



FEM based Estimation of Biological Interaction Using a Cantilever Array Sensor

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Abstract

- Nano fabricated cantilever array sensors
 - Applications in microcircuits and in estimating biological interaction.
 - Disease causing antigen in blood serum.
 - Antibody is immobilized using a Au-SH linkage.
 - When a antigen of attomolar concentration sits on the cantilever beam it creates a load in the order of femto newtons.



IgG

- Abundant protein
- 8-17 mg/mL – adult human blood
- Acts as a defense against micro organism



Introduction

- Force sensors -- force sensitivity in pN range
- Deflection -- Molecular adsorption, thermal effects, electric and magnetic fields, and fluid flow.
- Adsorption-induced deflections -- free energy change -- observed when a differential adsorption.
- Two modes of vibration
 - Static mode
 - Dynamic mode

Static mode

- Deflection
 - surface stress changes
 - analyte interaction

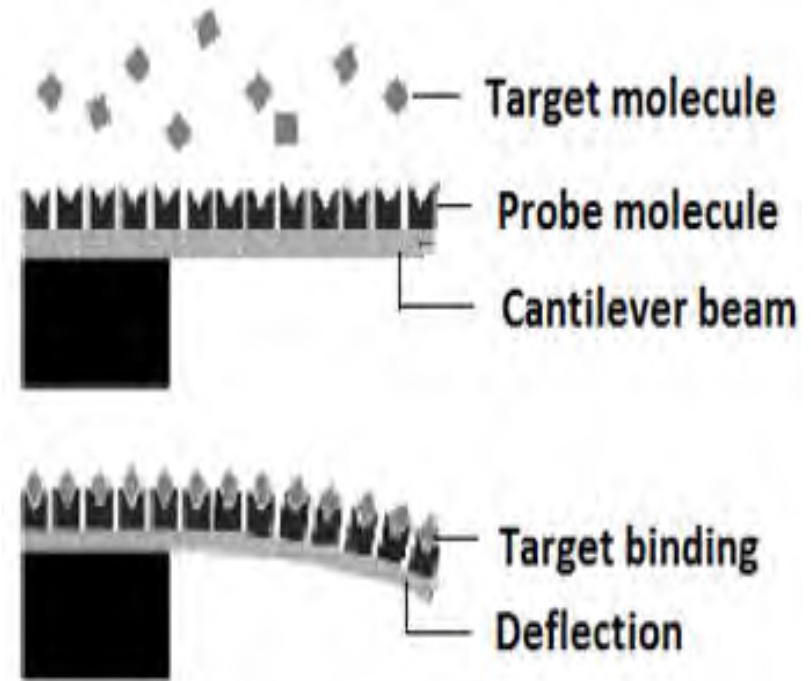


Illustration of static mode sensing

Dynamic mode

- Resonance frequency
- Target analyte interaction
- Oscillates at lower frequency
- Sensitivity is high

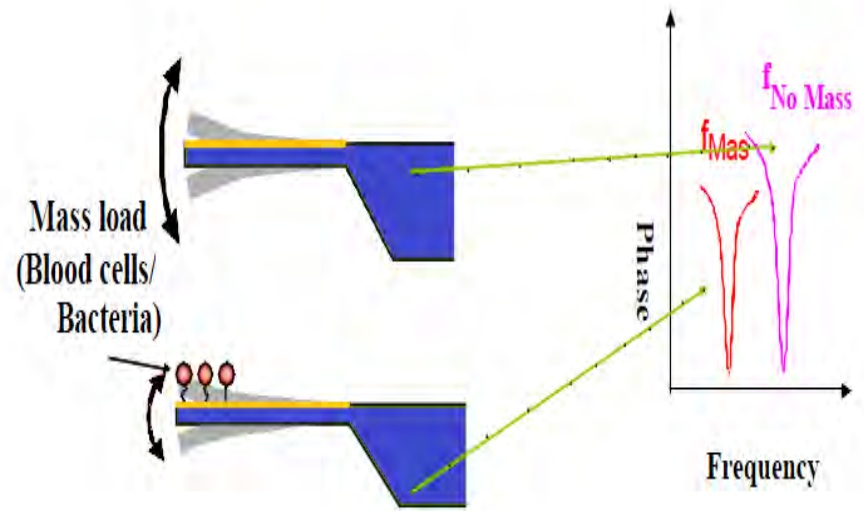


Illustration of dynamic mode sensing

Domain Equations

- Small periodic driving forces can produce large amplitude vibrations
- Mass Sensitivity
- Mass sensitivity \uparrow --
 \downarrow cantilever size.

