Technical University of Denmark

Macromechanical parametric amplification

Neumeyer, Stefan; Thomsen, Jon Juel

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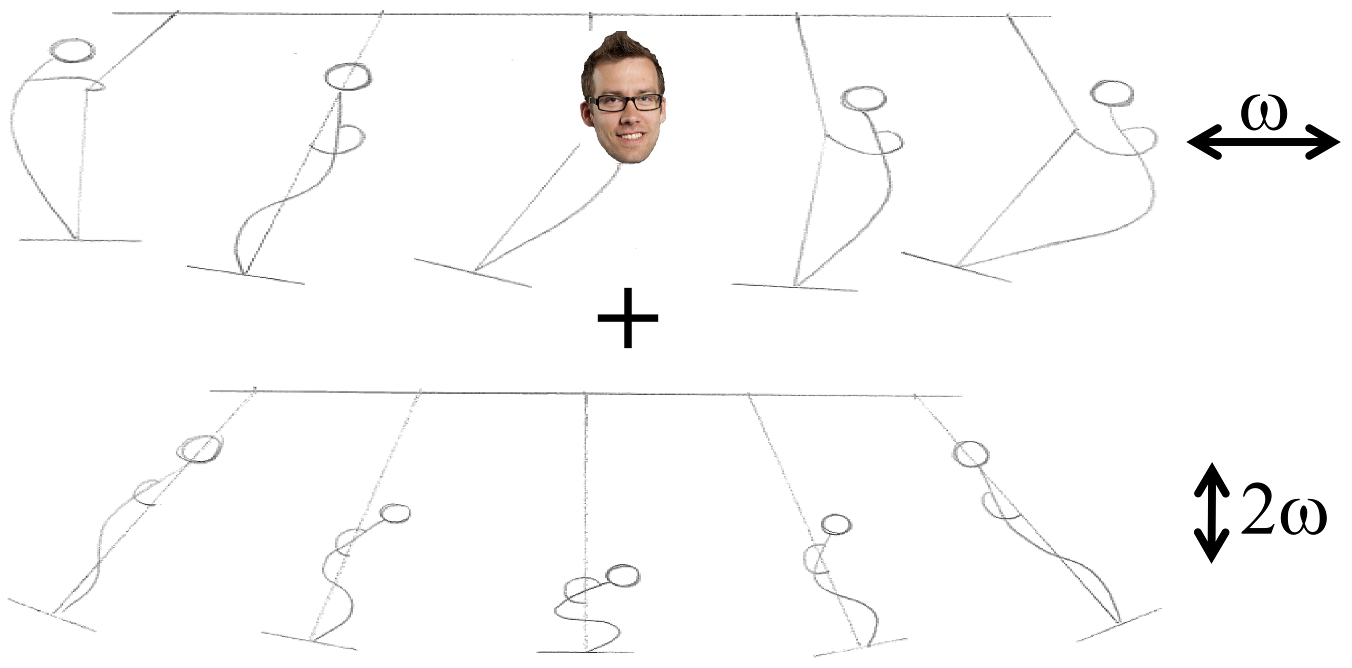
Macromechanical parametric amplification

S. Neumeyer*,# and J. J. Thomsen¤

1. What is it?

- Adding parametric excitations to externally driven near-resonant harmonic oscillations to amplify vibration amplitudes, e.g., a playground swing:



