Intrinsic Localized Modes in Nanocrystalline Arrays

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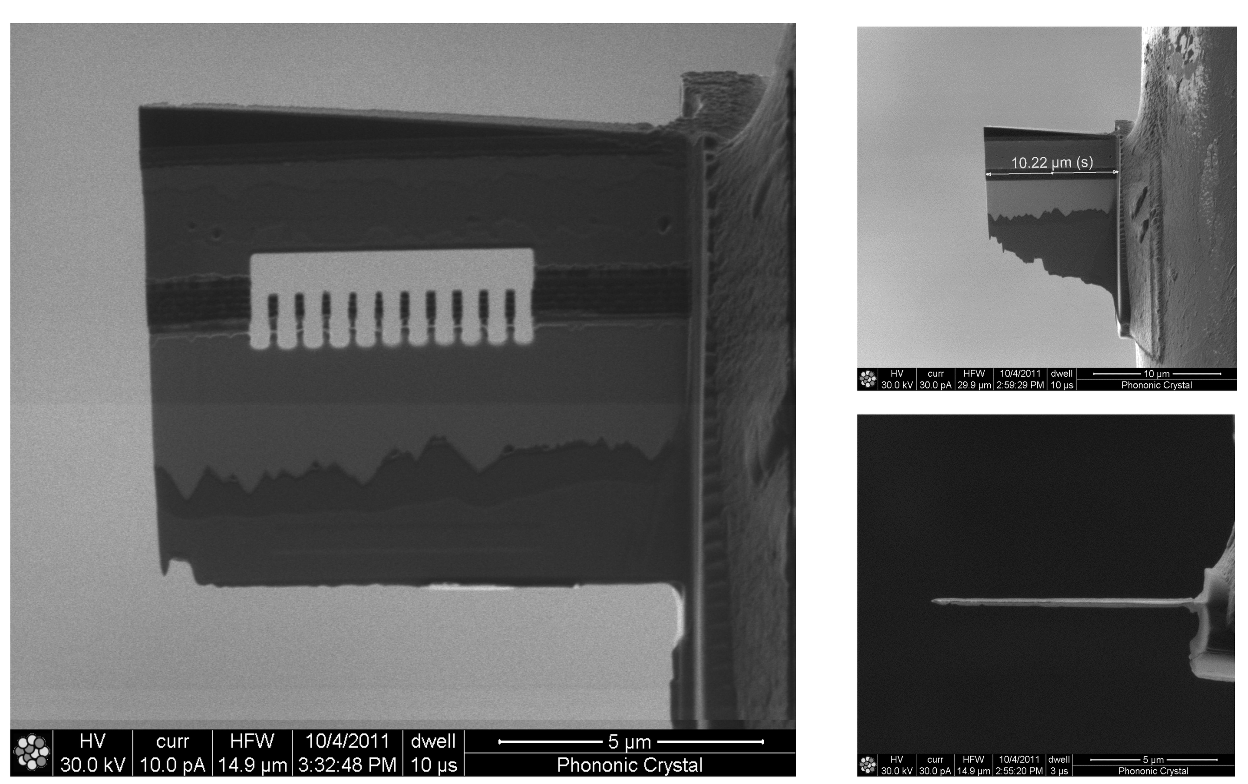
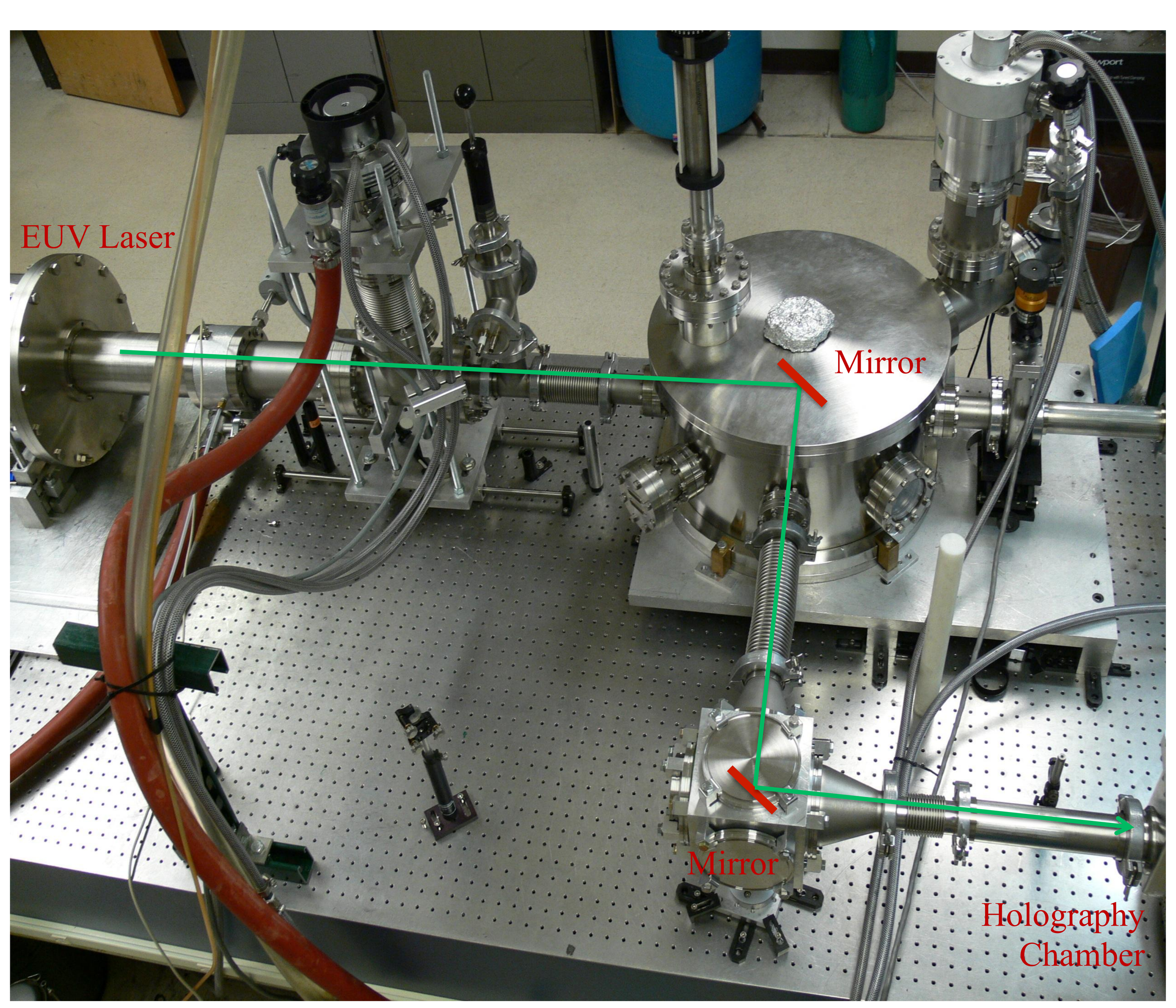
Motivation

