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A Novel Plug n Play MEMS-Based DNA Microarray

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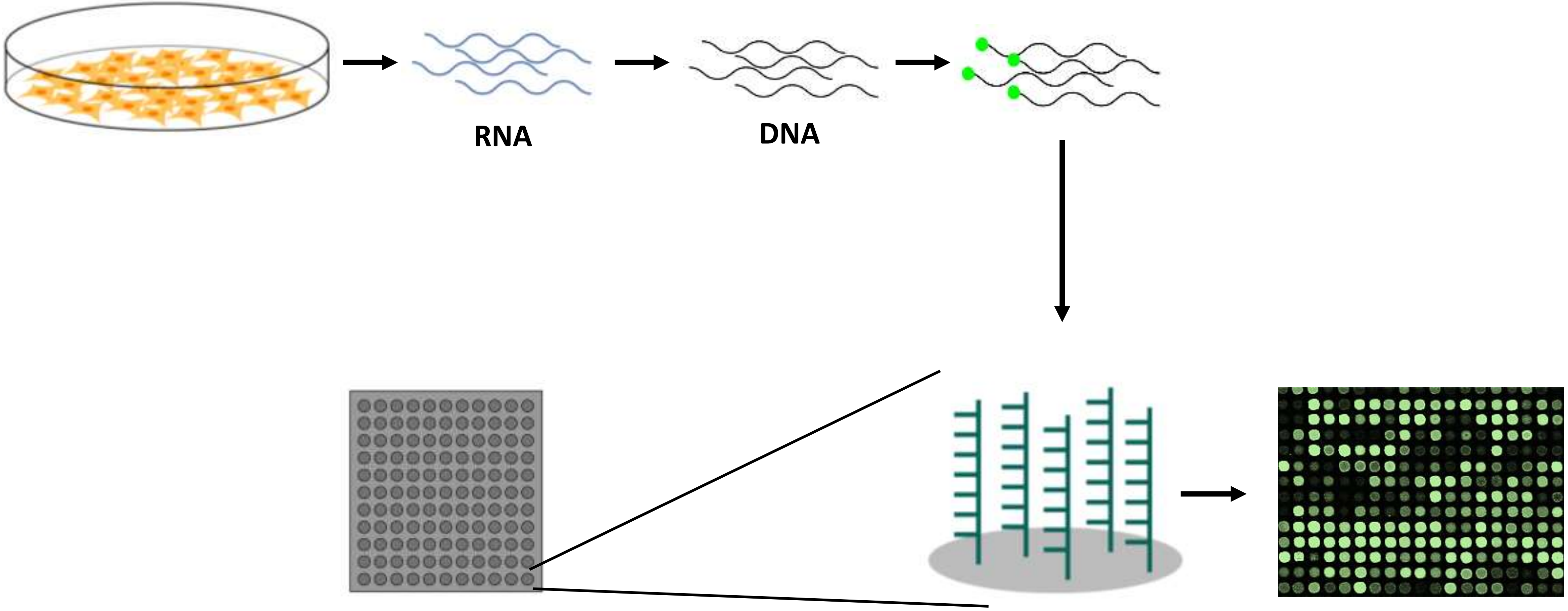
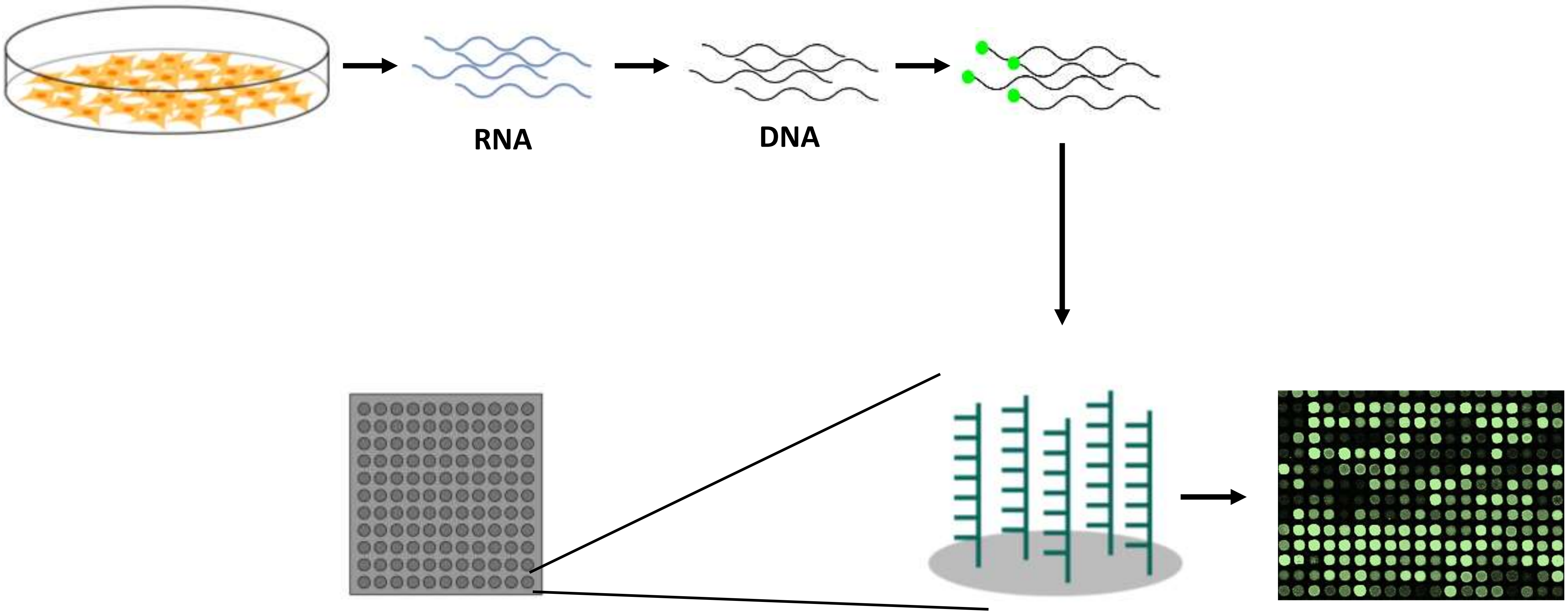
A typical microarray experiment