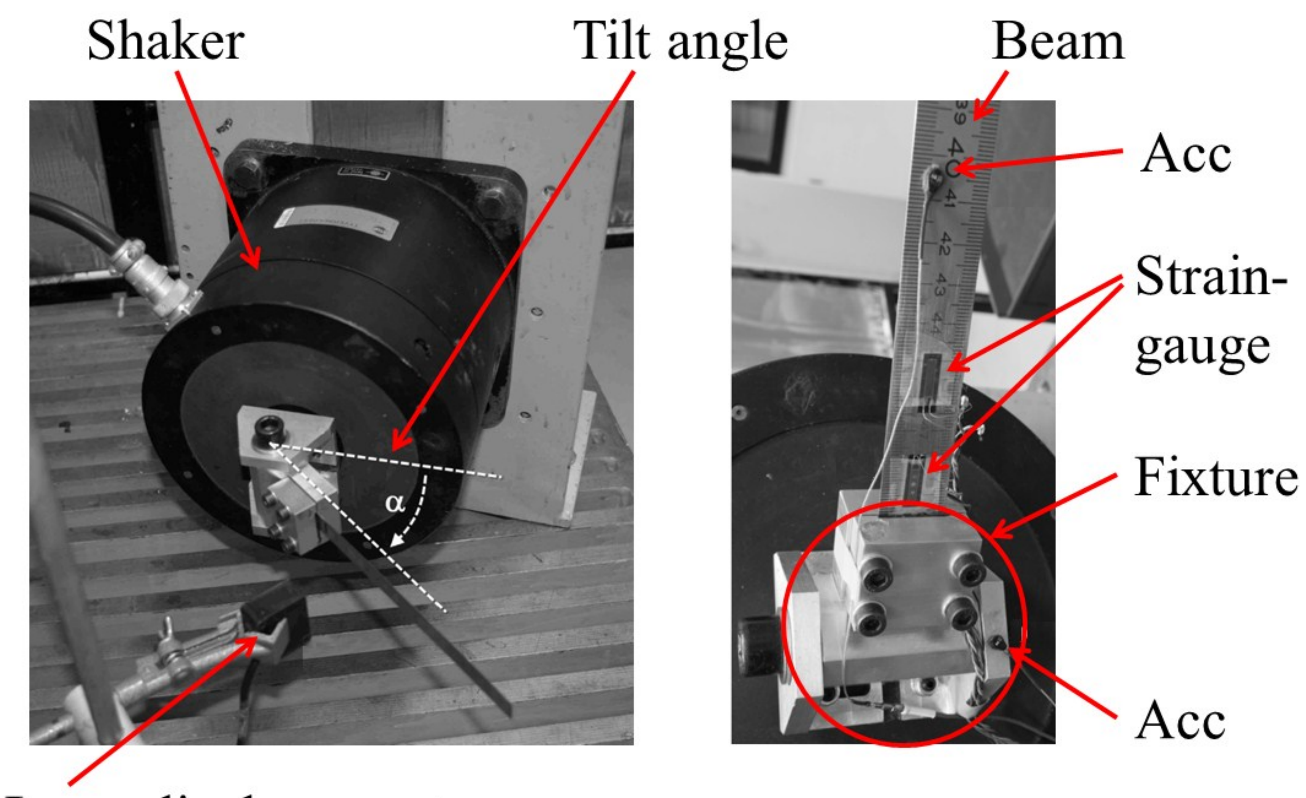
- The ratio between the stationary vibration amplitudes of the directly and parametrically excited system, and the directly excited system, is defined as the *gain*.

2. This study?

- Phenomenological study
- Effects of third-order nonlinearities
- Optimal gain and tilt angle
- Parametric amplification of higher order vibration modes
- Superthreshold pumping

