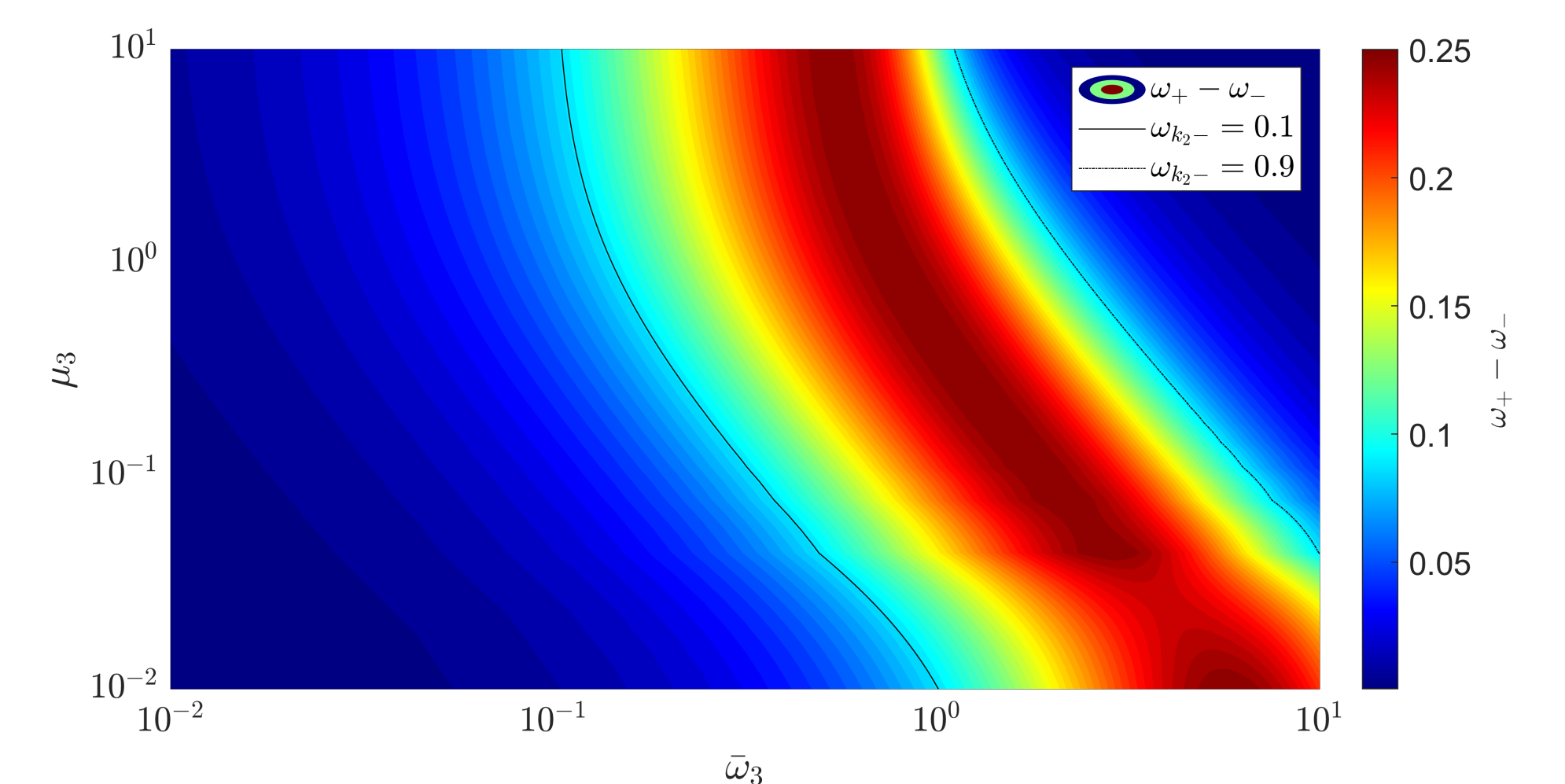
5-Optimisation

Study of $\mu_2 = \frac{m_2}{m_1}$:

