Paleta NanoRezonanta

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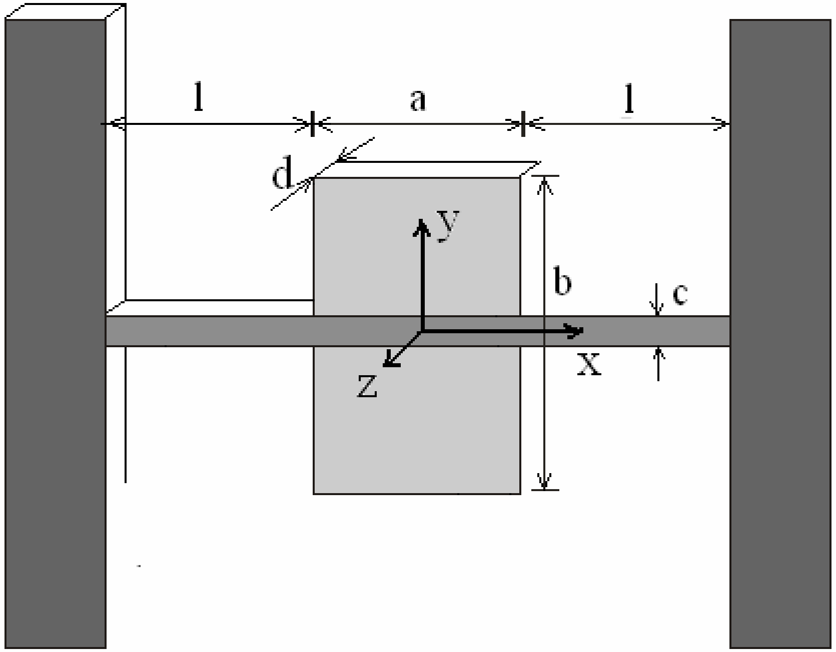
Geometria paletei



$l = 2.5\mu m$

$a = 2\mu m$

$b = 3.5\mu m$

$d = 200nm$

$c = 175nm$

$E = 150GPa$

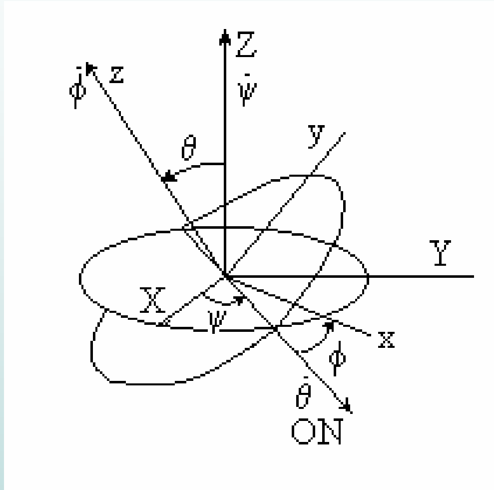
$\nu = 0.17$

$\rho = 2330kgm^{-3}$

$f = 200Nm^{-2}$

d asim =40nm

Ecuatii miscare



$$R\times R \ni (x,y,z,t) \to \{r(x,y,z,t), d_i(x,y,z,t)\} \in E^3$$

$$d_1 = (-\sin\psi\sin\varphi + \cos\psi\cos\varphi\cos\theta)e_1 + \\ + (\cos\psi\sin\varphi + \sin\psi\cos\varphi\cos\theta)e_2 - \sin\theta\cos\varphi e_3,$$

$$d_2 = (-\sin\psi\cos\varphi - \cos\psi\sin\varphi\cos\theta)e_1 + \\ + (\cos\psi\cos\varphi - \sin\psi\sin\varphi\cos\theta)e_2 + \sin\theta\sin\varphi e_3,$$

