Stable Casimir equilibria and quantum trapping

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QFLL Fall journal club

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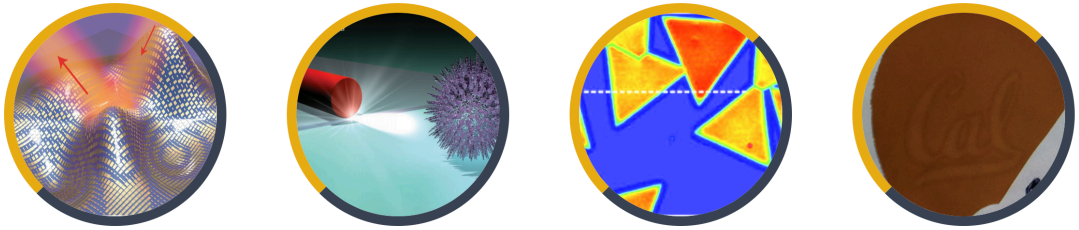
- Received Ph.D from UC Berkeley (1996) and MS from University of Minnesota and MS/BS from Nanjing University, PR China
- Assistant professor at Pennsylvania State University (1996-1999)
- Associate professor and full professor at UCLA (1999-2004) prior to joining Berkeley faculty in 2004
- 16th Vice-Chancellor and President of the University of Hong Kong

Research



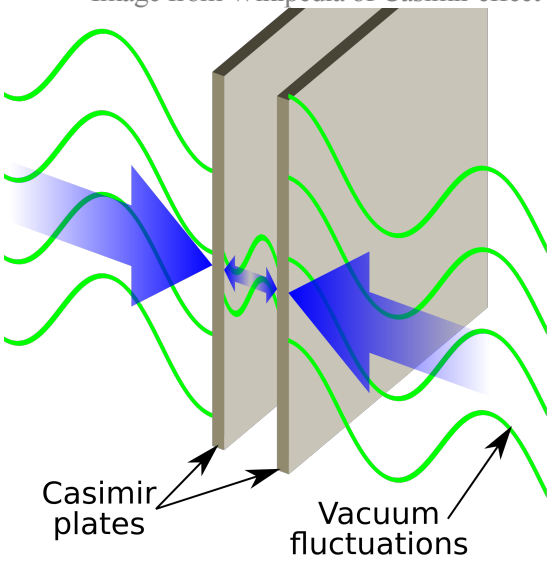
Metamaterials | Nanophotonics | 2D Materials | Energy

Our research group has diverse research interests, but primarily with a focus on light-matter interactions at the nanoscale. Much of our work has been in the fields of metamaterials and nanophotonics. In addition, we are interested in materials science, particularly in two-dimensional nanomaterials such as graphene and transition metal dichalcogenides. Many of our works have device applications, from energy to electronics. We frequently collaborate with other groups at Berkeley, as well as across the globe. Our group members have many different backgrounds, contributing to the many different research topics we're currently exploring and our past research topics.

current research focuses on **nano-scale science and technology, materials physics, photonics and bio-technologies**

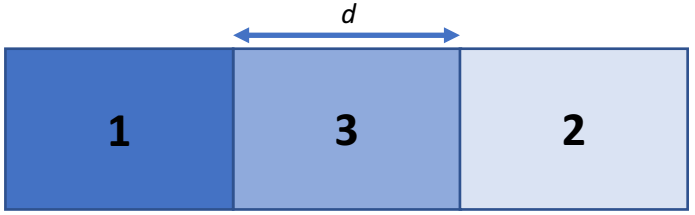
Quantum trapping – Casimir effect

Image from Wikipedia of Casimir effect



- Two uncharged conductive plate in a vacuum.
- The plates do affect the virtual photon, which constitute the field, and generate the net force.
  (attraction or a repulsion depending on the specific arrangement of the two plates)
- It is measurable only when the distance between the objects is extremely small.