$$f_n = \frac{\lambda_n^2}{2\pi \sqrt{12}} \frac{t}{L^2} \sqrt{\frac{E}{\rho (1 - \nu^2)}} \quad (n=0,1,2,\dots)$$

$$S_m = -\frac{\Delta f}{\Delta m}$$

$$S_m = \frac{\Delta f_n}{\Delta m} \cong \frac{1}{2} \frac{f_n}{M_e}$$

$$M_e = 0.236 Lwt\rho$$

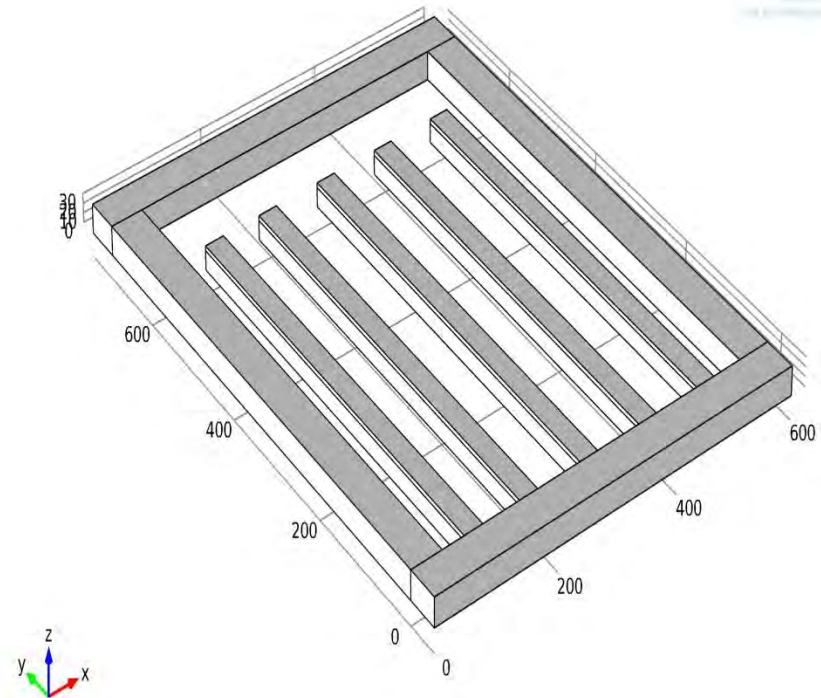
Geometrical Design

- **Materials**

- Gold(Au)
- Silicon Nitride (Si_3N_4)
- Thiol end group (fab-protein)

- **Physics Used**

- Solid Mechanics physics
- Displacement -- binding antigen
- Advantage – it can sense even in nano liters range





Force exerted on the cantilever surface

- Molecular weight of a single anti IgG – 150kDa
- 1kDa – 0.16604×10^{-20} g
- Force – $m * a$



Simulation Results



- **Result 1:**

- The displacement of the cantilever is maximum when the concentration of the analyte binded is more