$$d_3 = \sin\theta\cos\psi e_1 + \sin\theta\sin\psi e_2 + \cos\theta e_3.$$

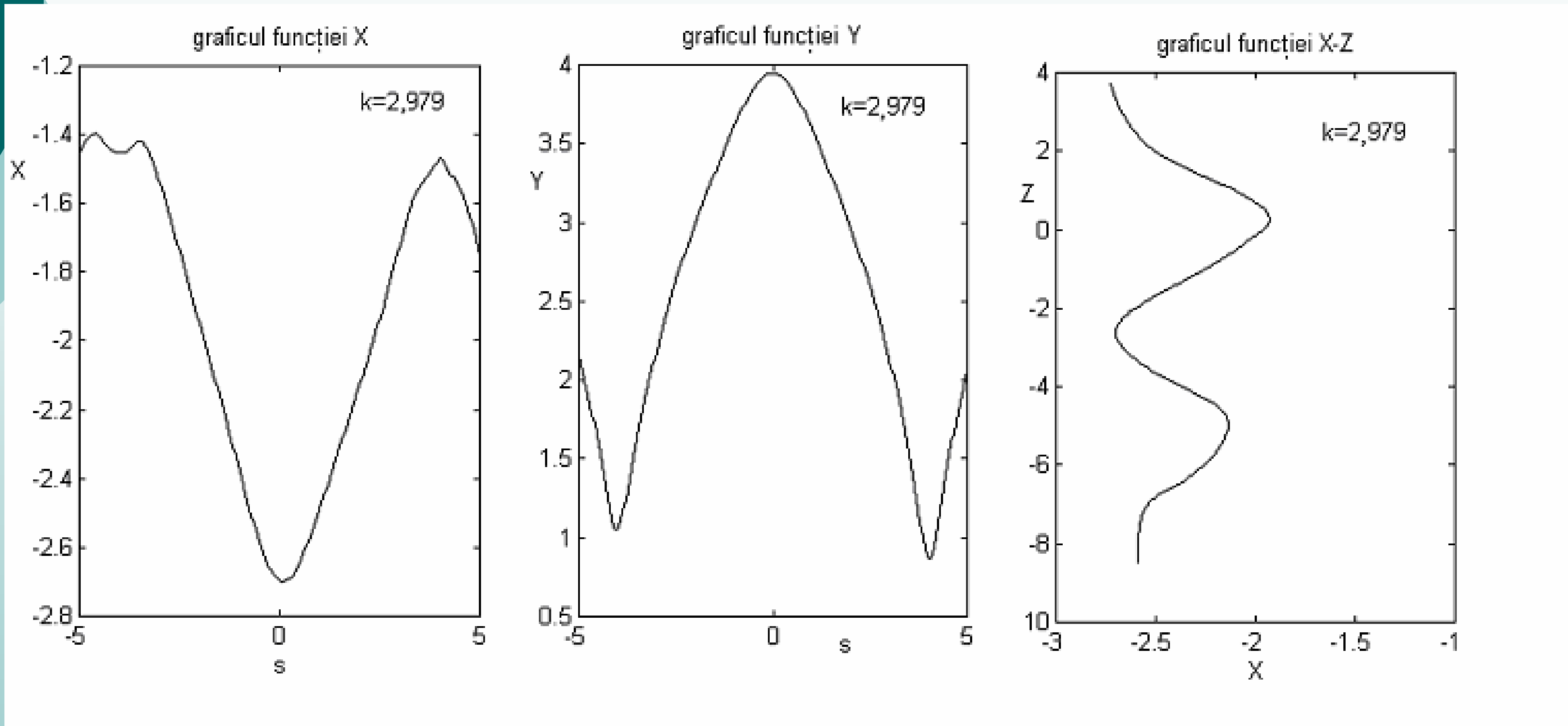
$$u_1 = \theta'\sin\varphi - \psi'\sin\theta\cos\varphi \qquad u_2 = \theta'\cos\varphi + \psi'\sin\theta\sin\varphi$$

$$u_3 = \tau = \varphi' + \psi'\cos\theta \qquad r = \int_0^s d_3 ds \qquad X(s) = \int_0^s \cos\psi\sin\theta ds$$

$$Y(s) = \int_0^s \sin\psi\sin\theta ds \qquad Z(s) = \int_0^s \cos\theta ds$$

$$s = k_1 x + k_2 y + k_3 z + \omega t$$

Forme de echilibru ale barei incepand cu locul de imbinare cu paleta si terminand cu suportul