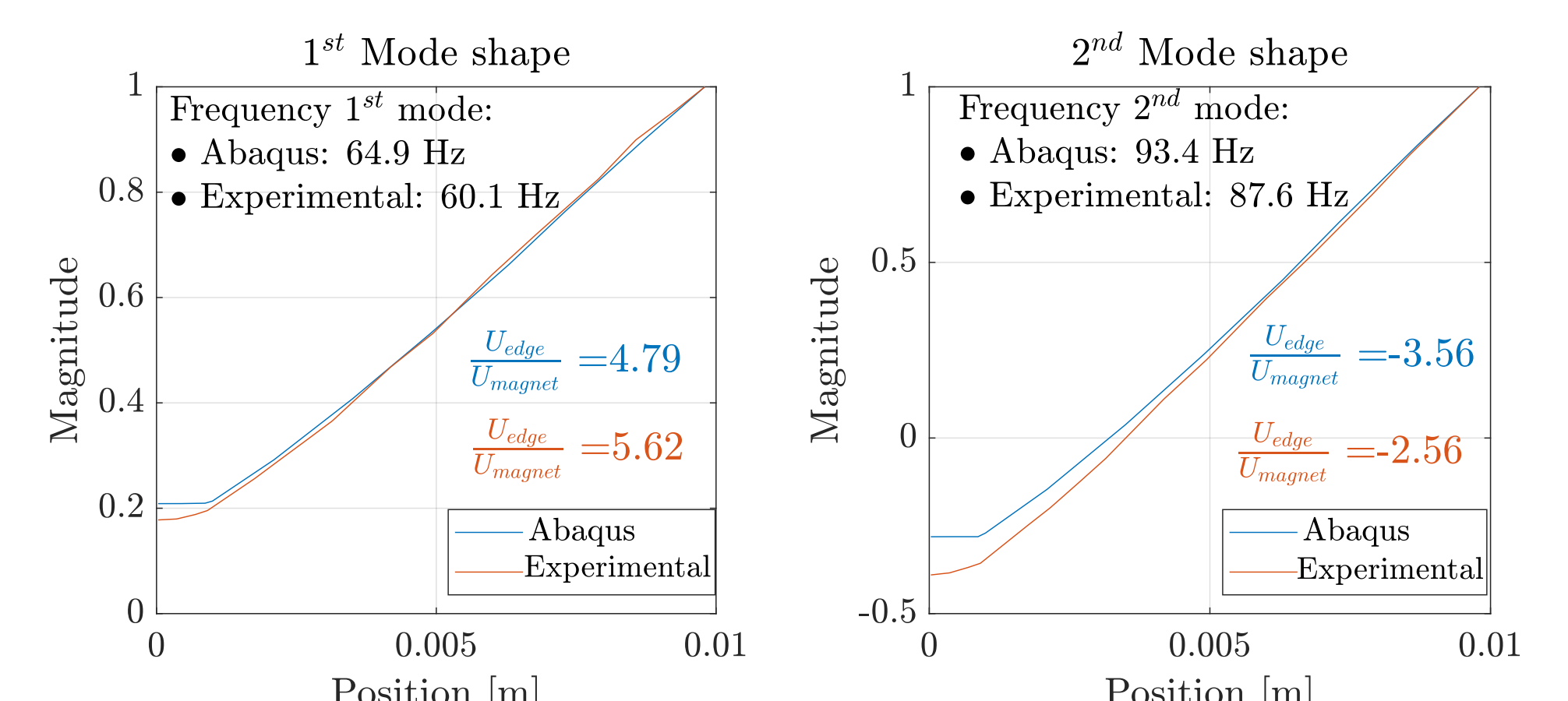
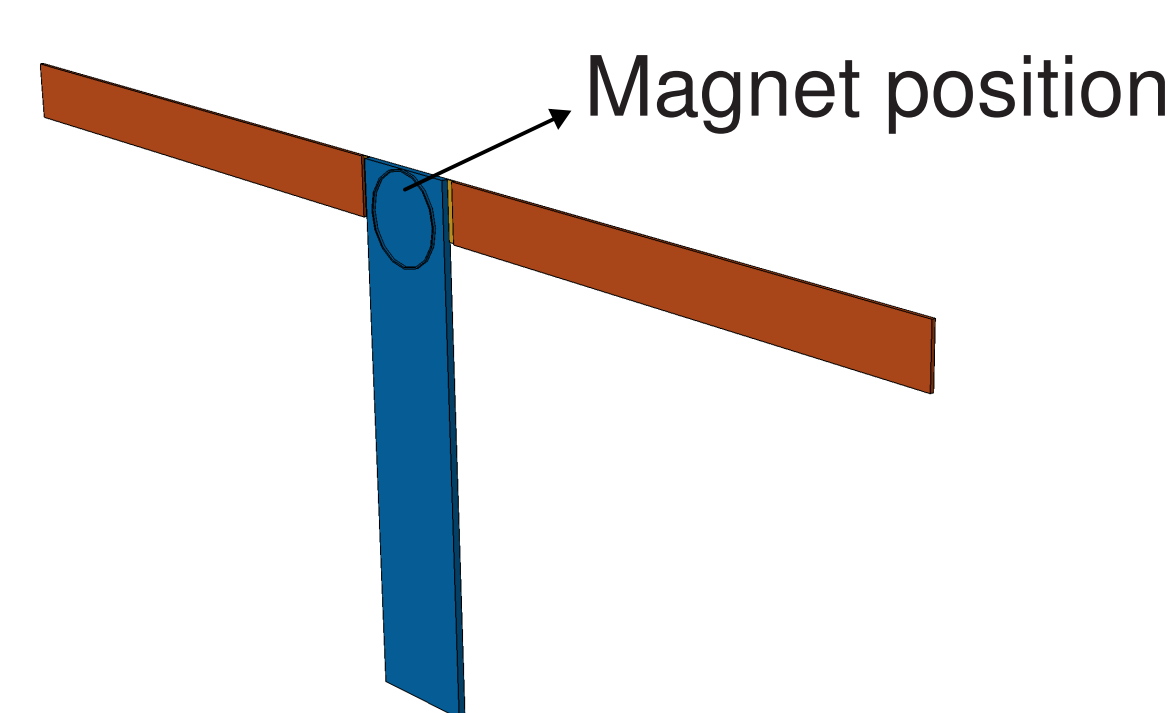