3. Realization in current study?

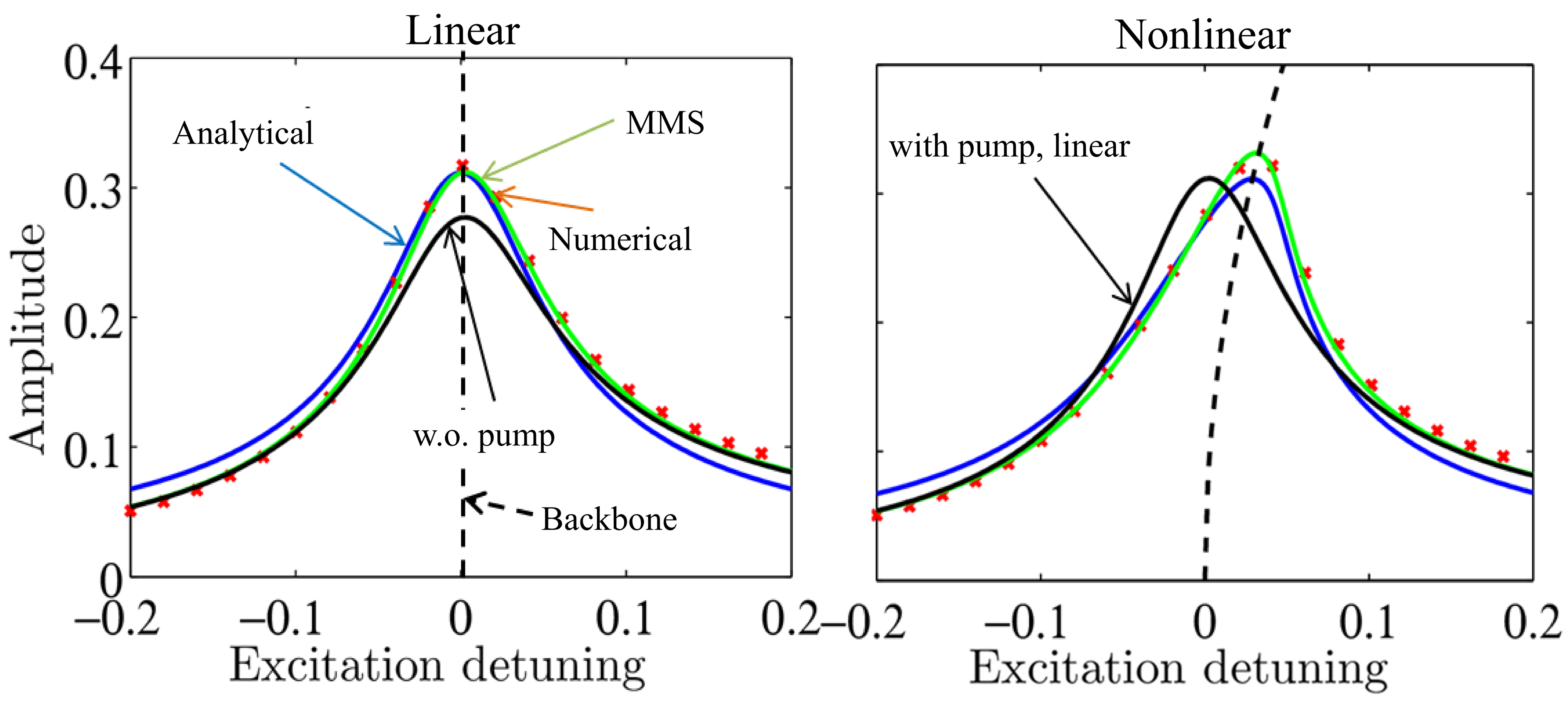
Tilted base-excited cantilever beam:



4. Current work? [1,2]

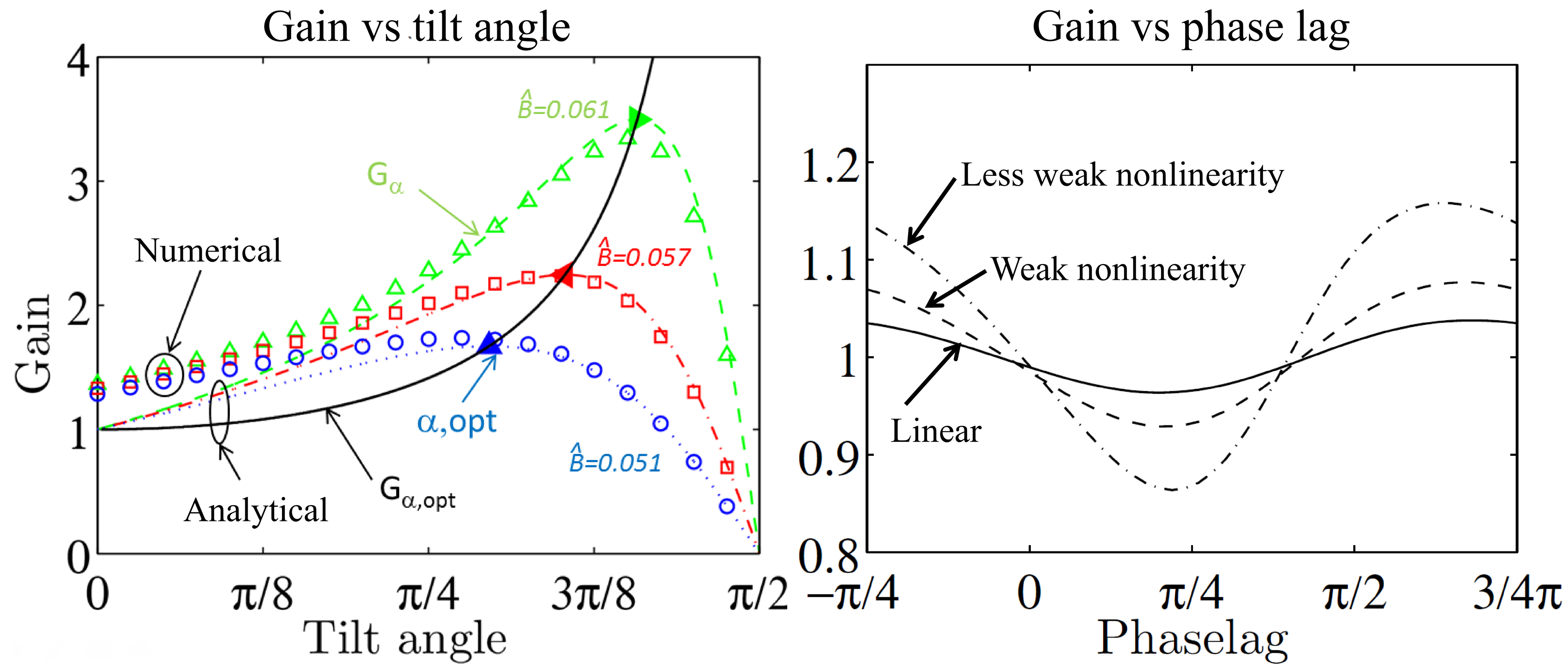
$$\ddot{z} + 2\varepsilon\zeta\dot{z} + z + \left(\varepsilon\lambda_1\Omega^2\cos\left(\Omega\tau+\phi\right) + \varepsilon\lambda_2\Omega^2\cos\left(2\Omega\tau\right)\right)z + \varepsilon k_3 z^3$$
$$+\left(\varepsilon\gamma_1\Omega^2\cos\left(\Omega\tau+\phi\right) + \varepsilon\gamma_2\Omega^2\cos\left(2\Omega\tau\right)\right)z^3 + \varepsilon\alpha_n\left(\ddot{z}z^2 + \dot{z}^2 z\right)$$
$$= \varepsilon\eta_1\Omega^2\cos\left(\Omega\tau+\phi\right) + \varepsilon\eta_2\Omega^2\cos\left(2\Omega\tau\right)$$