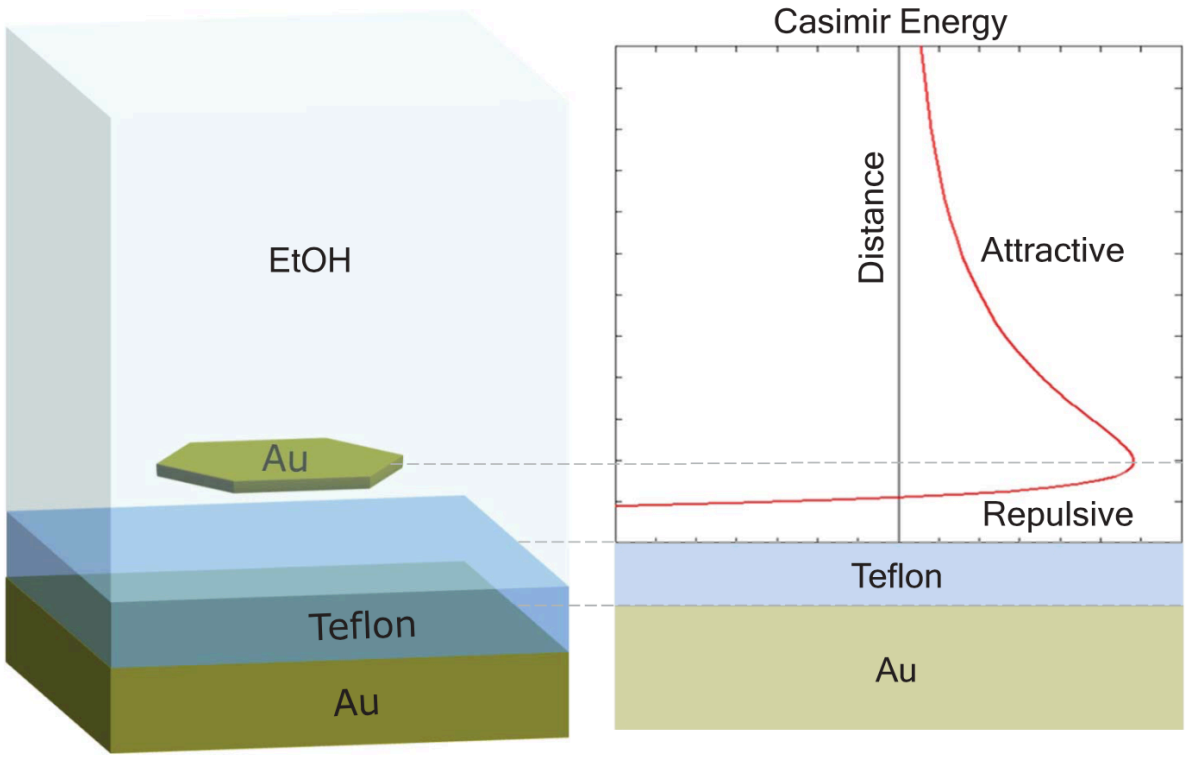
Casimir-Lifshitz theory for Casimir energy



$$\frac{E(d)}{A} = \frac{\hbar}{2\pi}\int_0^{+\infty} d\xi \int_0^{+\infty} \frac{dk_{||}}{2\pi} k_{||} \ln\det\left(1 - R_1 R_2 e^{-2k_3 d}\right)$$

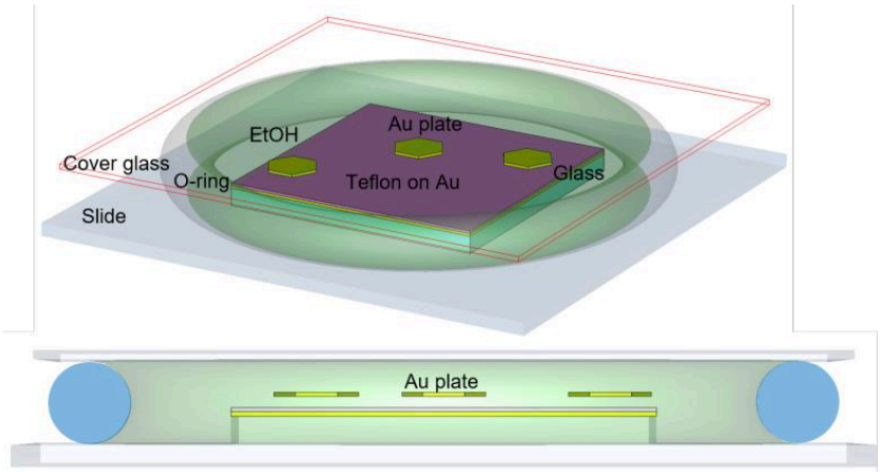
$$R_j = \begin{vmatrix} r_j^s & 0 \\ 0 & r_j^p \end{vmatrix} \qquad k_3 = \sqrt{k_{||}^2 + \epsilon_0\mu_0\epsilon_3(i\xi)\mu_3(i\xi)\xi^2}$$