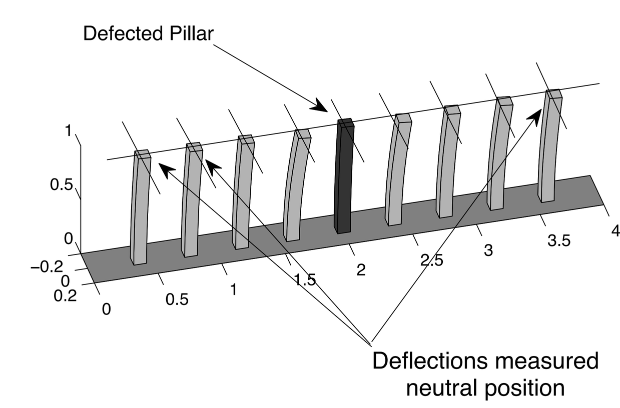
- Single Molecule Detection.
- Monitor amplitude envelope of array
- Intrinsic Localized Modes (ILMs) pin to defect locations.
- Molecule attaches to a pillar in the array -- shape of entire envelope will change.
- Use Fourier Transform Holography via EUV laser for real-time imaging.
- Use Gallium Arsenide (GaAs) crystals with square lattice.





Simulation

- Hamiltonian for the system of oscillators gives rise to the equations of motion.
- Potential energy functional is:



$$E_{pot} = E_2 + E_4$$

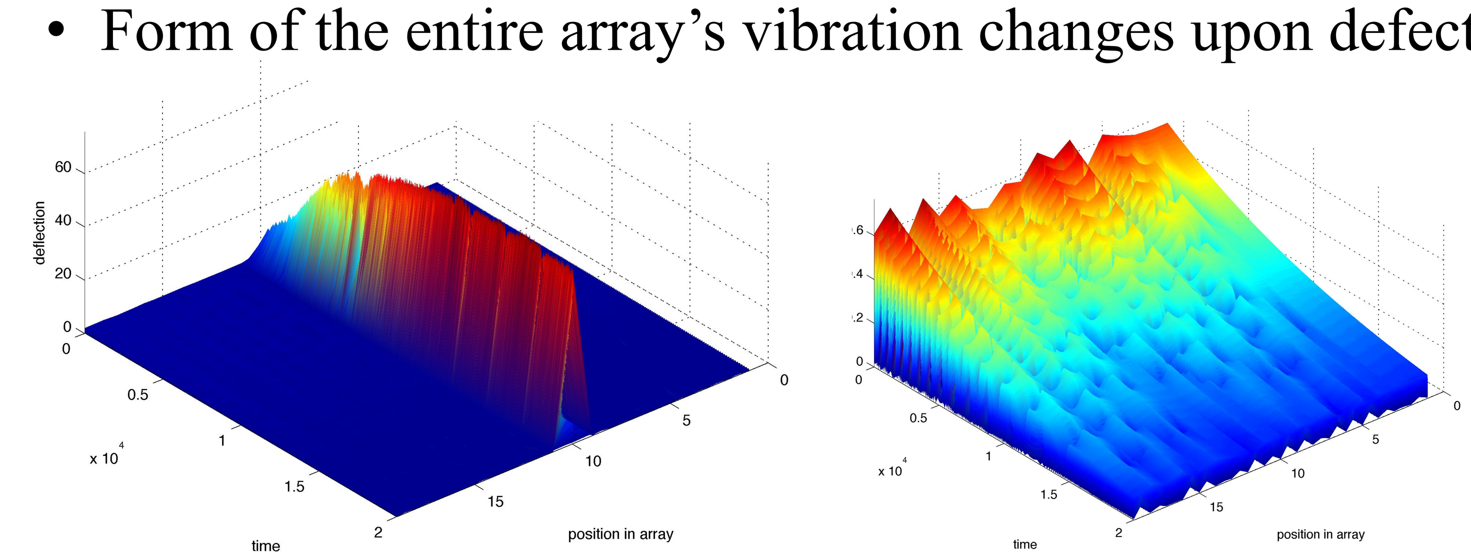
$$E_2 = \frac{1}{2}\sum_k \alpha_{1,x}u_{k,x}^2 + \alpha_{1,y}u_{k,y}^2 + \alpha_{2,x}\left(u_{k,x}-u_{k-1,x}\right)^2 + \alpha_{2,y}\left(u_{k,y}-u_{k-1,y}\right)^2 + \alpha_{3,y}\left(u_{k,x}-u_{k,y}\right)^2$$

$$E_4 = \frac{1}{4}\sum_k \beta_{1,x}u_{k,x}^4 + \beta_{1,y}u_{k,y}^4 + \beta_{2,x}(u_{k,x}-u_{k-1,x})^4 + \beta_{2,y}(u_{k,y}-u_{k-1,y})^4 + \beta_{3,x}(u_{k,x}-u_{k,y})^4$$

$$\ddot{u}_{x,n} = -\frac{\partial E}{\partial u_{x,n}} + friction + forcing \qquad \ddot{u}_{y,n} = -\frac{\partial E}{\partial u_{y,n}} + friction + forcing$$

Intrinsic Localized Modes

- ILM: special oscillatory mode which concentrates energy at one location in an array
- ILMs also `pin' to defects in an array.
- Form of the entire array's vibration changes upon defect