- Microarrays are used to determine expression levels of **thousands of genes in a sample of cells at once.**

A typical microarray experiment

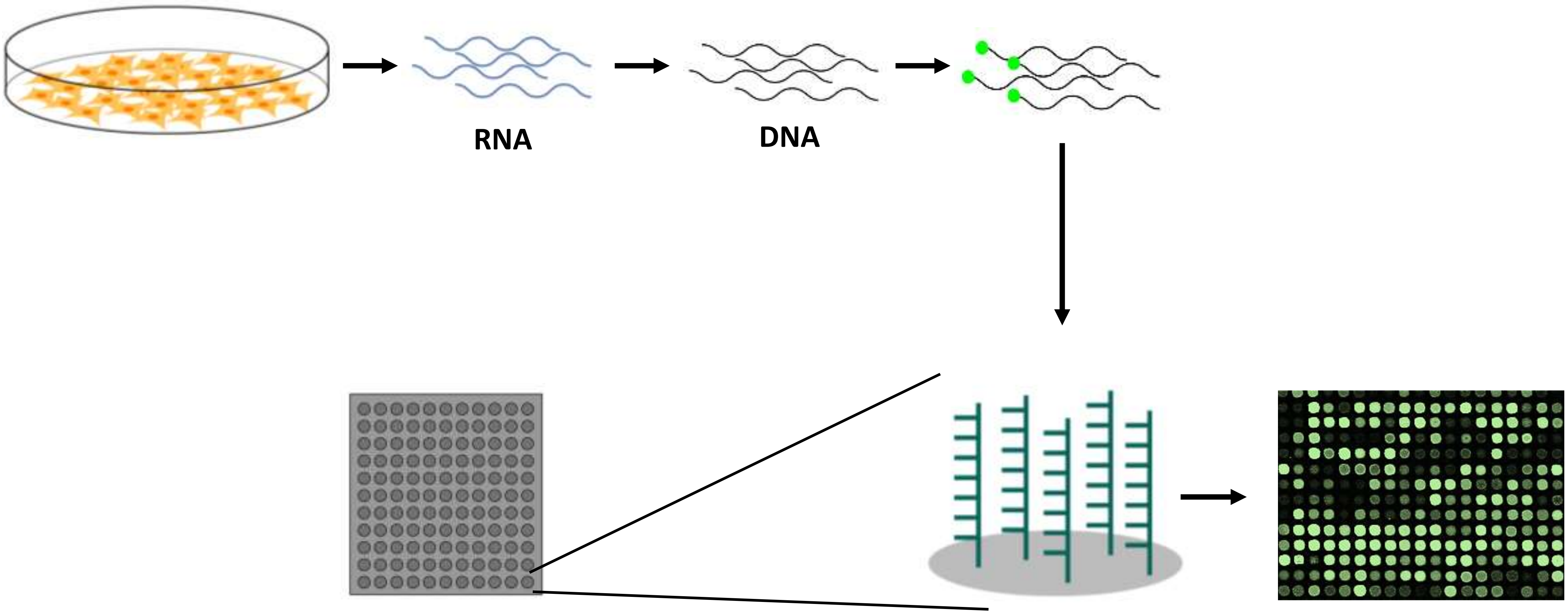


A typical microarray experiment



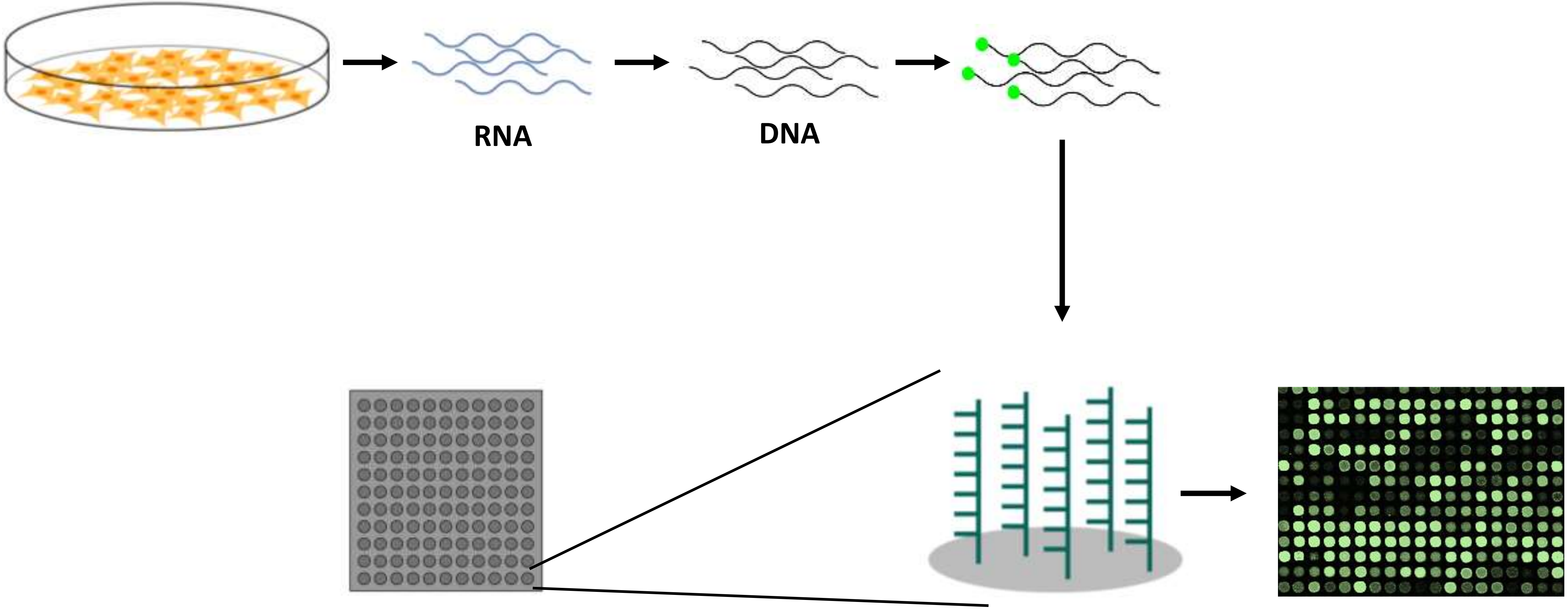
DNA → Fluorescence → Electrical Signal

A typical microarray experiment



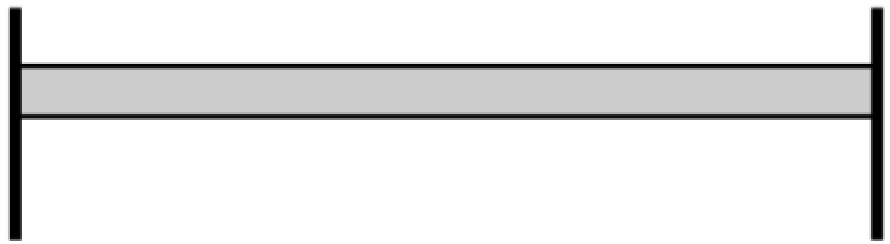
DNA → Fluorescence → Electrical Signal