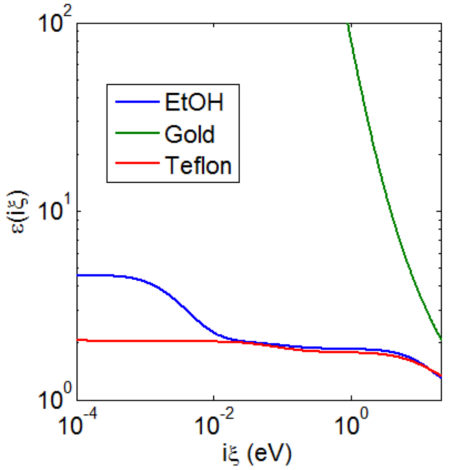
Experimental model



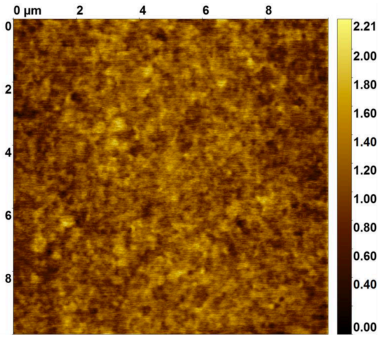
Stable Casimir equilibria can be achieved by coating one high-refractive index object with a thin layer of a low-refractive index dielectric

Experiment Setup (Sample)

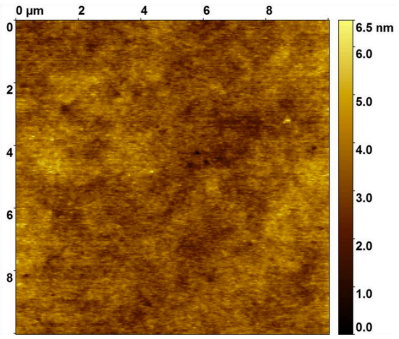




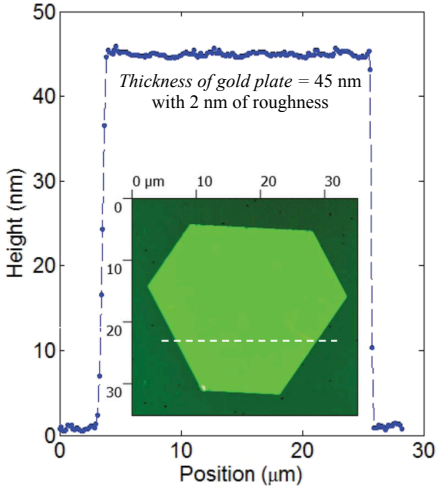
Thickness of gold substrate = 200 nm
with 2 nm of roughness