Left: x-direction of vibration
Right: y-direction

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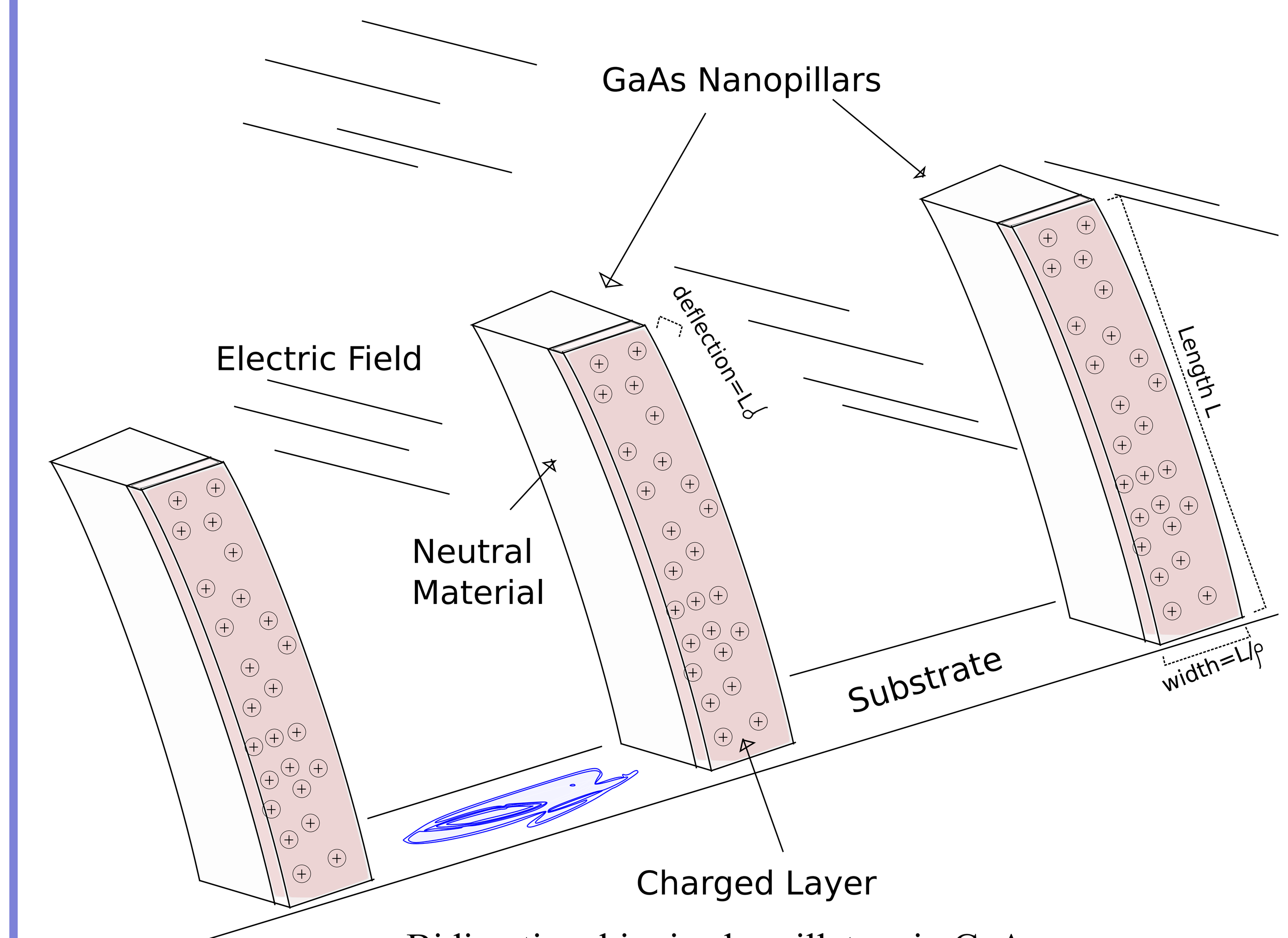
ILM Excitement

- Create Charged layer on one side of pillars
- Shoot ion beam at pillars
- Drive pillar array with electric field
- Breakdown Field of GaAs is ~ 4×10^7 V/m



Bidirectional ionized oscillators in GaAs nanocrystal array

- Length of pillars $= L$ [nm]
- Ratio length:width $= k$ [dimensionless]
- Deflection $= u$ [nm]
- Max deflection $= L\delta$ [nm] (δ is percent)

- Strength of field needed:

$$E_{field} = \frac{\delta}{k^3}\cdot 4.65\times10^{11}\ \text{V/m}$$

Deflection percent δ	Aspect ratio k	Electric field E
0.01	40	73.20 KV/m
0.01	100	4.65 KV/m
0.005	100	2.32 KV/m