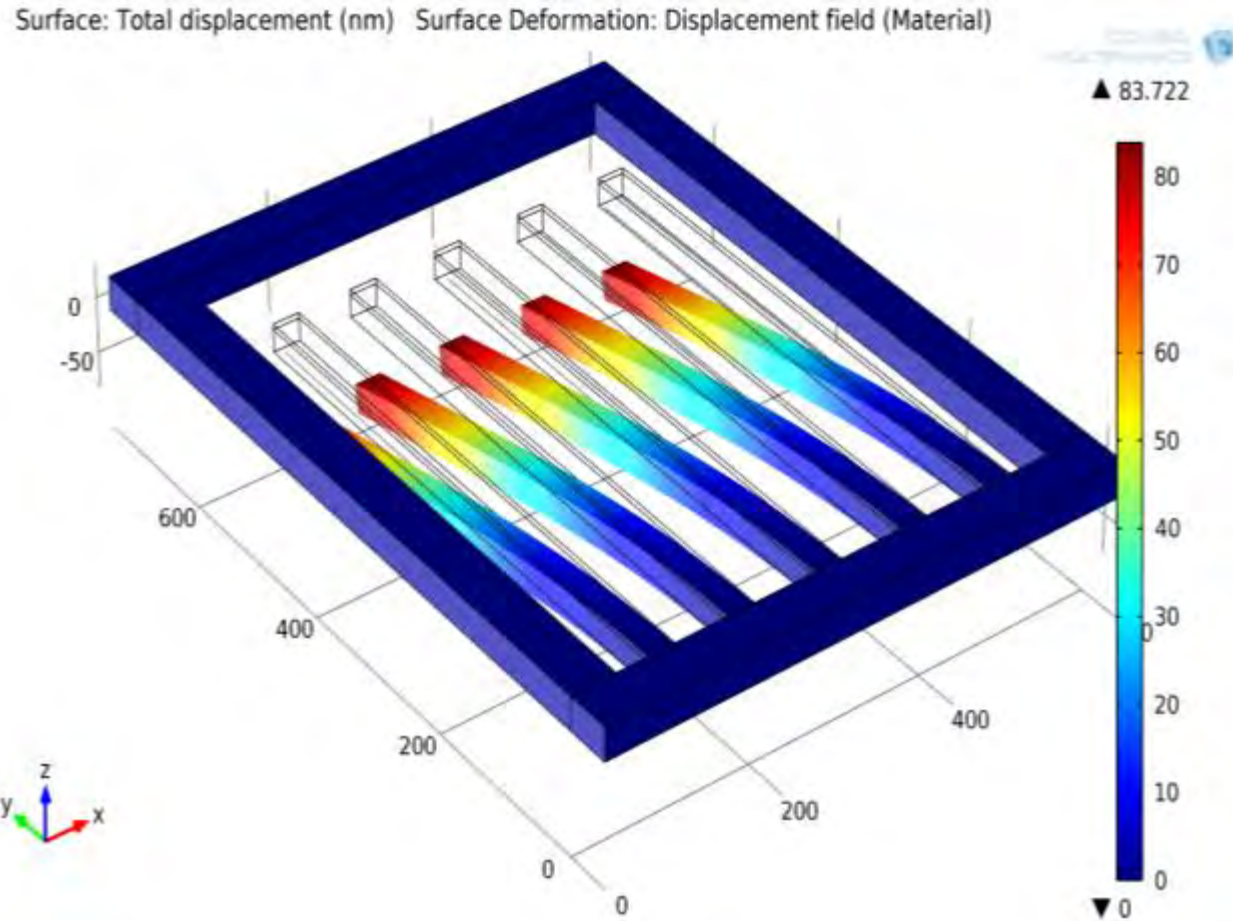
- **Result 2:**

- The resonant frequency of the nano cantilever, changes as the analyte to be sensed attaches to the nano cantilevers