Stripped Au surface AFM image

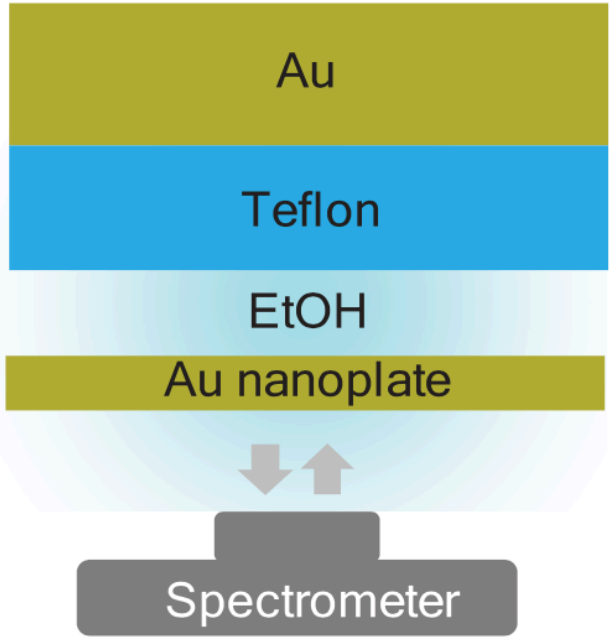


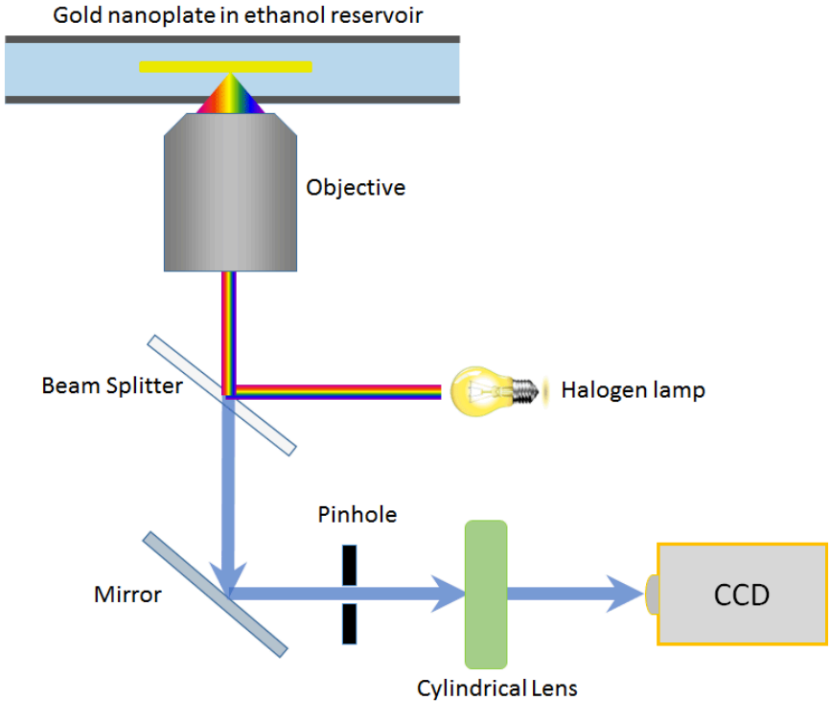
Teflon surface AFM image



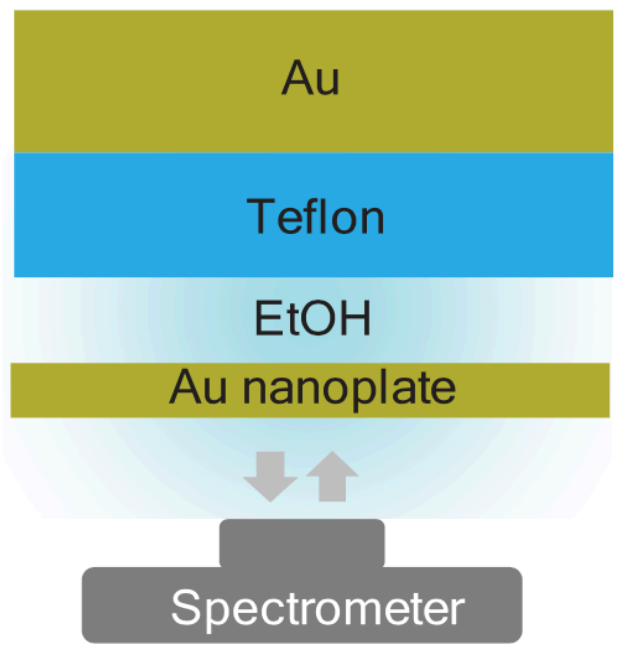
AFM image of gold plate

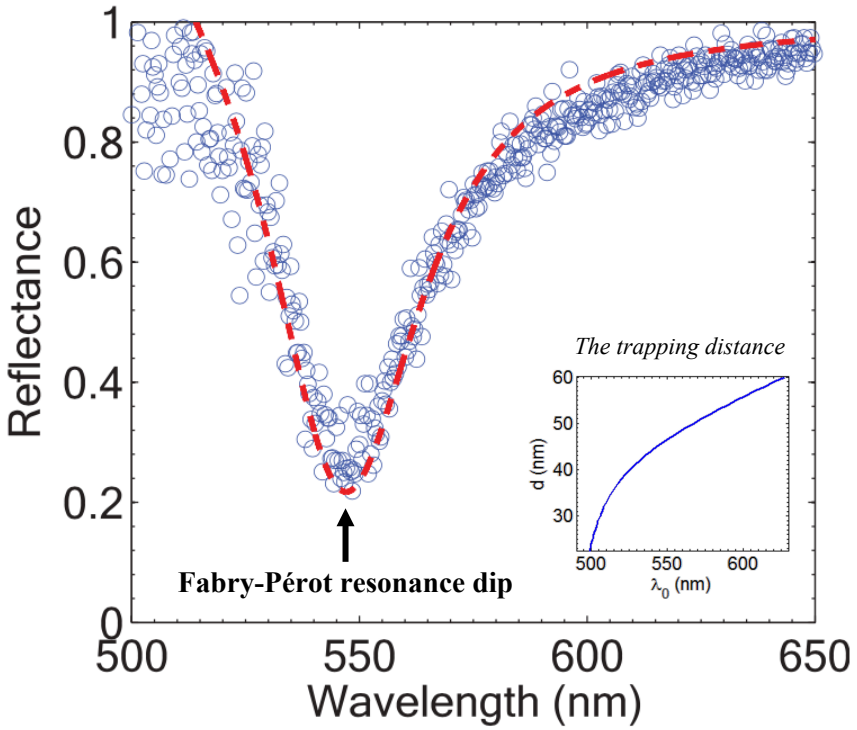
Experiment Setup