A typical microarray experiment

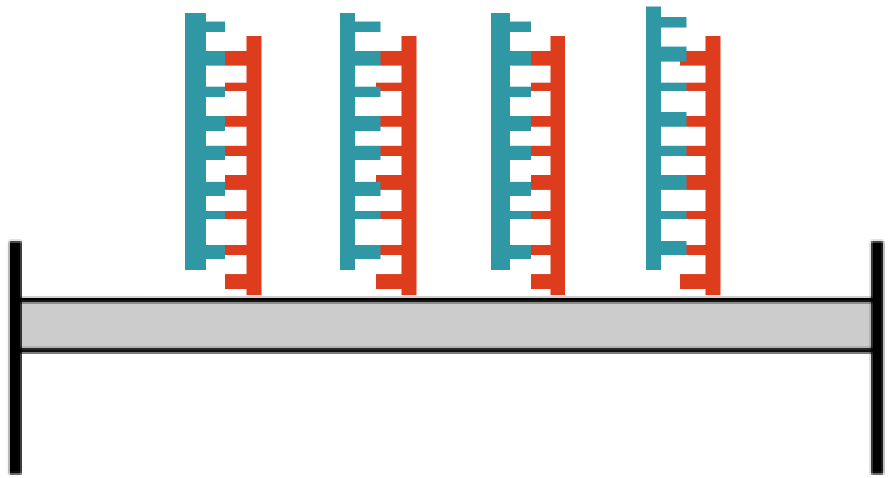


DNA → Electrical Signal

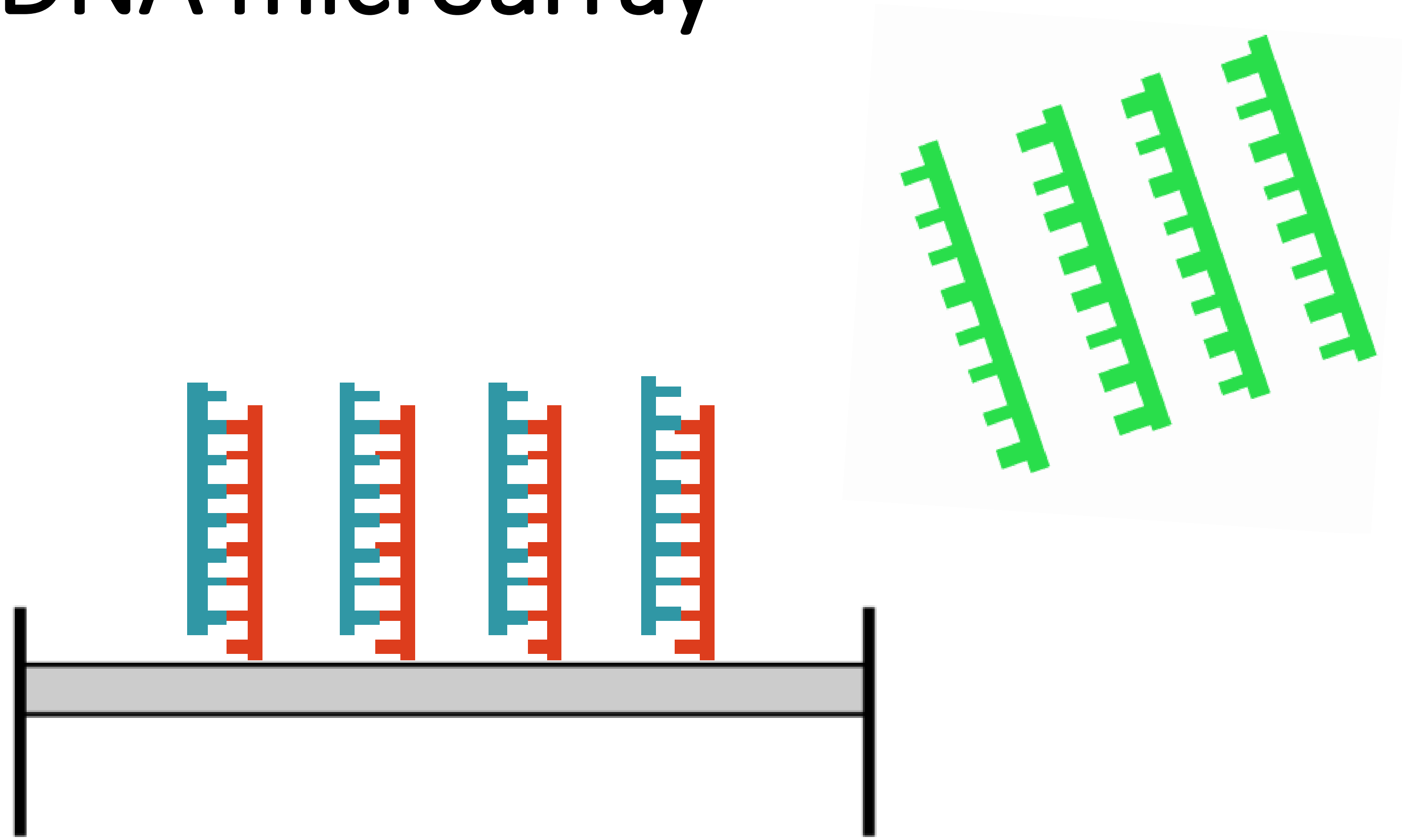
MEMS based DNA microarray



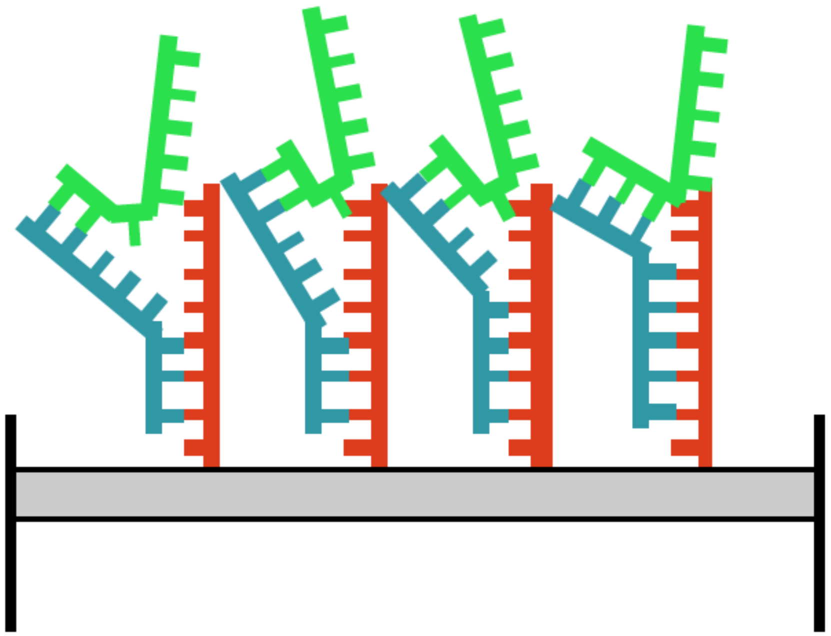
MEMS based DNA microarray



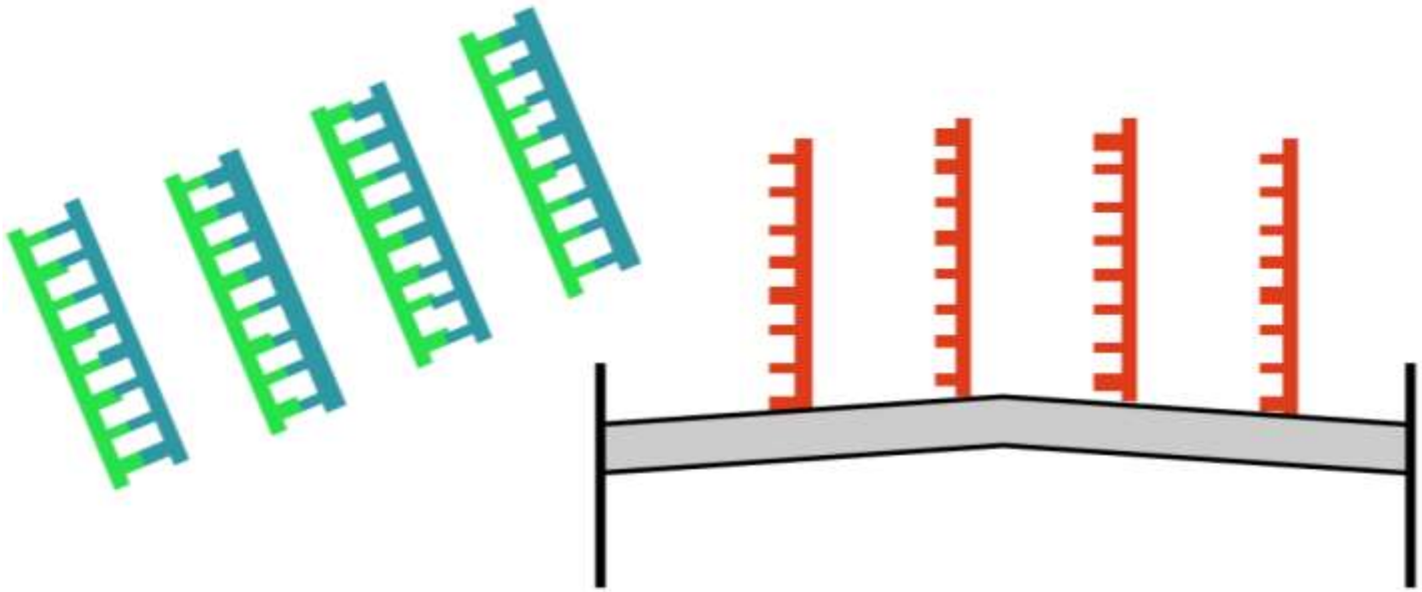
MEMS based DNA microarray



MEMS based DNA microarray

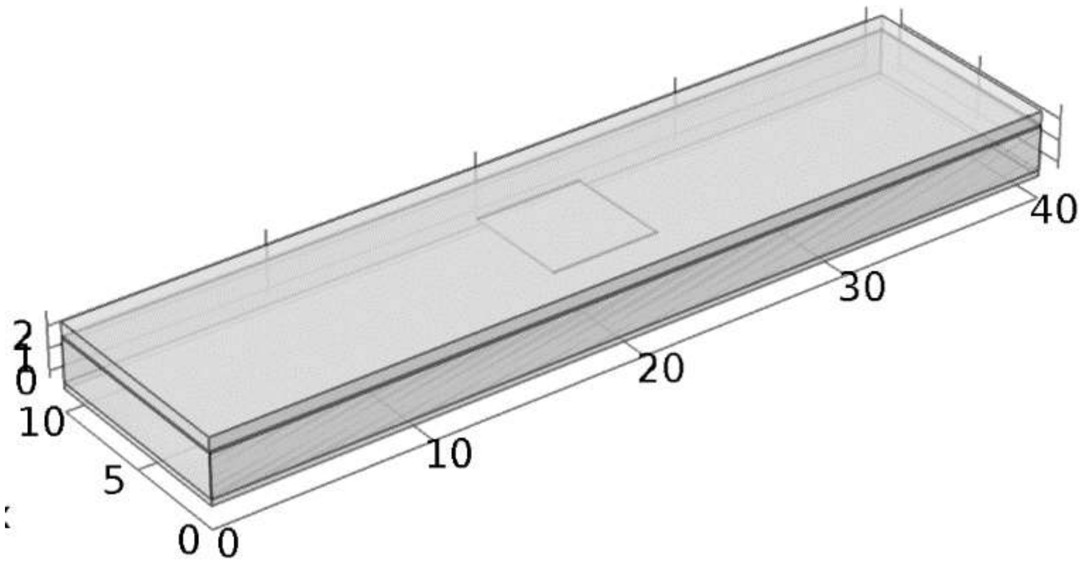


MEMS based DNA microarray