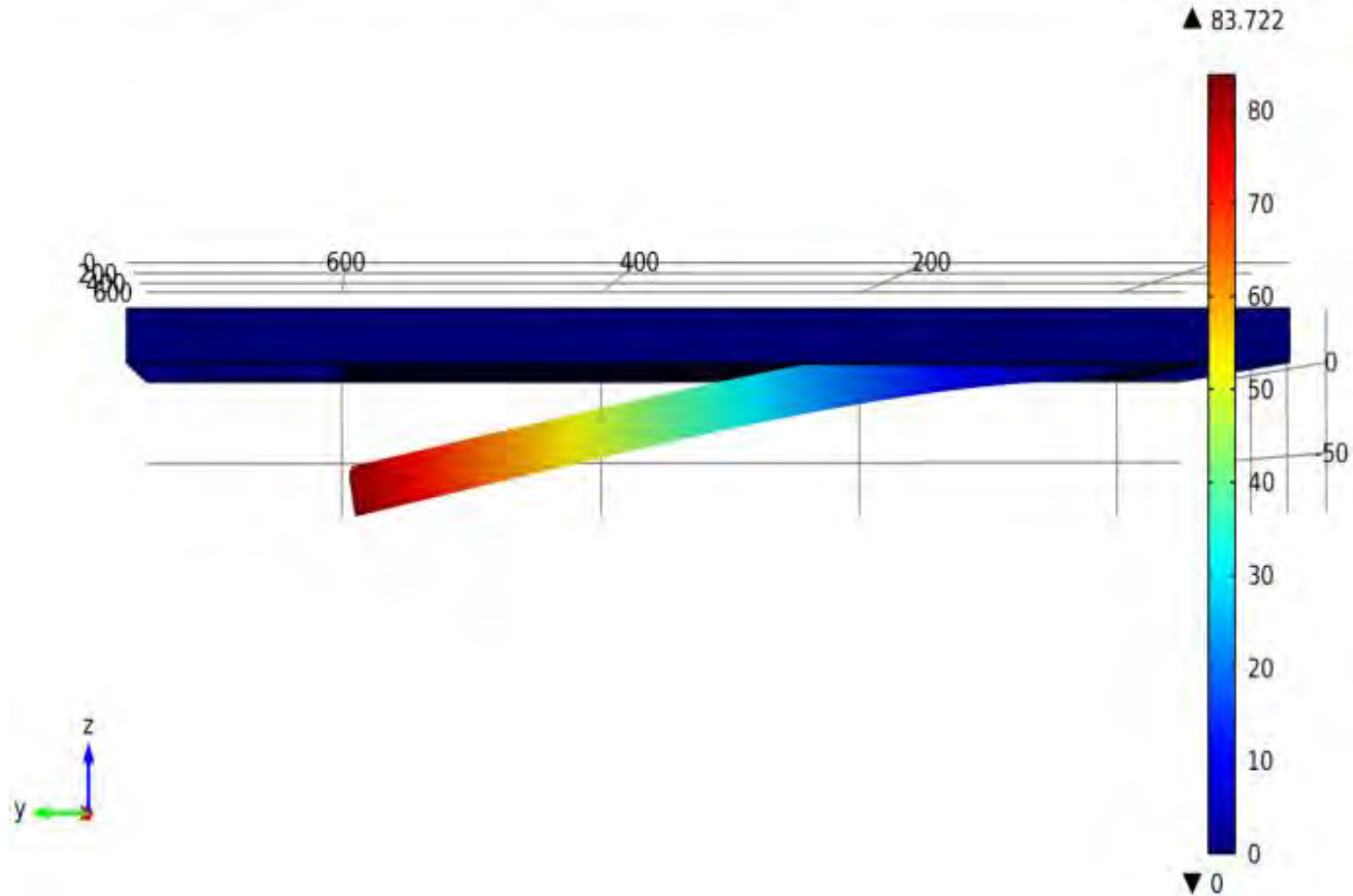
Simulation output for various analyte concentration

S.No	No of molecules	Force applied (nN)	Displacement (nm)
1.	10	24.407	28.731
2.	15	36.611	42.990
3.	20	48.814	57.383
4.	25	61.018	71.564
5.	30	73.220	85.266
6.	35	85.425	99.5