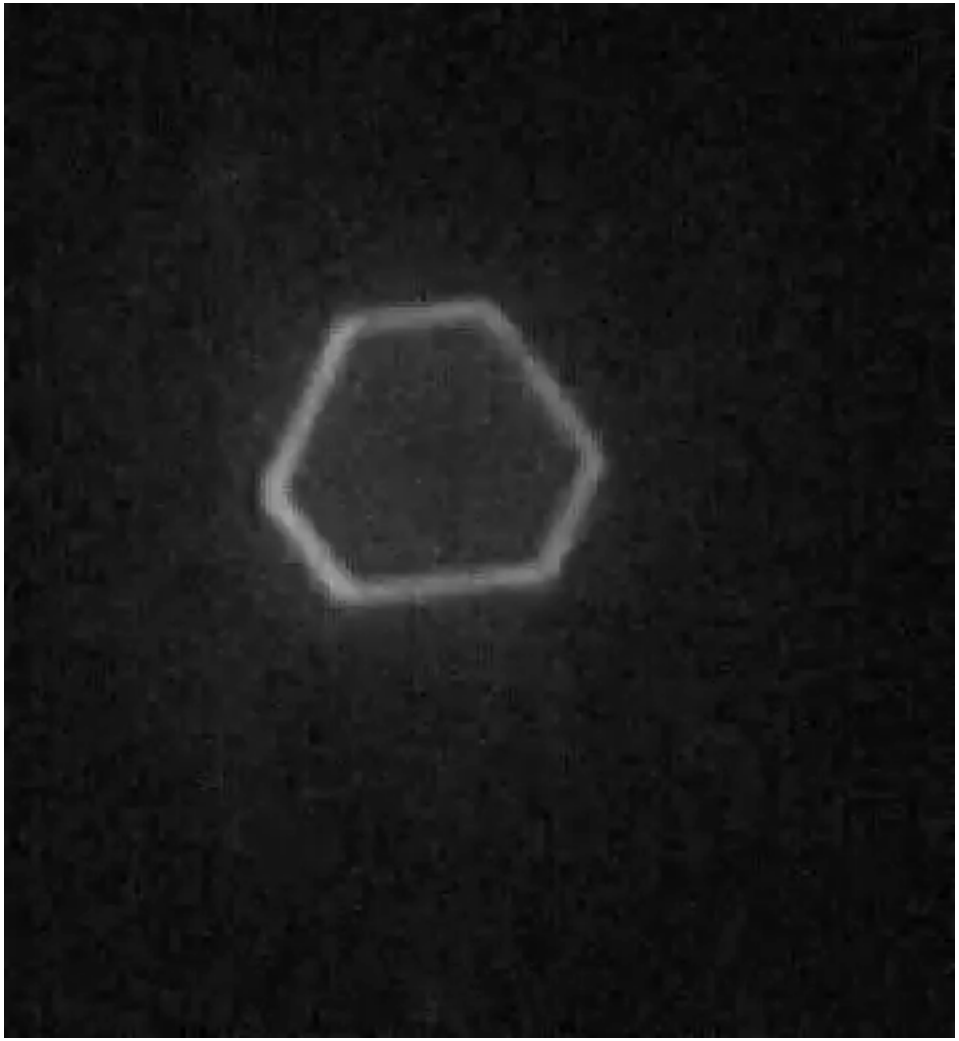


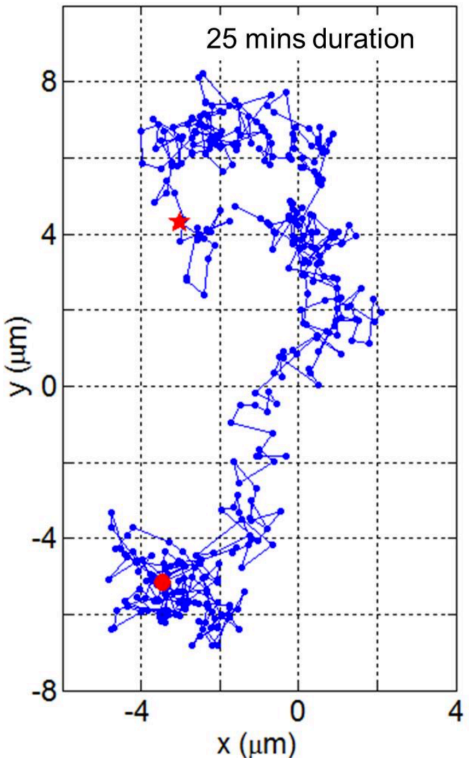
Result


Au
Teflon
EtOH
Au nanoplate
Spectrometer

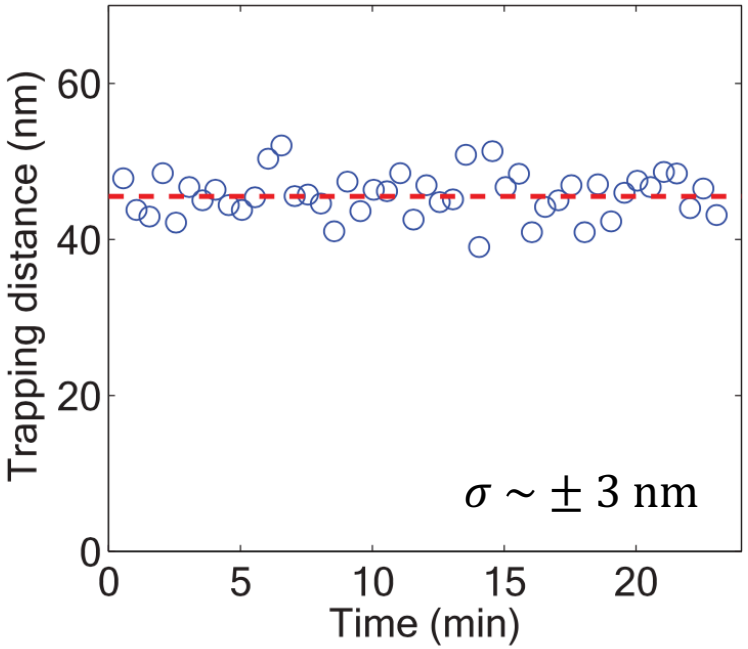

Reflectance
Wavelength (nm)
Fabry-Pérot resonance dip
The trapping distance
d (nm)
λ0 (nm)