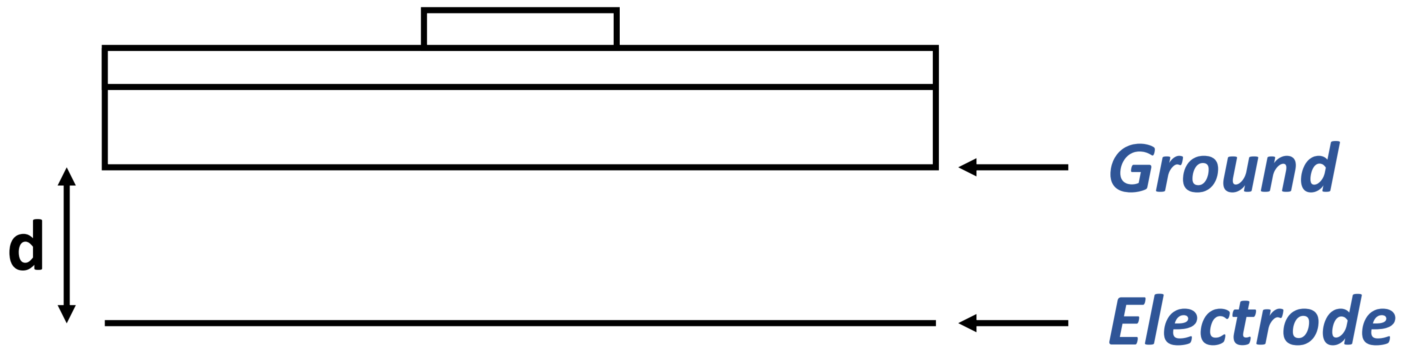
Geometry of the sensor

- Clamped-clamped beam which acts as a resonant mass sensor.
- The base is made of silicon, a piezoelectric layer of PZT atop the base and a patch of silica on the top.
- Capacitive actuation; bottom face grounded and electrode placed a certain distance below it.



Component	Dimensions (l x b x h) (um)
Silicon Base	40 x 10 x 2
Piezoelectric Transducer (PZT)	40 x 10 x 0.1
Silica Patch	5 x 5 x 0.1

Design of Actuation Circuit



DC pre-stressing voltage: 40V

AC actuating voltage: 1V

- When an AC voltage is applied on the electrode, the force on the ground plate varies sinusoidally, hence leading to vibration of the sensor.
- Actuation circuit was designed so that the sensor gives an output of ~100μV peak to peak at resonance.