3D view of the Displacement field

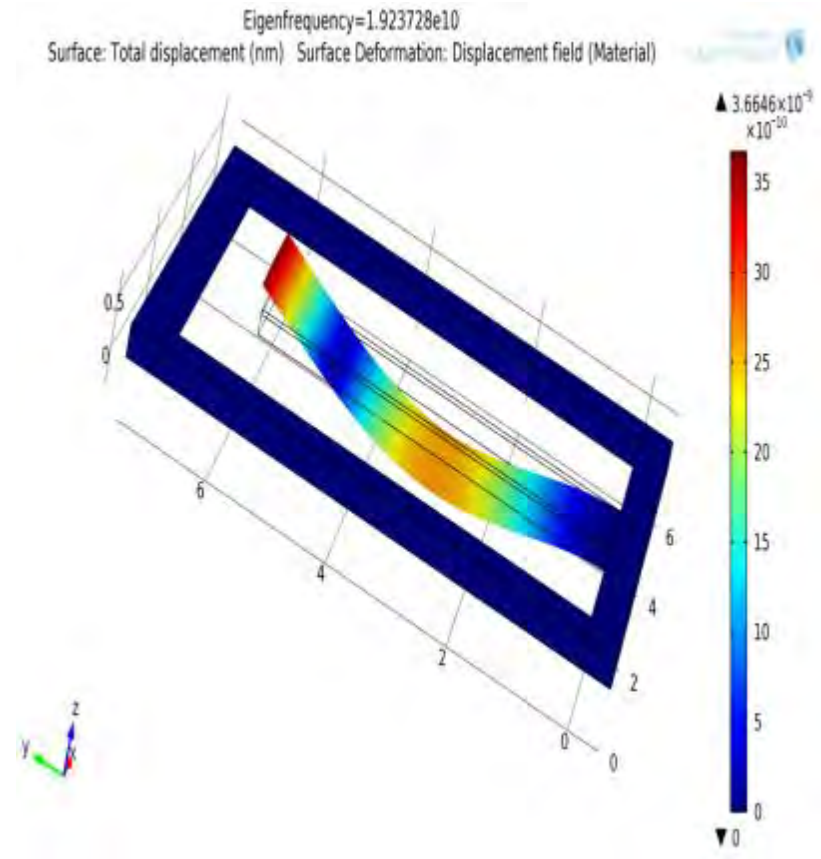
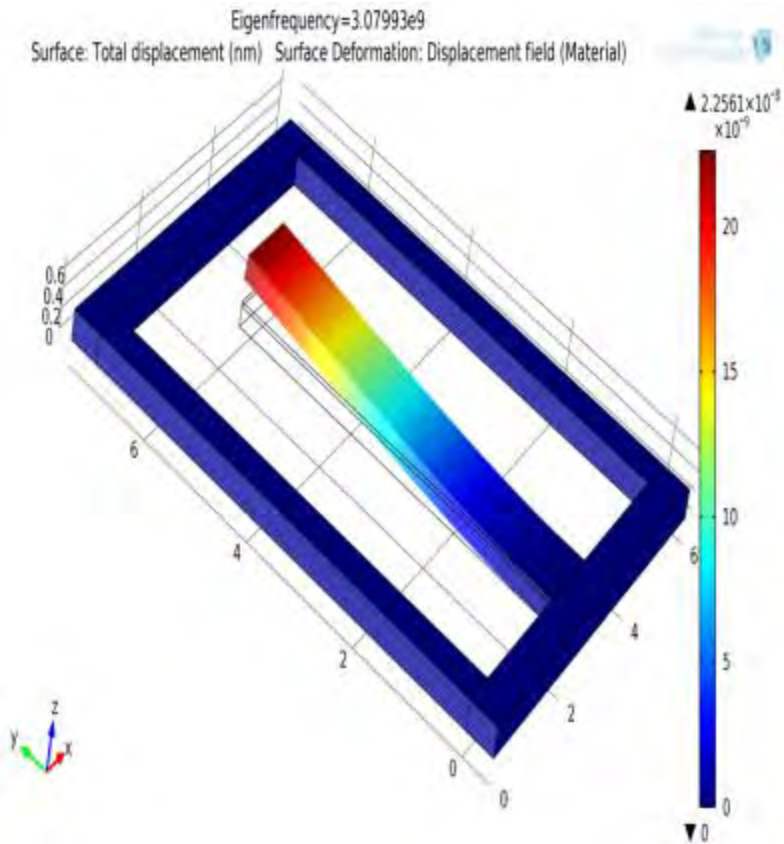


