

LED control of Gene Expression in a NanoBioSystem Composed of Metallic Nanoparticles and a Genetically Modified *E. coli* strain

Hossein Alishah Aratboni^{a,b, Ψ}, Nahid Rafiei^{a,b,c, Ψ}, Larousse Khosravi Khorashad^d, Albert Isaac Lerma-Escalera^{a,b}, Francisco de Jesús Balderas Cisneros^{a,b}, Zhaowei Liu^d, Abbas Alemzadeh^{c,*}, Sadasivan Shaji^e, José Rubén Morones Ramírez^{a,b,*}

^a*Universidad Autónoma de Nuevo León, UANL. Facultad de Ciencias Químicas. Av. Universidad s/n. CD. Universitaria, 66451, San Nicolás de los Garza, NL, México.*

^b*Centro de Investigación en Biotecnología y Nanotecnología, Facultad de Ciencias Químicas, Universidad Autónoma de Nuevo León. Parque de Investigación e Innovación Tecnológica, Km. 10 autopista al Aeropuerto Internacional Mariano Escobedo, 66629, Apodaca, Nuevo León.*

^c*Department of Crop Production and Plant Breeding, School of Agriculture, Shiraz University, 71441-65186, Km. 12 Shiraz-Isfahan highway, Bajgah area, Shiraz, Iran*

^d*Department of Electrical and Computer Engineering, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA 92093, USA.*

^e*Universidad Autónoma de Nuevo León, UANL. Facultad de ingeniería mecánica y eléctrica. Universidad s/n. CD. Universitaria, 66451, San Nicolás de los Garza, NL, México.*

^Ψ Both authors contributed equally to the work

Supplementary Table 1. ANOVA for the experimental parameters of full factorial design.

Variable	SS	df	MS	F-value	p-value
Concentration (X ₁)	409.71	2	204.85	247.57	< 0.0001
Volume (X ₂)	89.57	2	44.79	54.12	< 0.0001
Distance (X ₃)	3283.61	2	1641.80	1984.14	< 0.0001
Time (X ₄)	245.49	2	122.74	148.34	< 0.0001
X ₁ X ₃	89.08	4	22.27	26.91	< 0.0001
X ₁ X ₄	17.58	4	4.39	5.31	0.0012
X ₂ X ₃	29.82	4	7.45	9.01	< 0.0001
X ₂ X ₄	22.44	4	5.61	6.78	0.0002
X ₃ X ₄	95.87	4	23.97	28.97	< 0.0001

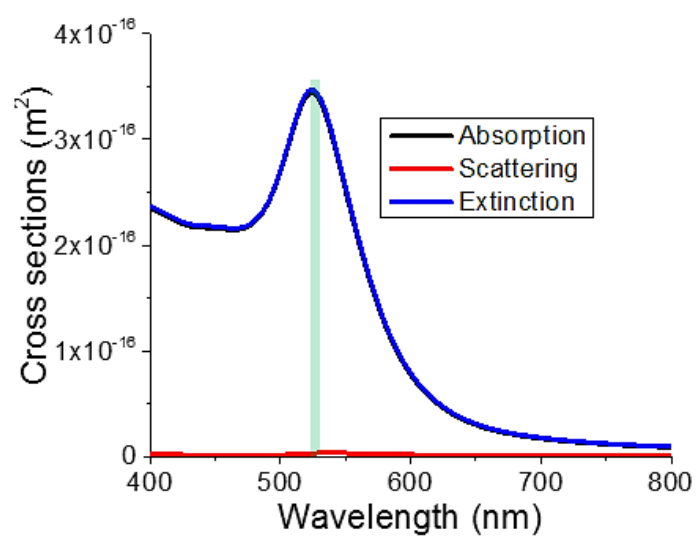
$R^2 = 0.99$; Adjusted $R^2 = 0.98$; SS, sum of squares; DF, degrees of freedom and MS, mean square.

P-values less than 0.005 indicate model terms are significant.

Supplementary Table 2. Analysis of variance (ANOVA) for response surface Quadratic model.