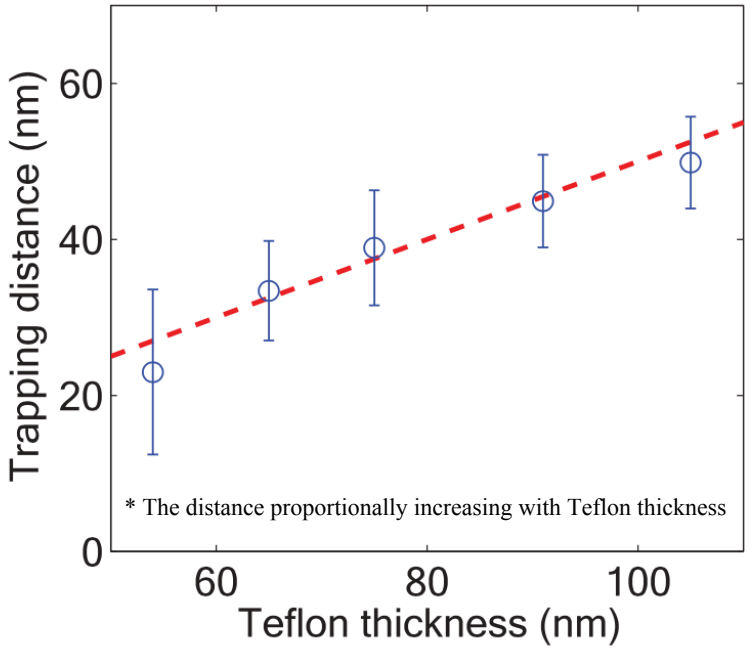
Result





Result

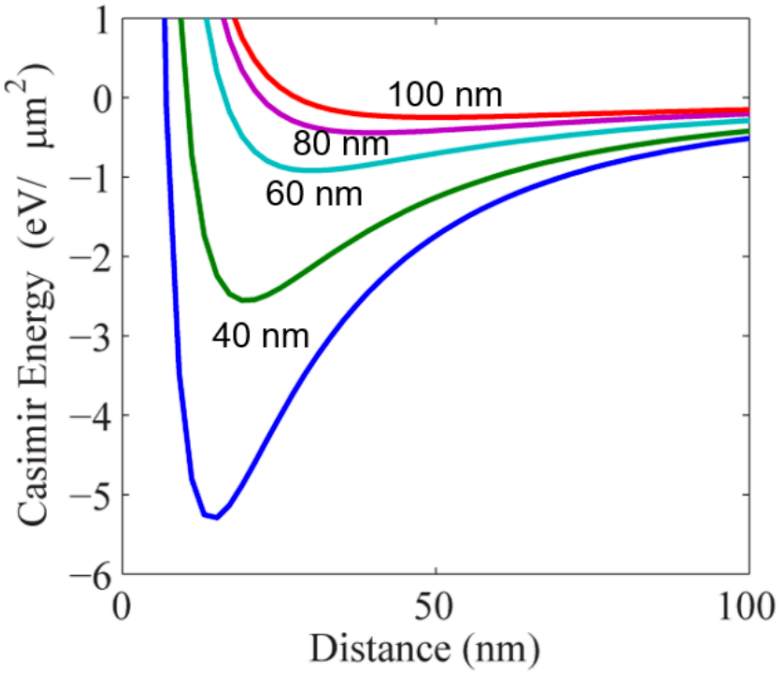


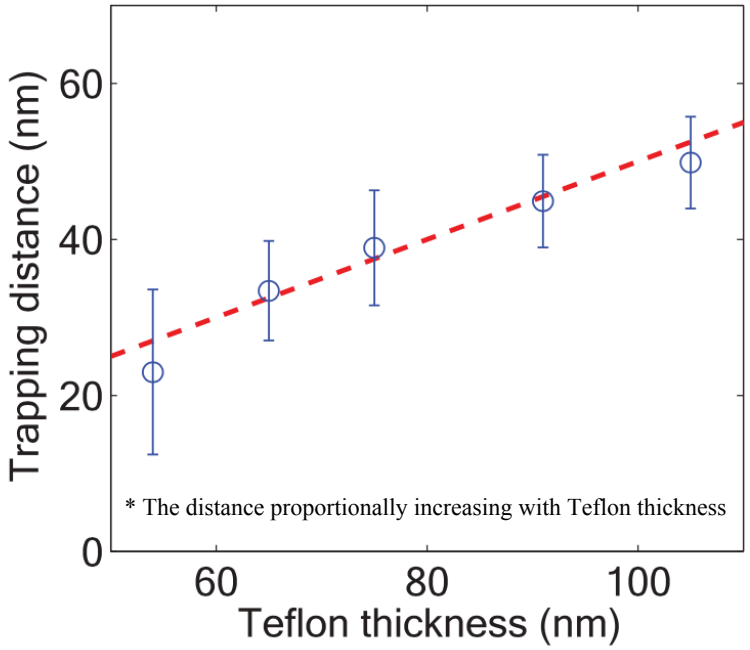


Strong passive trapping force