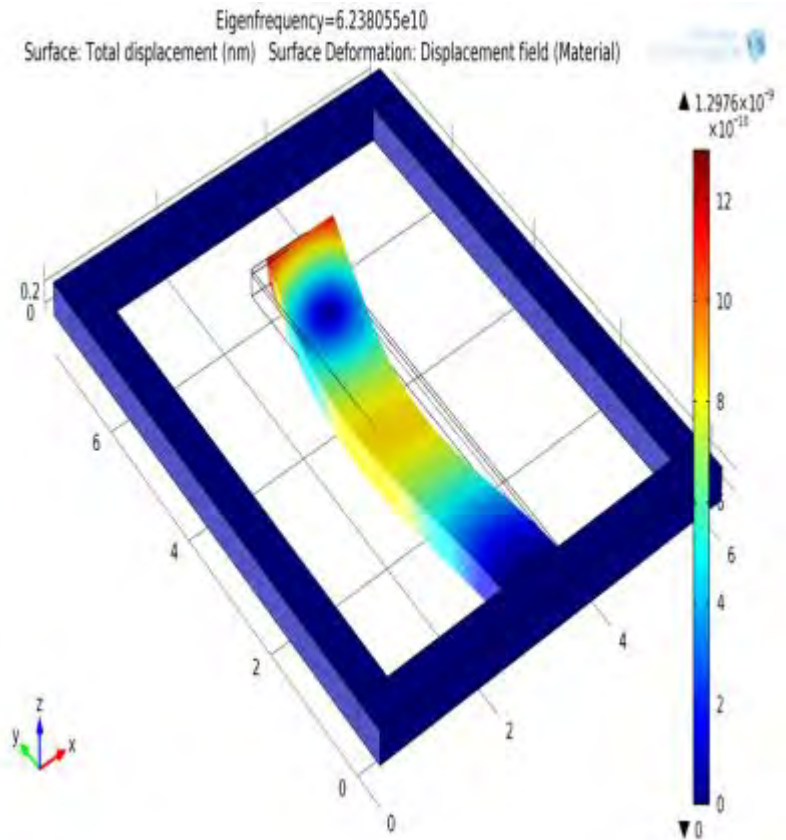
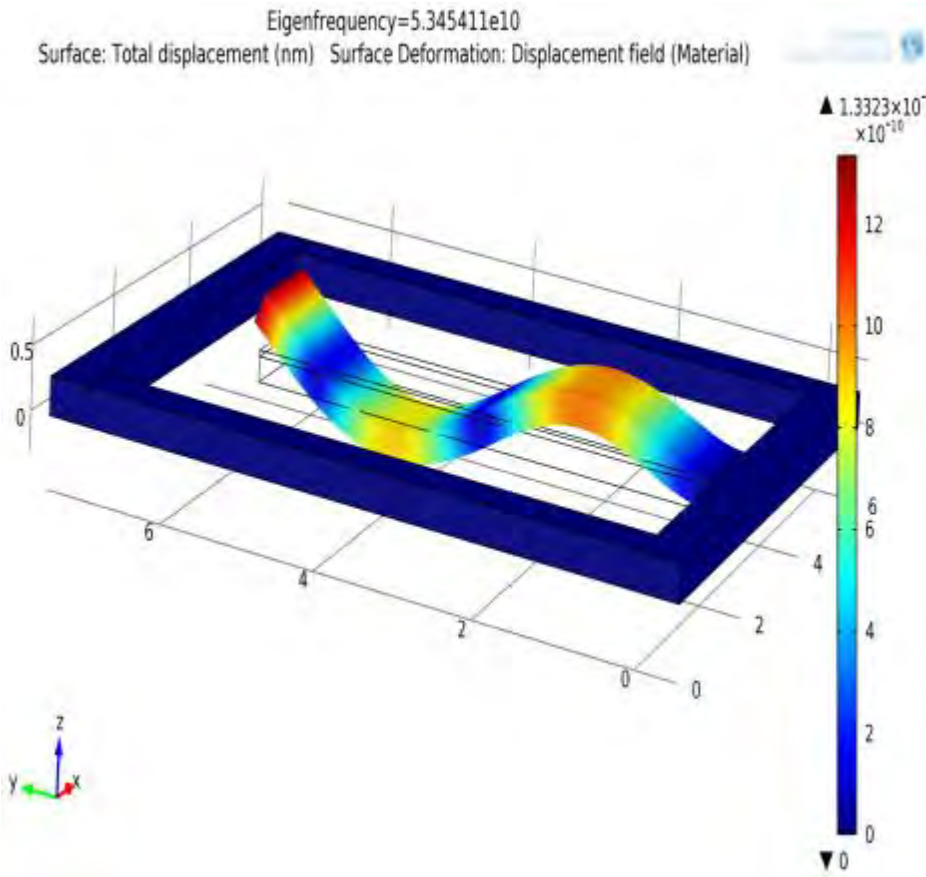
Surface: Total displacement (nm) Surface Deformation: Displacement field (Material)