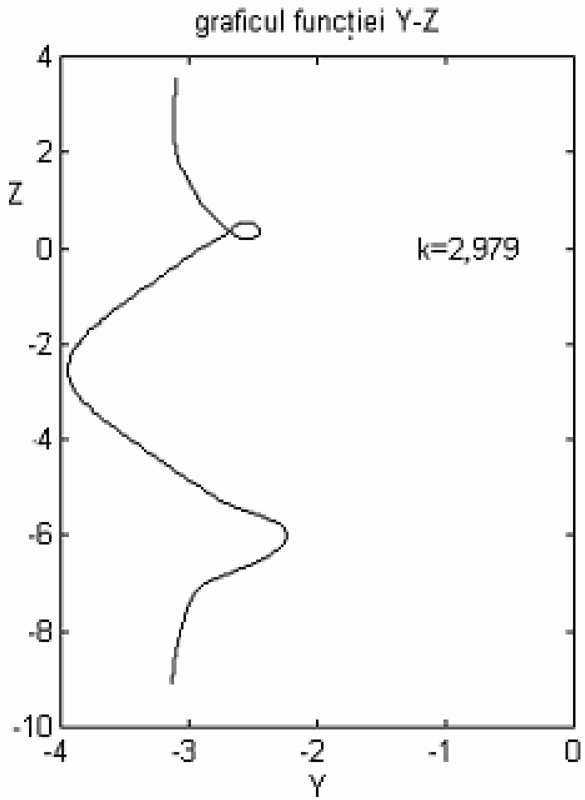


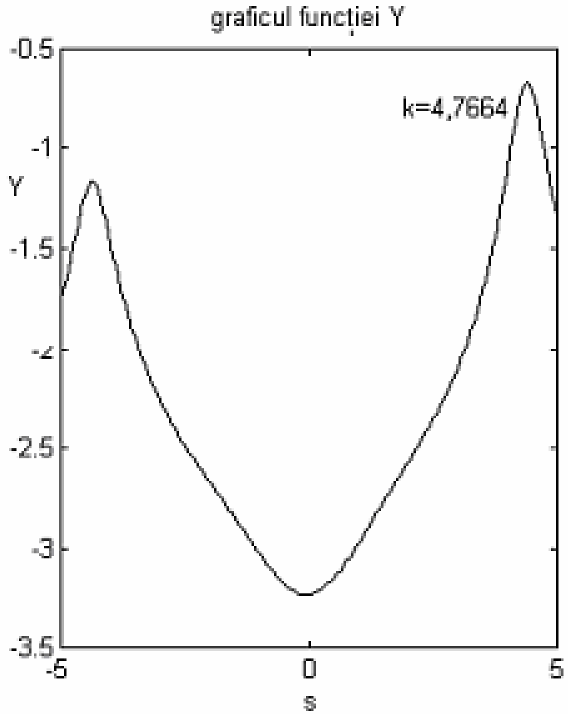
$$\cos\theta = u_2 - (u_2 - u_3)\mathrm{cn}^2\left(\sqrt{\frac{|\lambda_3|}{2A}(u_1 - u_3)}\ (s_2 - s_3), m\right) = u_2 - (u_2 - u_3)\mathrm{cn}^2[w(s - s_3), m] \qquad m = \frac{u_2 - u_3}{u_1 - u_3} \qquad w = \sqrt{\frac{|\lambda_3|}{2A}(u_1 - u_3)}$$

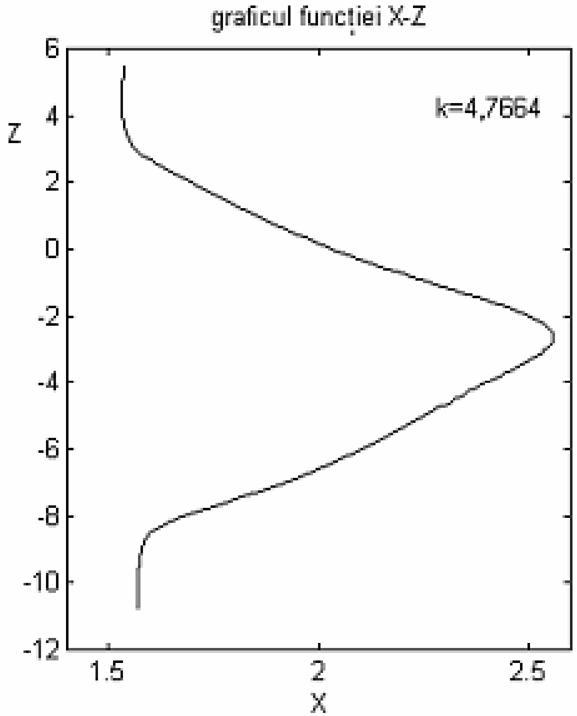
$$\psi = \frac{1}{4A^2 w^2}\left\{-\frac{\beta + C\tau}{1 - u_3}\Pi\left[w(s - s_3), \frac{u_2 - u_3}{1 - u_3}, m\right] - \frac{\beta - C\tau}{1 + u_3}\Pi\left[w(s - s_3), \frac{u_2 - u_3}{1 + u_3}, m\right]\right\},$$

$$\varphi = -\frac{\tau(C - A)}{A}s + \frac{1}{4A^2 w^2}\left\{\frac{\beta + C\tau}{1 - u_3}\Pi\left[w(s - s_3), \frac{u_2 - u_3}{1 - u_3}, m\right] - \frac{\beta - C\tau}{1 + u_3}\Pi\left(w(s - s_3), \frac{u_2 - u_3}{1 + u_3}, m\right)\right\}. \qquad \Pi(x, z, m) = \int_0^x \frac{\mathrm{d}y}{1 - z\,\mathrm{sn}^2(y, m)}$$