(steep Casimir trapping potential)

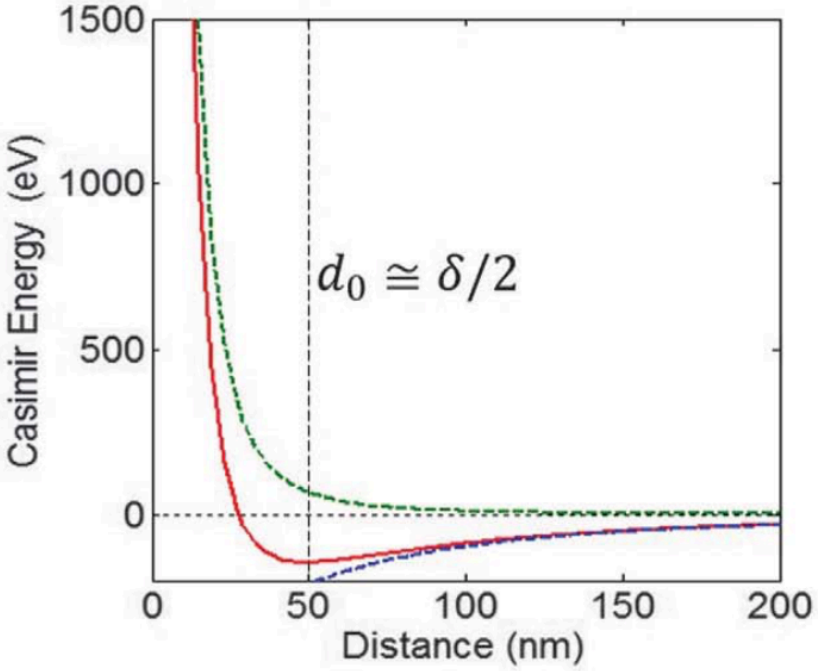
Result

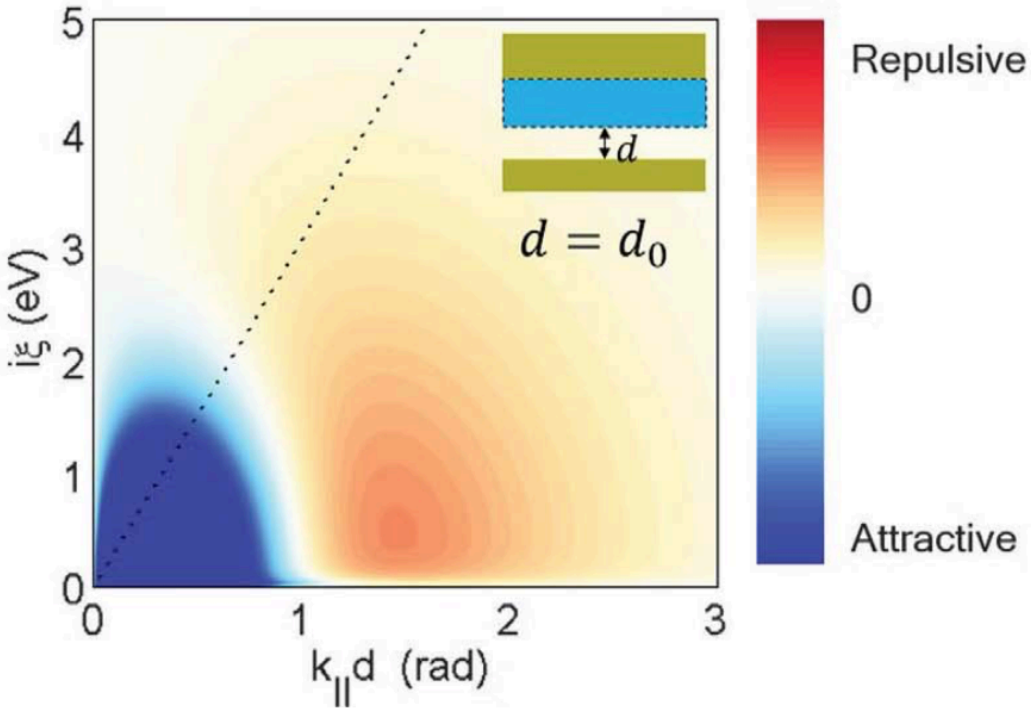
Theoretical curve of relation between
Teflon thickness and the trapping distance

