

Pull-in retarding in nonlinear Mathieu NEMS resonators under superharmonic excitation

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In order to compensate the loss of performance when scaling resonant sensors down to NEMS, a complete analytical model including all main sources of non linearities is presented as a predictive tool for the dynamic behaviour of Mathieu NEMS resonators. The nonlinear dynamics of such resonators under superharmonic resonance of order half their fundamental natural frequency is investigated.

The device consists of a clamped-clamped nanobeam subject to viscous damping and actuated by an electric load $v(t) = V_{ac} \cos[\tilde{\Omega}t] - V_{dc}$ where V_{dc} is the DC polarization voltage, V_{ac} is the amplitude of the applied AC voltage, and $\tilde{\Omega}$ is the excitation frequency.

The particularity of this device is the use of two electrodes with different gap thickness: a first electrode for the actuation and a second one for the transduction.

The transverse deflection of the nanobeam $\tilde{w}(x,t)$ is governed by the nonlinear Euler-Bernoulli equation for thin beams. The fringing field effects are introduced into the model since they can have a significant influence.

A Galerkin discretization procedure with basis functions satisfying the boundary conditions of a clamped-clamped nanobeam permits the transformation of the nonlinear partial differential equations of motion into a finite system of nonlinear Mathieu equations.

Since we are interested in the response of the resonator at resonance when the first mode is dominant, only the first equation is considered.

A perturbation technique is then used in order to obtain two first order non-linear ordinary-differential equations which describe the amplitude and phase modulation of the response and permit a stability analysis.

It is shown that the critical amplitude has the same dependence on the quality factor Q and the vibrating width h as in the case of the primary resonance. Finally, a way to shift up the pull-in amplitude by decreasing the AC voltage is proposed in order to enhance the performances of NEMS resonators.

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