Source	SS	df	MS	F-value	p-value	
Model	527.67	14	37.69	66.87	< 0.0001	significant
Concentration (x_1)	146.03	1	146.03	259.07	< 0.0001	
Volume (x_2)	21.66	1	21.66	38.43	< 0.0001	
Distance (x_3)	218.41	1	218.41	387.47	< 0.0001	
Time (x_4)	34.56	1	34.56	61.31	< 0.0001	
x_1x_2	0.4900	1	0.4900	0.8693	0.3659	
x_1x_3	13.69	1	13.69	24.29	0.0002	
x_1x_4	0.4900	1	0.4900	0.8693	0.3659	
x_2x_3	0.6400	1	0.6400	1.14	0.3035	
x_2x_4	0.0400	1	0.0400	0.0710	0.7936	
x_3x_4	3.24	1	3.24	5.75	0.0300	
x_1^2	5.15	1	5.15	9.14	0.0086	
x_2^2	0.9219	1	0.9219	1.64	0.2204	
x_3^2	87.23	1	87.23	154.76	< 0.0001	
x_4^2	2.61	1	2.61	4.63	0.0482	
Residual	8.45	15	0.5637			
Lack of Fit	6.25	10	0.6247	1.41	0.3685	not significant
Pure Error	2.21	5	0.4417			
Cor Total	536.12	29				
Quality of quadratic model						
Correlation coefficient (R^2)				0.9842		
Adjusted R^2				0.9695		
Predicated R^2				0.9270		

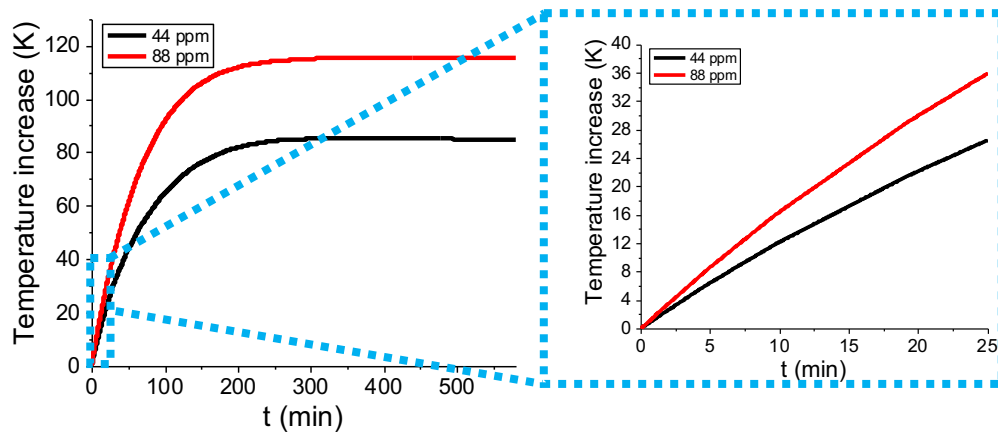
Supplementary Figure 1



Supplementary Figure 1

Extinction, absorption, and scattering cross sections for a 20.44 nm AuNP in water. The green vertical line shows the LED wavelength excitation range.

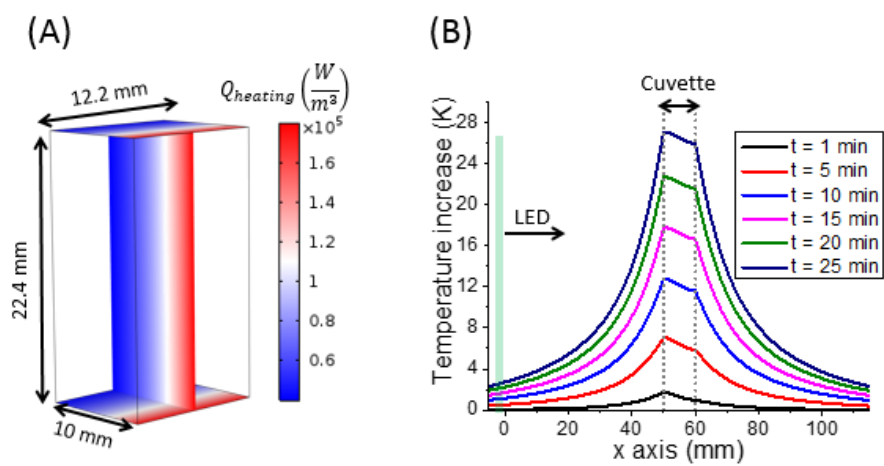
Supplementary Figure 2



Supplementary Figure 2

Time dependent temperature calculations for two concentrations of 44ppm and 88ppm. The inset is the zoom in plot for early times. It shows linear behavior.

Supplementary Figure 3



Supplementary Figure 3

(A) Calculated local collective heating of ensemble of AuNPs in the cuvette of 10mm $\times$ 12.2mm. The LED excitation is along positive x axis at wavelength of 522nm. (B) Temperature profile of the middle of cuvette along x axis for increasing time. The position of LED and cuvette is also shown.