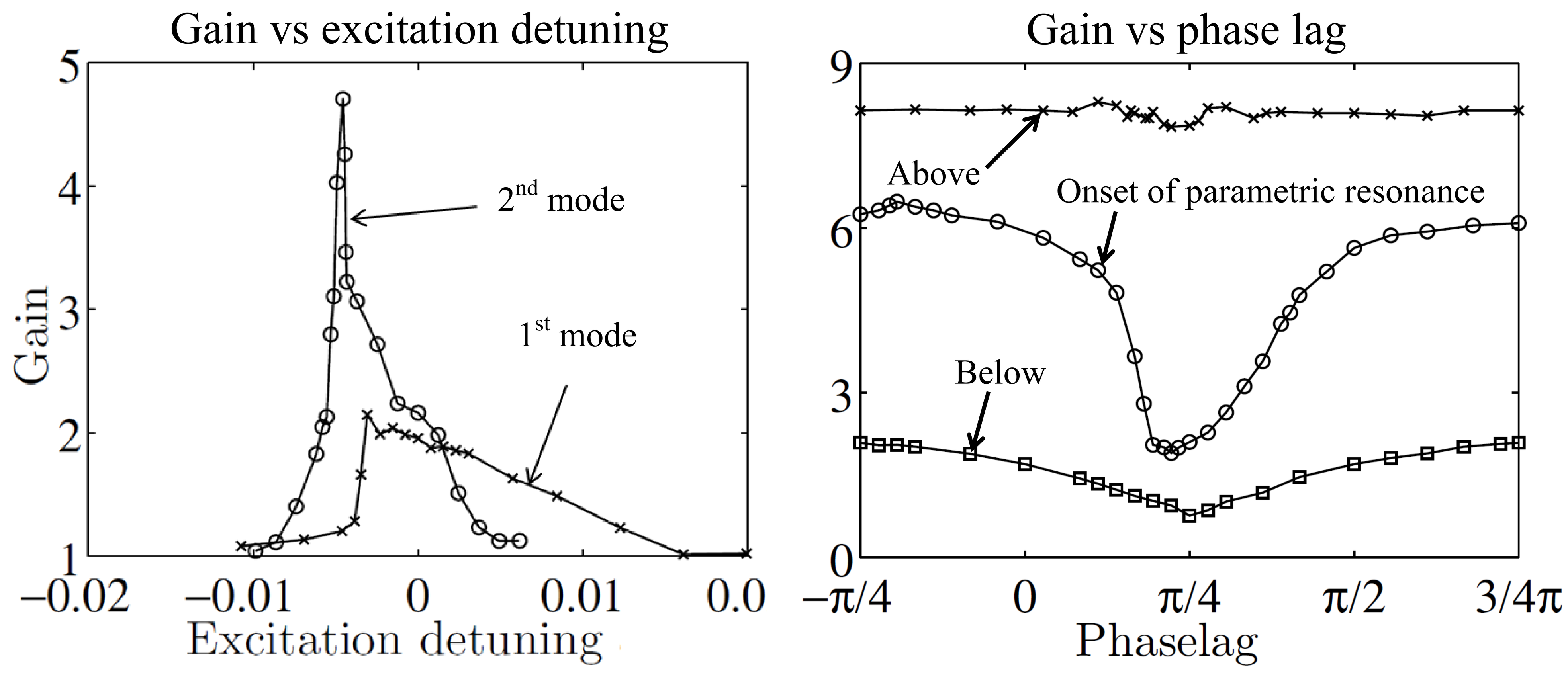
Amplitude vs excitation detuning



Gain squared:

$$G_\alpha^2(\sigma=0) = \frac{\left(1+\left(\kappa\sin\alpha - 2\sin 2\phi\right)\kappa\sin\alpha\right)\cos^2\alpha}{\left(1-\kappa^2\sin^2\alpha\right)^2}, \quad \kappa = \frac{\zeta}{\mu\hat{B}}, \quad G^2_{\alpha,\mathrm{opt}} = \frac{1}{1-\kappa^2}$$





5. Conclusions? ...and so what?

- Insight through derivation of analytical expressions
- Gain is realized (larger than unity)
- Optimal mix between excitation parameters
- Other nonlinear effects
- Energy-considerations
- High-frequency excitation effects

[1] Neumeyer, S. and Thomsen, J. J., Macroscale mechanical domain parametric amplification: superthreshold pumping and optimal excitation parameters, Euromech Colloquium 532 Time-Periodic Systems: Current trends in theory and application, 2012.

[2] Kumar V., Miller, J. K. and Rhoads J. F., Nonlinear parametric amplification and attenuation in a base-excited cantilever beam, Journal of Sound and Vibration, 330(22) (2011) 5401-5409.

* Corresponding author, stene@mek.dtu.dk
# The guy on the picture
¤ Supervisor, Associate Professor, Dr. Techn.

DTU Mechanical Engineering
Department of Mechanical Engineering