Forme de echilibru





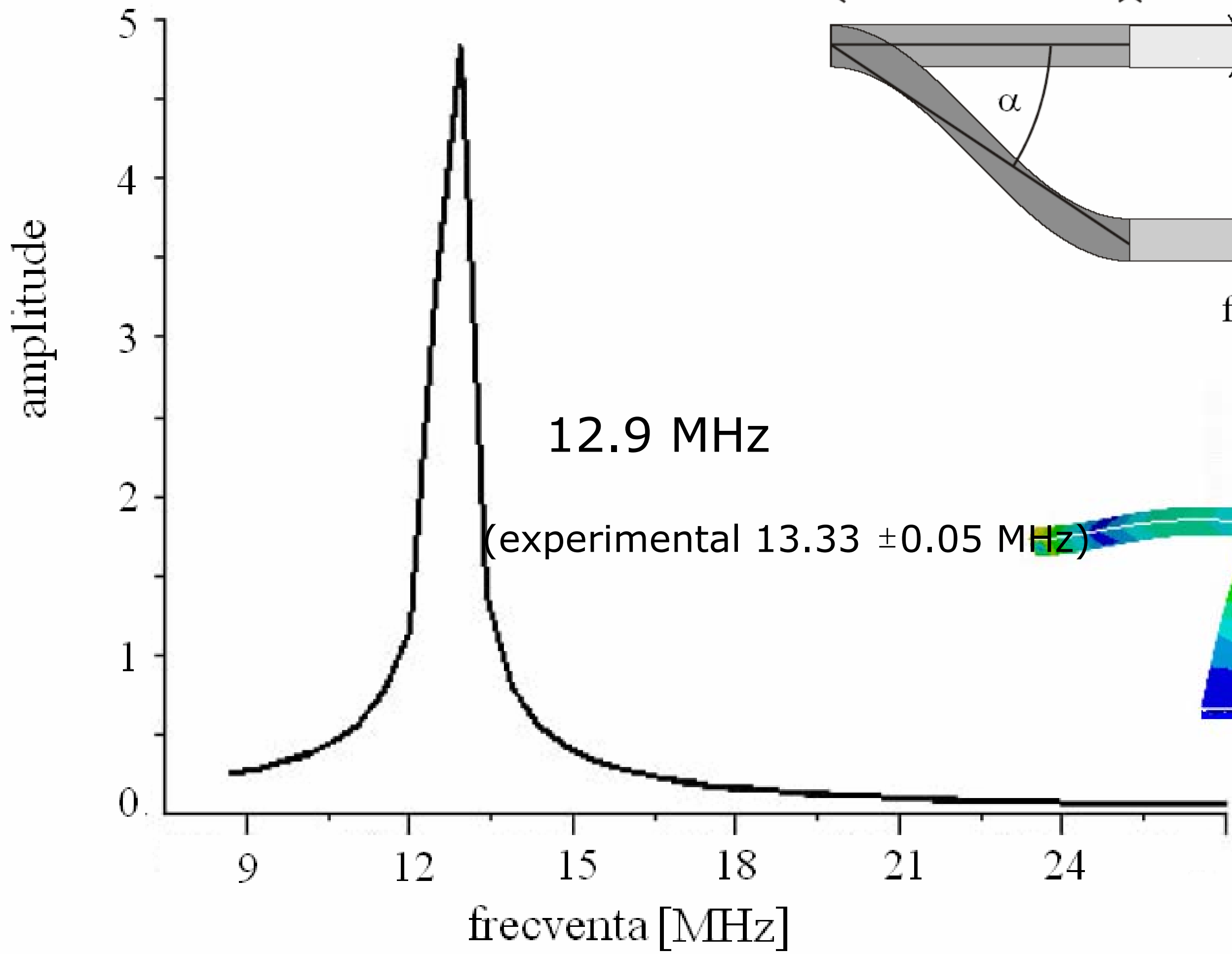


$$x = R\sin(\psi + \Delta) = R\sin\Phi \qquad y = R\cos(\psi + \Delta) = R\cos\Phi \qquad R = \frac{1}{\lambda_3}\sqrt{2|\lambda_3|Au + C^2\tau^2 A\gamma\beta^2} \qquad \Delta = -\arctan\left(\frac{A}{\beta u + C\tau}\sqrt{2f(u)}\right)$$

$$z = u_1 s - \frac{(u_1 - u_3)}{w}\mathrm{E}[\mathrm{am}(w(s - s_3)), m] \qquad E(am(v), m) = E(v, m) = \int_0^{\phi}\sqrt{1 - m\sin^2\theta}\;\; d\theta = \int_0^{v}\mathrm{dn}^2(y, m)dy \qquad \Phi = \frac{\beta}{2A}s + C_0\Pi(ws, C_1, m)$$

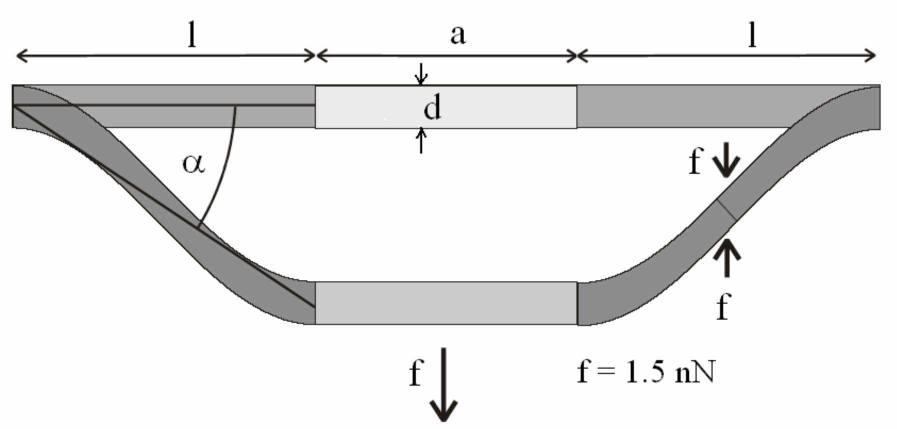
Frecventa de rezonanta I mod (translatie)