Design of Actuation Circuit

Peak voltage across sensor →

$$V_{sensor} = \left(\frac{d_{31}Yb}{C}\right)\int_l \varepsilon_1 dx$$

$$\varepsilon_1 = \frac{3F}{YbH^2}\left[1 - \frac{x}{l}\right]$$

$$F = \frac{\varepsilon_0 A V_{AC} V_{DC}}{d^2}$$

→ Plate separation

Plate separation obtained: 286nm

Damping

- Rayleigh damping model was assumed and damping coefficients were calculated using the following equation:

$$\begin{bmatrix} 1/4\pi f_1 & \pi f_1 \\ 1/4\pi f_2 & \pi f_2 \end{bmatrix} \begin{bmatrix} \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix}$$

- α = 53615.8643 1/s
- Β = 1.2275e-11 s

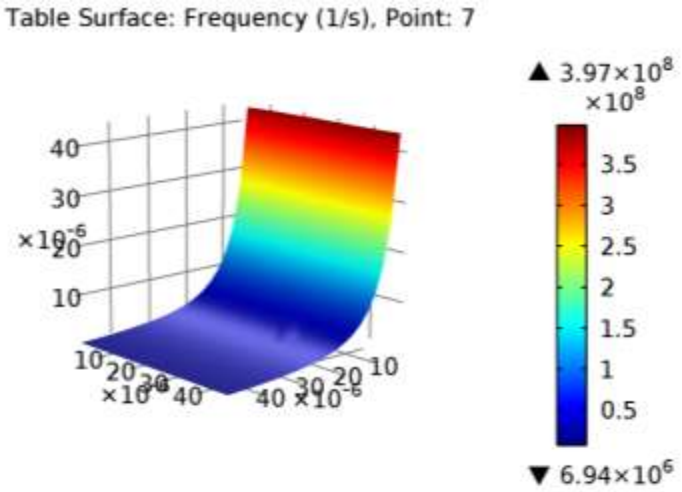
Resonant frequency-mass relation

- The new resonance frequency can be found out in terms of the existing resonance frequency and change in mass as:

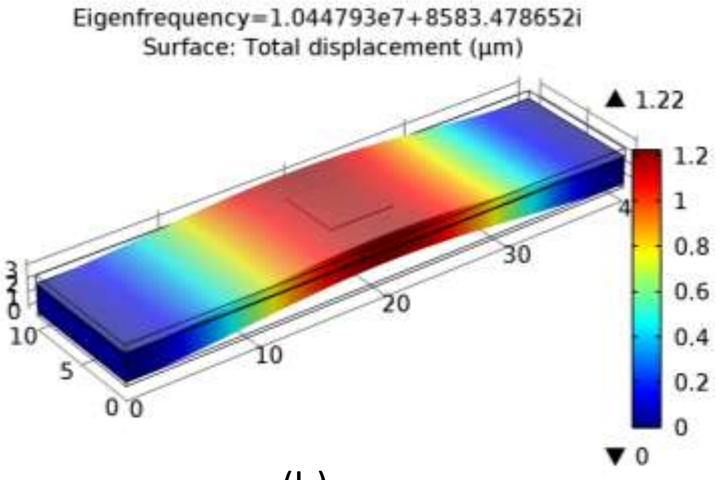
$$\omega_{n,\Delta m}^2 = \omega_n^2 \left(1 + 2\frac{\Delta m}{m_0} U_n^2(z_{\Delta m})\right)^{-1}$$

where $U_n(z) = sin\left(\frac{n\pi z}{L}\right)$

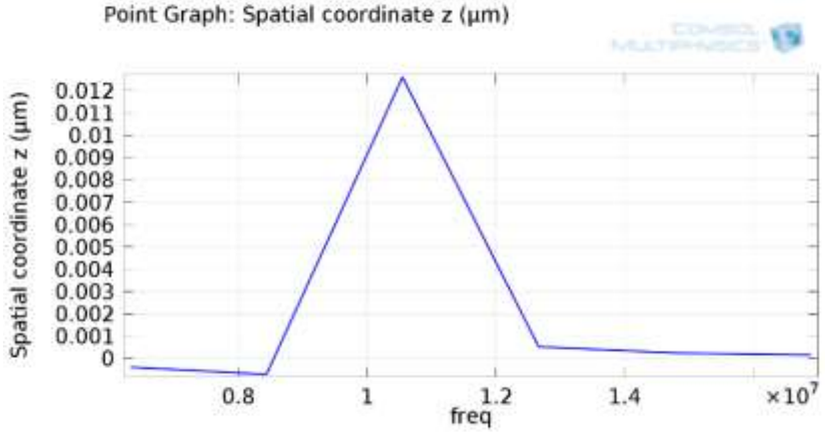
Simulation results



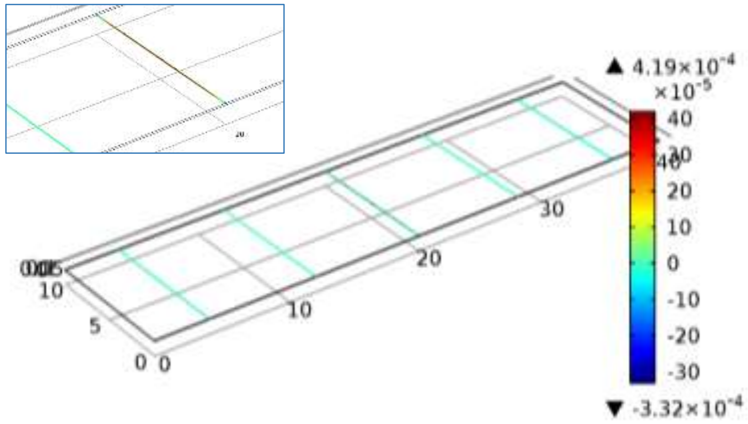
(a)



(b)