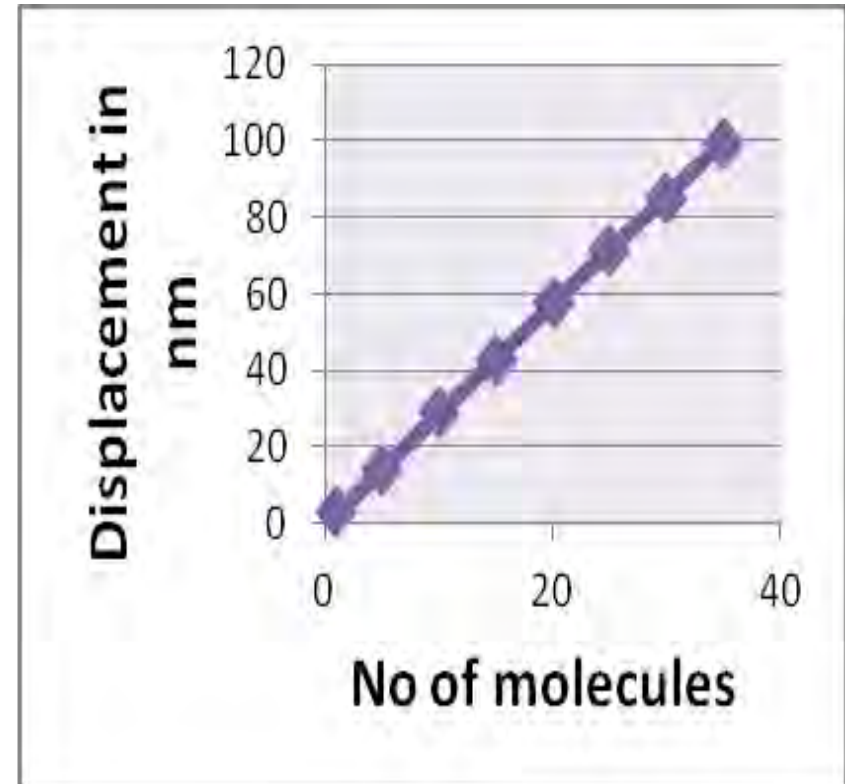
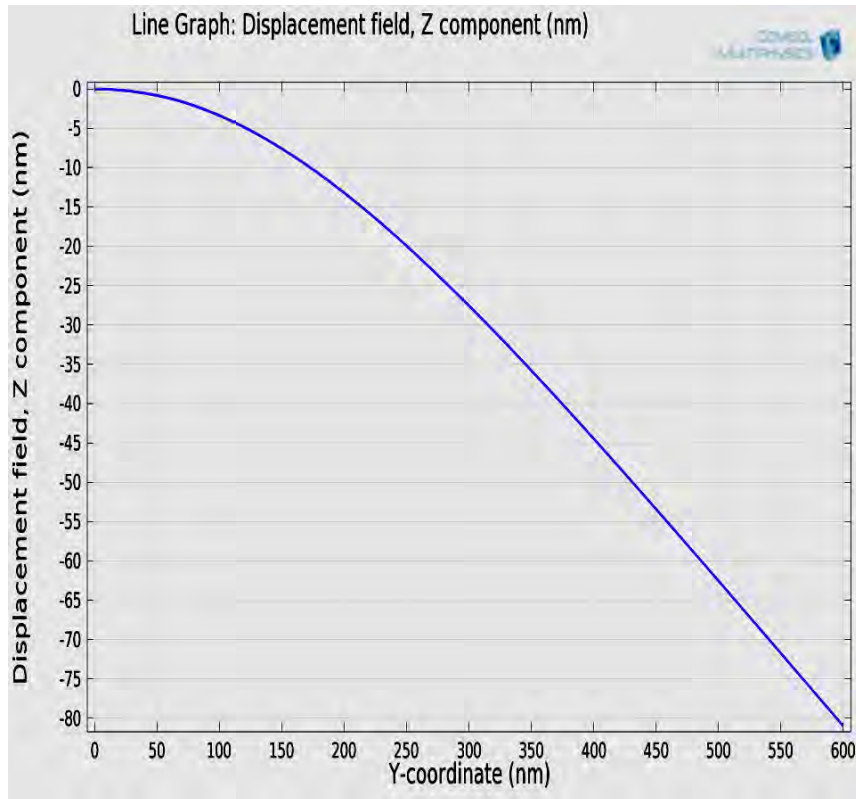


2D view

Modes of vibration







Maximum deflection of the cantilever from its free position

Displacement of the cantilever array with respect to number of molecules interacted with the surface

Conclusion

- So far we have seen how a cantilever array sensor can be used as a estimator for biological interactions with high specificity to target molecule and selectivity towards the particular analyte.
- A design holds for higher sensitivity, stability, repeatability and recurrence.

References

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