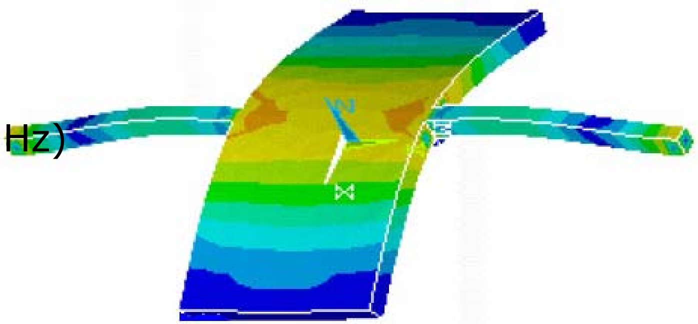
Distributia tensiunilor (Femlab)



12.9 MHz

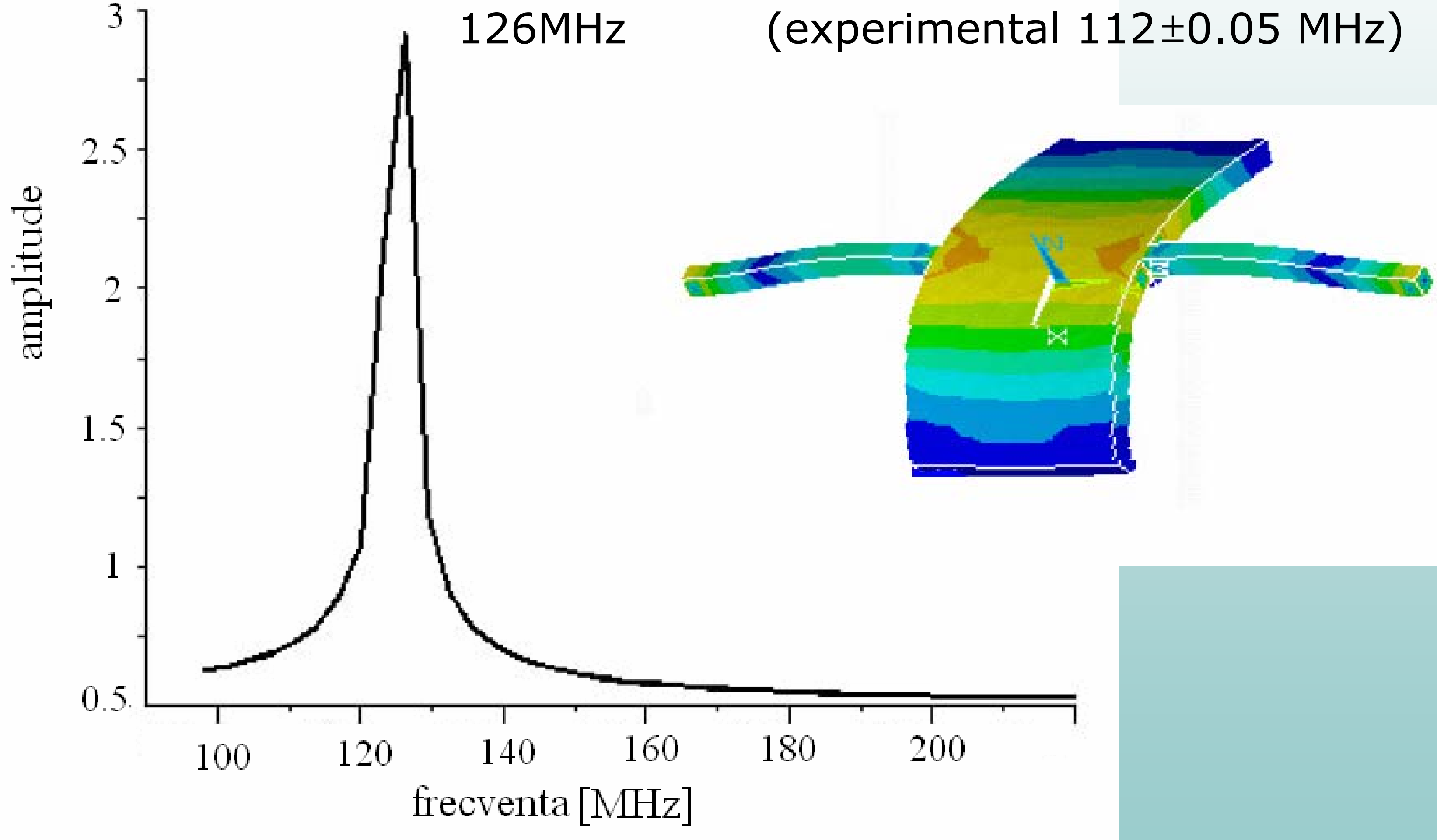
(experimental 13.33 ±0.05 MHz)