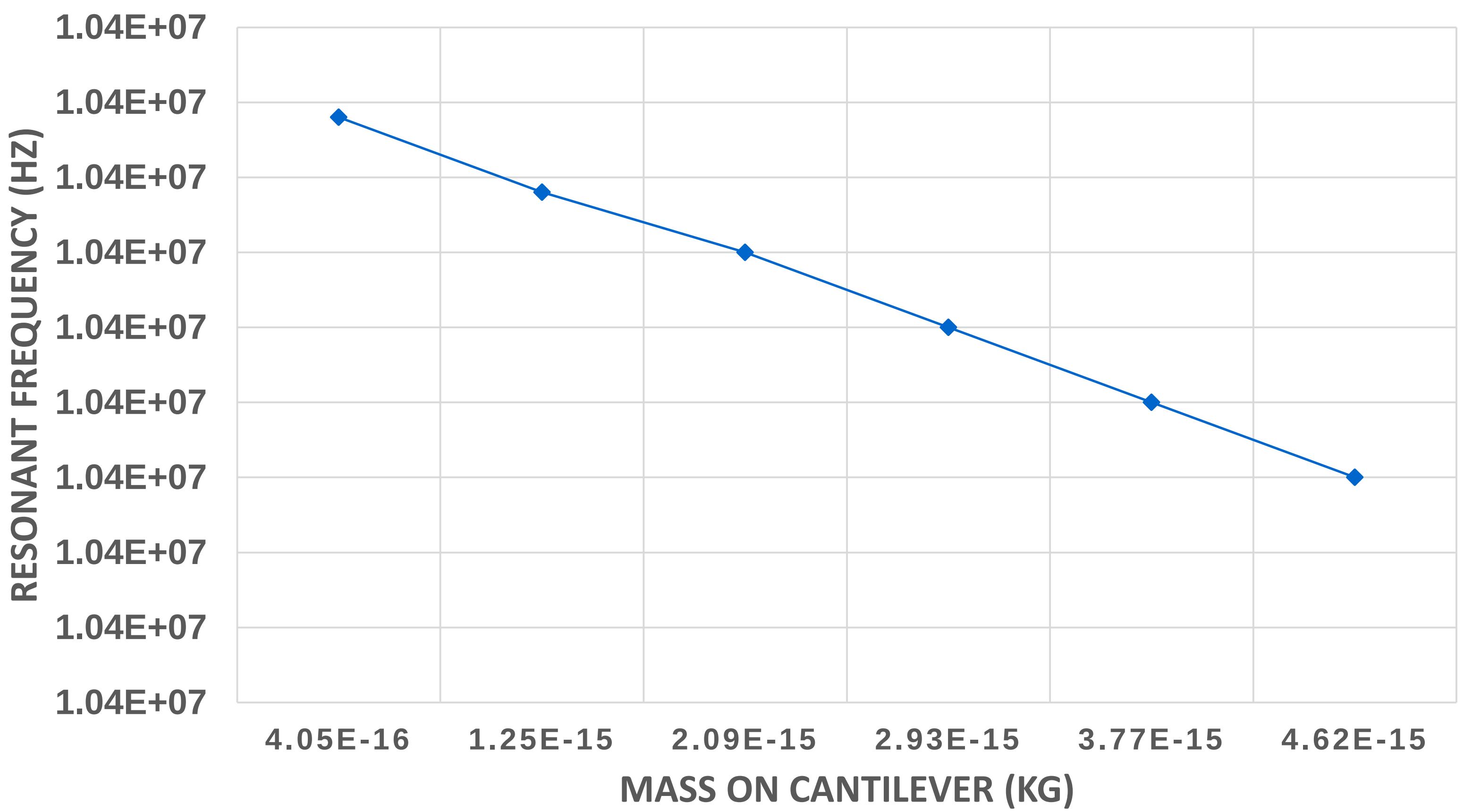


(c)