- $\mu_2 = \frac{m_2}{m_1} \ll 1$
- $\bar{\omega}_2 = \frac{\xi_2}{\omega_1}$ function of $\bar{\omega}_3 = \frac{\omega_3}{\omega_1}$ and $\mu_3 = \frac{m_3}{m_1}$

Study of $\bar{\omega}_3$ and μ_3 :

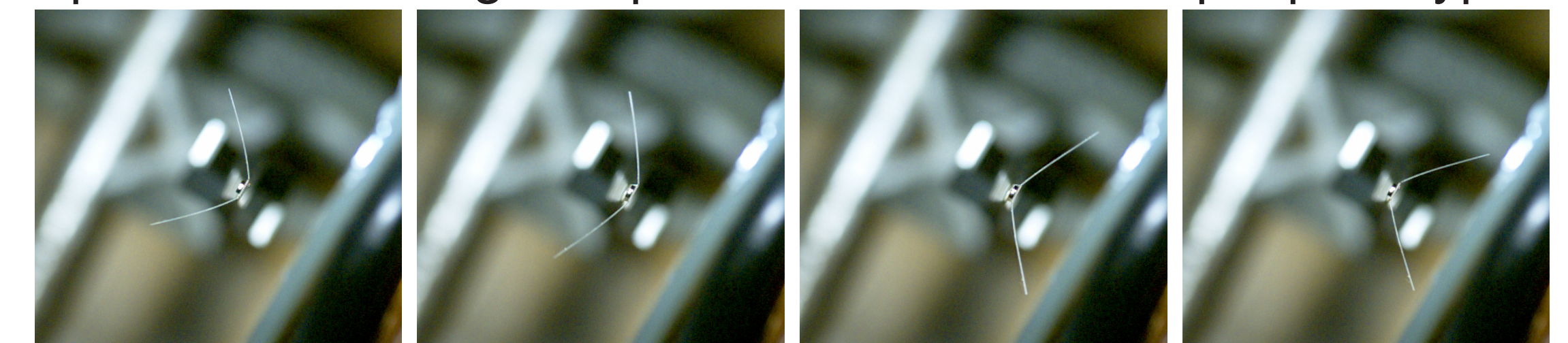


6-First Validation



- The rigid bodies assumption is valid: only the compliant links deform.
- We can achieve high amplitudes: angles of 70° peak to peak.

snapshots of the large amplitude motion of a simple prototype



8-Bibliographies

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