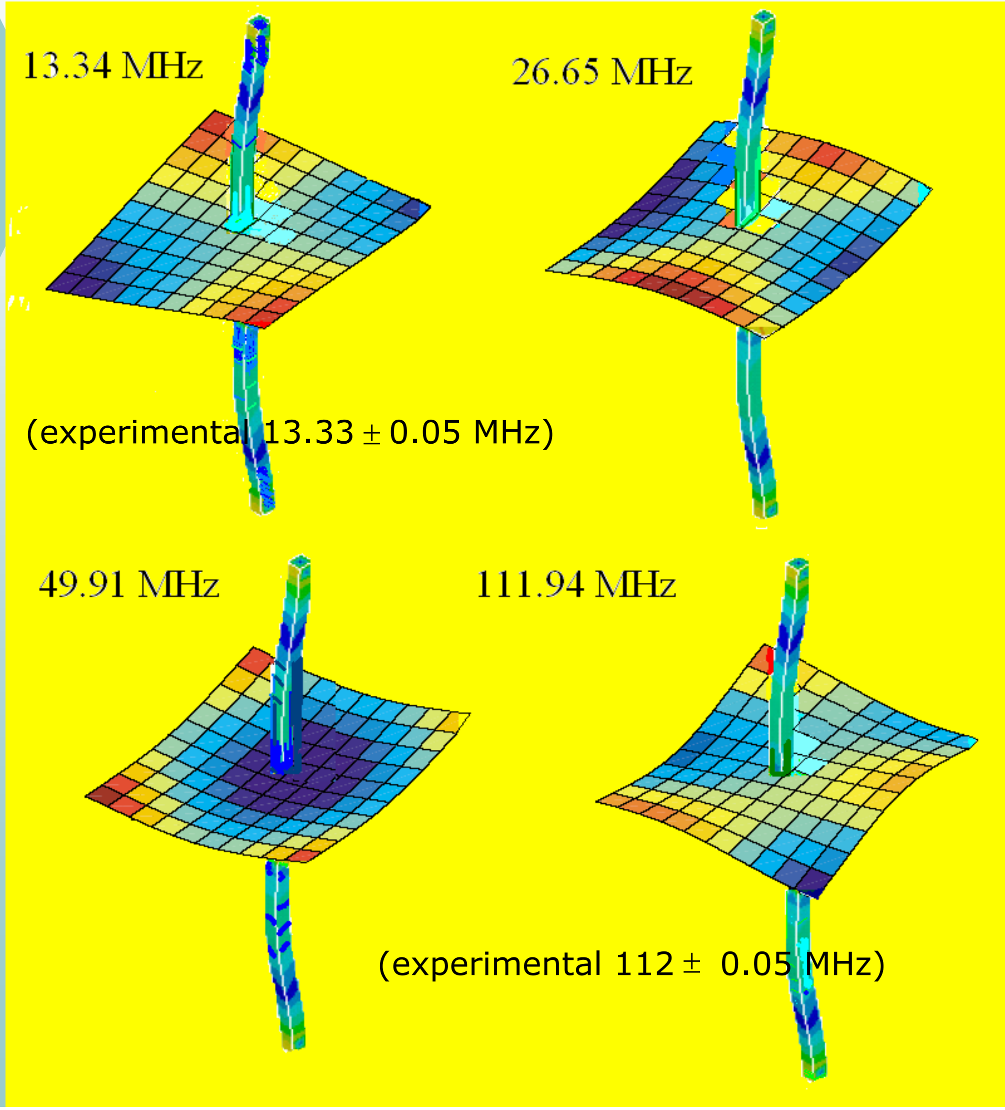
Frecventa de rezonanta II mod (translatie) | *Distributia tensiunilor (Femlab)*

126MHz (experimental 112±0.05 MHz)