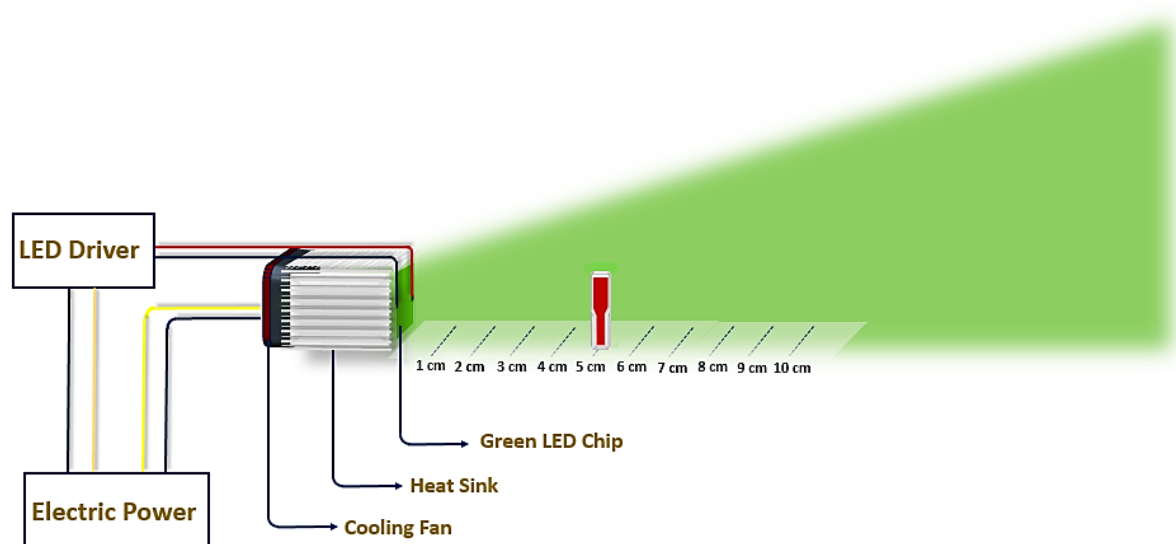
Supplementary Figure 4



Supplementary Figure 4

Bacterial pellets of *E. coli* DH5 α cloned with our sensor after an overnight culture in LB medium at: (right) 37°C, where the bacteria shows production of the mCherry protein, and at (left) 30°C where the bacteria does not show production of the mCherry protein.

Supplementary Figure 5



Supplementary Figure 5

Experimental setup for measuring the temperature profile of AuNPs solutions.

Supplementary Table 3

Supplementary Table 3

Four experimental variables screened by full factorial design at different levels.

Variable	Units	Levels		
		1	2	3
Time	min	5	10	15
Concentration	ppm	22	44	88
Distance	cm	3	5	10
Volume	μL	200	1400	2800

Supplementary Figure 6

>Temperature sensor sequence

GAATTCGCGGCCGCTTCTAGAGGttgacagctagctcagtcctaggtataatgctagcggatccTCTCCTTCa
aaaaaAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAGGAGATATACCCATGGTTAGCAA
AGGTGAAGAAGATAATATGGCAATTATTAAGAATTTATGCGTTTTAAAGTTCAT
ATGGAAGGTAGCGTTAATGGTCATGAATTTGAAATTGAAGGTGAAGGTGAAGGT
CGTCCGTATGAAGGTACCCAGACCGCAAACTGAAAGTTACCAAAGGTGGTCCG
CTGCCGTTTGCATGGGATATTCTGAGCCCGCAGTTTATGTATGGTAGCAAAGCAT
ATGTTAAACATCCGGCAGATATTCCGGATTATCTGAAACTGAGCTTTCCGGAAGG
TTTTAAATGGGAACGTGTTATGAATTTTGAAGATGGTGGTGTGTTACCGTTACC
CAGGATAGCAGCTTACAGGATGGTGAATTTATTTATAAAGTTAAACTGCGTGGTA
CCAATTTTCCGAGCGATGGTCCGGTTATGCAGAAAAAACAATGGGTTGGGAAG
CAAGCAGCGAACGTATGTATCCGGAAGATGGTGCACTGAAAGGTGAAATTAAAC
AGCGTCTGAAACTGAAAGATGGTGGTCATTATGATGCAGAAGTTAAAACACCT
ATAAAGCAAAAAAACCGGTTTCAGCTGCCGGGTGCATATAATGTTAATATTAAAC
TGGATATTACCAGCCATAATGAAGATTATACCATTGTTGAACAGTATGAACGTGC
AGAAGGTCGTCATAGCACCGGTGGTATGGATGAACTGTATAAACTGGTTGCATA
AACTAGTAGCGGCCGCTGCAGCATAACCCCTTGGGGCCTCTAAACGGGTCTTGA
GGGGTTTTTTGAAGCTT

Supplementary Figure 6

Nucleotide sequence of synthetic temperature sensor.