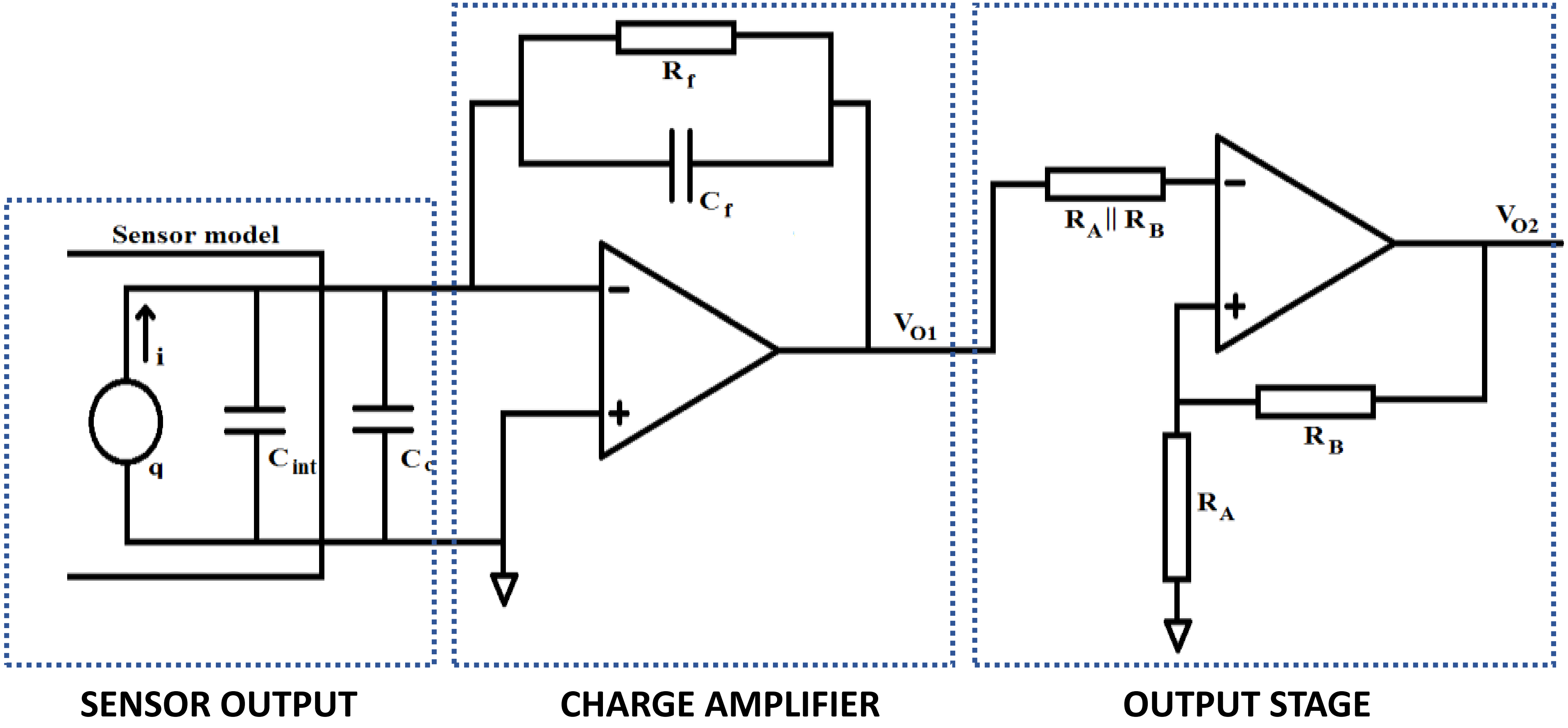


(d)

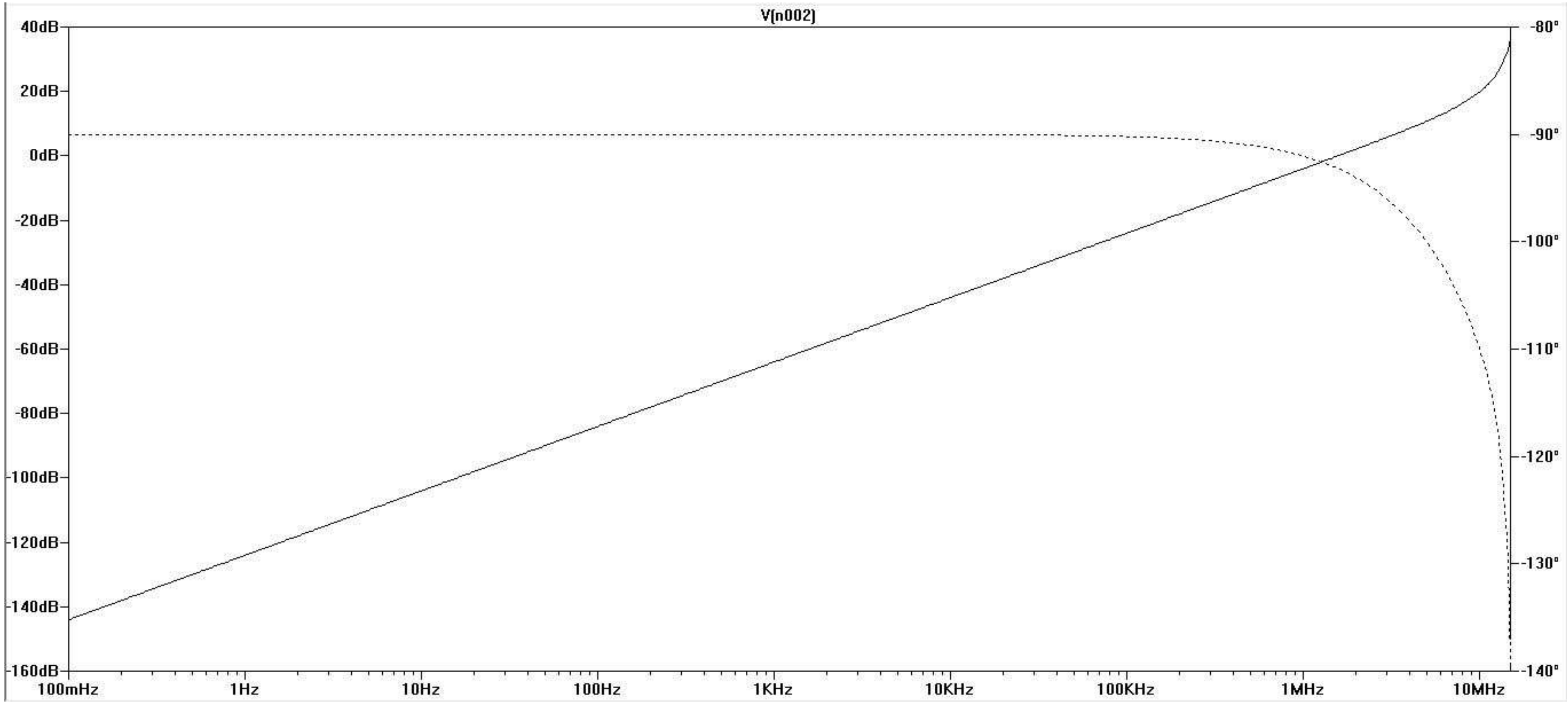
Simulation results



Electronic Circuit



Electronic Circuit Bode plot



Magnitude: 20dB **Phase:** -110^o

Conclusion

- The study demonstrates simulation of a functioning linear MEMS based DNA sensor with tunable sensitivity.
- We feel that such a device, if implemented successfully would be very useful in making microarray technology available to a wider group of researchers.

Thank You

Questions?