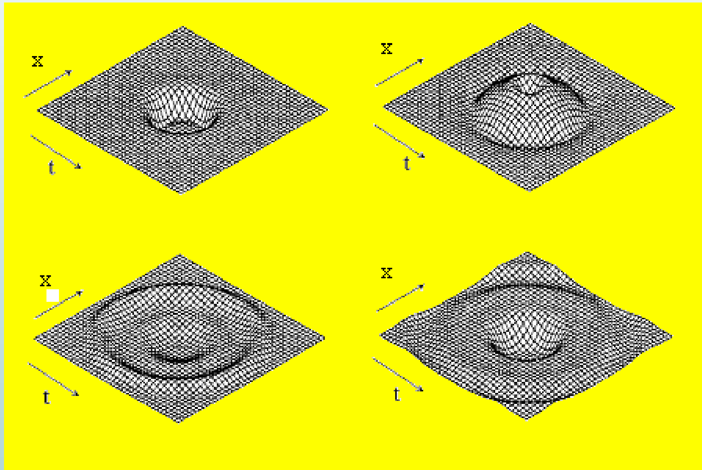


	Mod translatie	
	ecuatie	frecventa [MHz]
Olkhovets 2001	$f_0 = 0.22\sqrt{\frac{d^2c}{l^3ba}\frac{E}{\rho}}$	14.5
Dowell si Tang 2001 singur mod	$f_0 = 0.14\sqrt{\frac{d^2c}{l^3ba}\frac{E}{\rho}}$	9.3
Dowell si Tang 2001 multi mod	$f_0 = 0.19\sqrt{\frac{d^2c}{l^3ba}\frac{E}{\rho}}$	12.1
Duemling 2002	FEM- ANSIS	12.4
model neliniar CMP	Femlab	12.9
Experimental Evoy et al. 1999 Virginia Tech. Cornell Univ.		13.33 ± 0.05

Distributia tensiunilor (femlab) pt primele 4 moduri (translatie + incovoiere + torsiune)



Tensiunea normala ca functie de *s* si timp

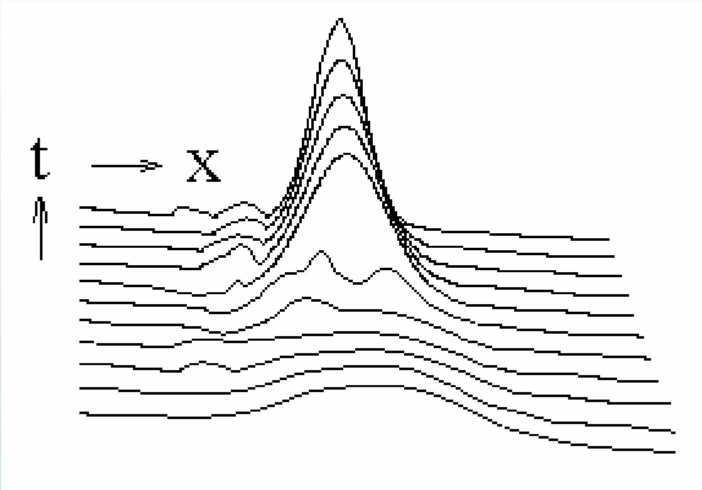


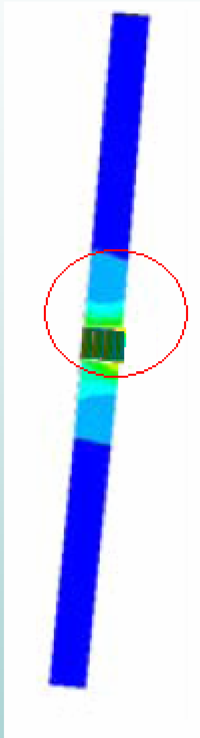
$$\frac{1}{2}\sigma'^{\,2}_{xx} = f(\sigma_{xx}(x,t))$$

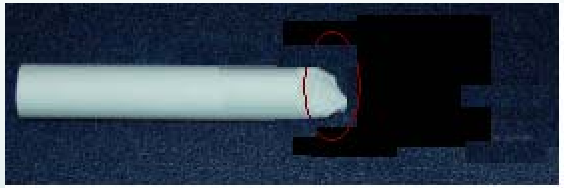
$$f(\sigma_{xx}) = -\frac{1}{A-k_1v^2}[\lambda_3\sigma_{xx}^{\;3} - \frac{1}{2}(\gamma - \frac{(C-k_2v^2)^2\tau^2}{A-k_1v^2})\sigma_{xx}^{\;2} -$$

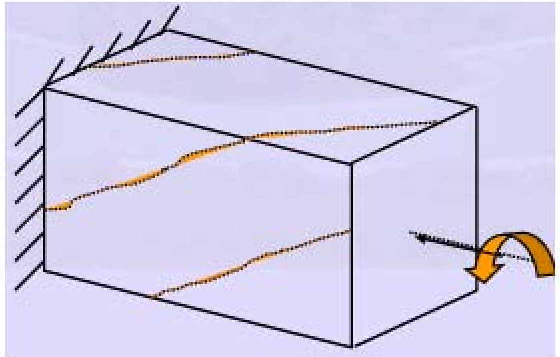
$$-\lambda_3\sigma_{xx} + \frac{1}{2}(\gamma - \frac{\beta^2}{A-k_1v^2})]$$

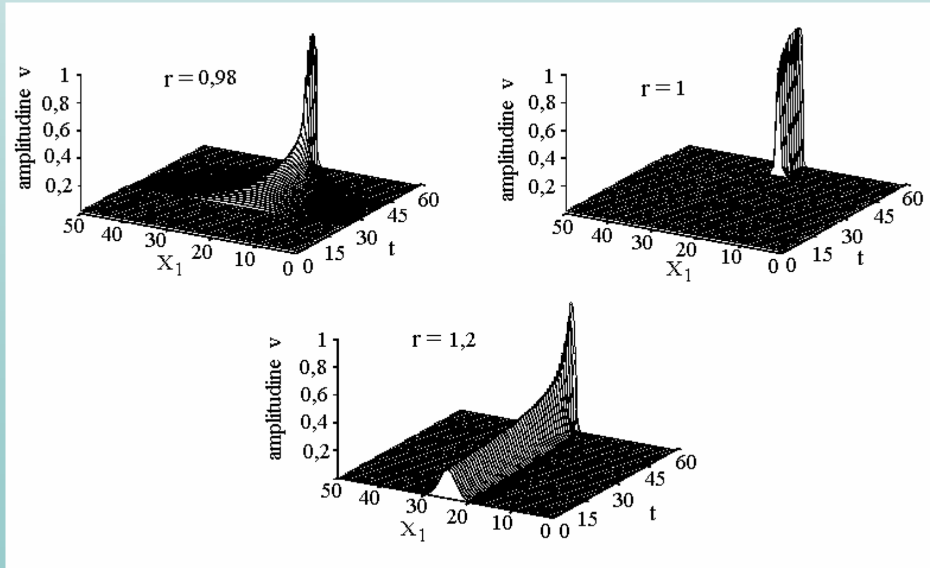
Rupere - dilatoni











Multumim pe aceasta cale CNCSIS PNII idei pentru sprijin financiar prin grantul nr.106/2007 ,cod 247/2007.

Concluzii

1. Se analizeaza paleta nanorezonanta. Paleta poate detecta deformatii la scara nanometrica, fapt pentru care este ideala pentru studiul proprietatilor electromagnetice si mecanice ale nanomaterialelor.

2. Spre deosebire de teoriile existente (in care paleta este considerata rigida si se scriu si se trateaza separat ecuatiile pentru translatie, incovoiere sau torsiune), in aceasta lucrare atat barele cat si paleta sunt corpuri elastice deformabile. Miscarea paletei este tratata *unitar*, scriindu-se un *singur set de ecuatii exacte neliniare ale miscarii paletei*. Se utilizeza *teoria solitonilor* pentru determinarea *solutiilor exacte ale acestor ecuatii*.

3. Noutatea lucrarii consta in determinarea primelor frecvente de rezonanta si a modurilor asociate. Rezultatele sunt mai apropiate de datele experimentale decat ale altor teorii, deoarece frecventele calculate nu reprezinta separat frecvente de translatie, incovoiere sau torsiune, ci reprezinta *unitar*, ca si in experiment, frecventele de rezonanta ale paletei.

4. Noutatea lucrarii consta in analiza ruperii barei la imbinarea cu paleta cu ajutorul *teoriei dilatonilor*

Bibliografie

1. L.Munteanu, St.Donescu, *Introduction to Soliton Theory: Applications to Mechanics*, Book Series “Fundamental Theories of Physics”, vol.143, Kluwer Academic Publishers, 2004.
2. V.Chiroiu, P.Ştiuca, L.Munteanu, St.Donescu, *Introducere in nanomecanica*, Eitura Academiei, 2005.
3. M.Duemling, *Modeling and characterization of nanoelectromechanical systems*, PhD thesis Virginia Polytechnic Institute and State Univ., 2002.
4. A.Olkhovets, *Nano Electro Mechanical Systems and their applications*, PhD thesis, Cornell UNiv., 2001.
5. E.H.Dowell, D.Tang , *Mathematical model of a nanopaddle oscillator*, J. Appl. Phys. 90, 11, 5606, 2001.
6. S.Evoy, D.W.Carr, L.Sekaric, A.Olkhovets, J.M.Parpia, H.G.Craighead, Nanofabrication and electrostatic operation of single-crystal silicon paddle oscillators, J. Appl. Phys. 86, 6072, 1999.
7. S.Evoy, A.Olkhovets, L.Sekaric, J.M.Parpia, H.G.Craighead, D.W.Carr, Appl. Phys. Lett. 77,2397, 2000.

8. J.Engelbrecht, *An introduction to asymmetric solitary waves*, Longman Scientific&Technical, John Wiley&Sons, New York, 1991.

9. S.N.Zhurkov, *Dilaton mechanism of the strength of solids*, Soviet Phys. Solid State, 25, 1797-1800, 1983.

10. Viorel-Puiu Păun, L.Munteanu, M.Agop, cap.14, *Transport phenomena at nanometer scale*, Research Trends in Mechanics, vol.3, Ed.Academiei (eds. D.Popa, V.Chiroiu, L.Munteanu), 2009.

11. P.P.Delsanto, L.Munteanu, V.Chiroiu, St.Donescu, *On the nanotorsional pendulum*, Proc. of the Romanian Academy, Series A: Mathematics, Physics, Technical Sciences, Information Science, 10, 3, 2009.

MULTUMIM PENTRU ATENTIE !!