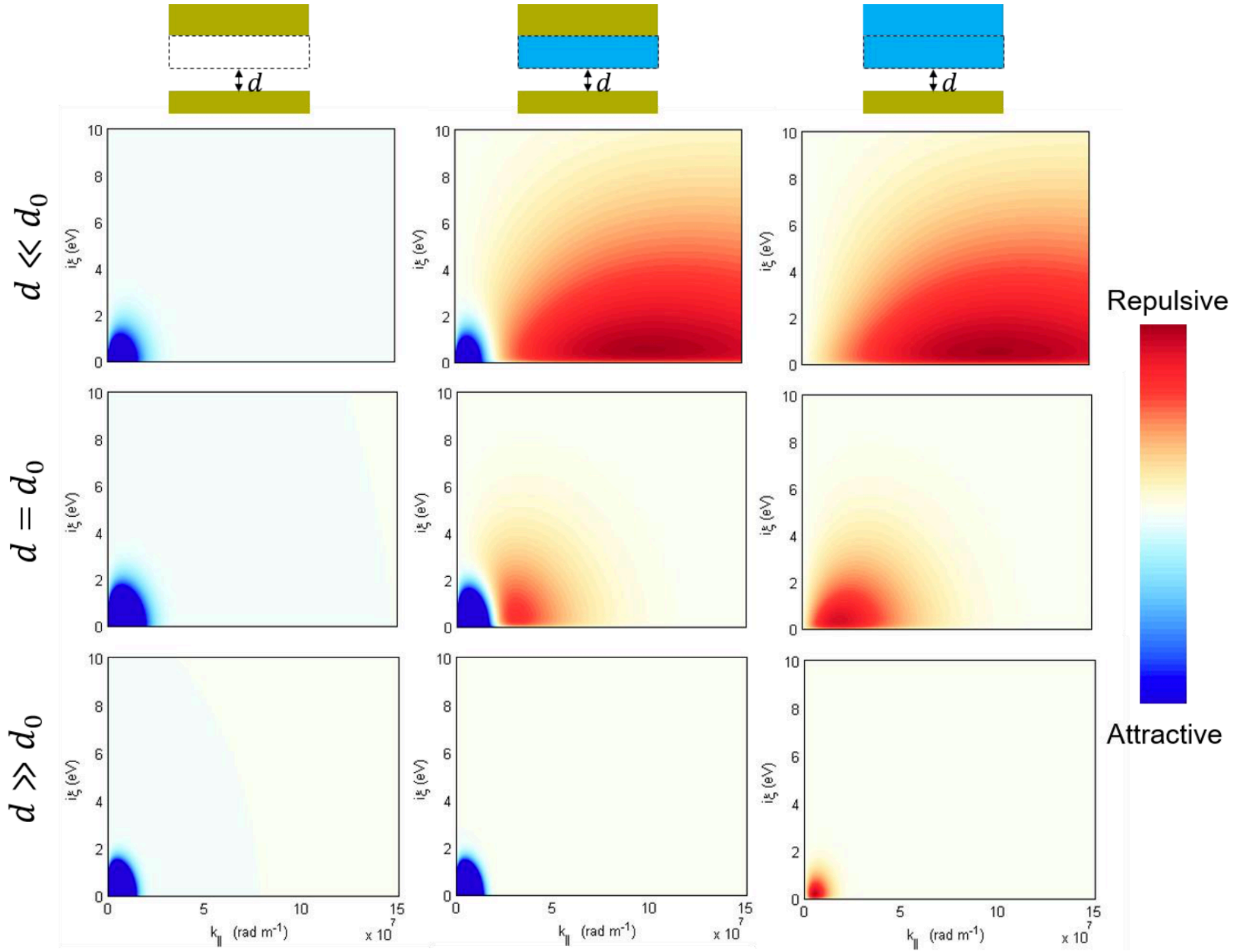


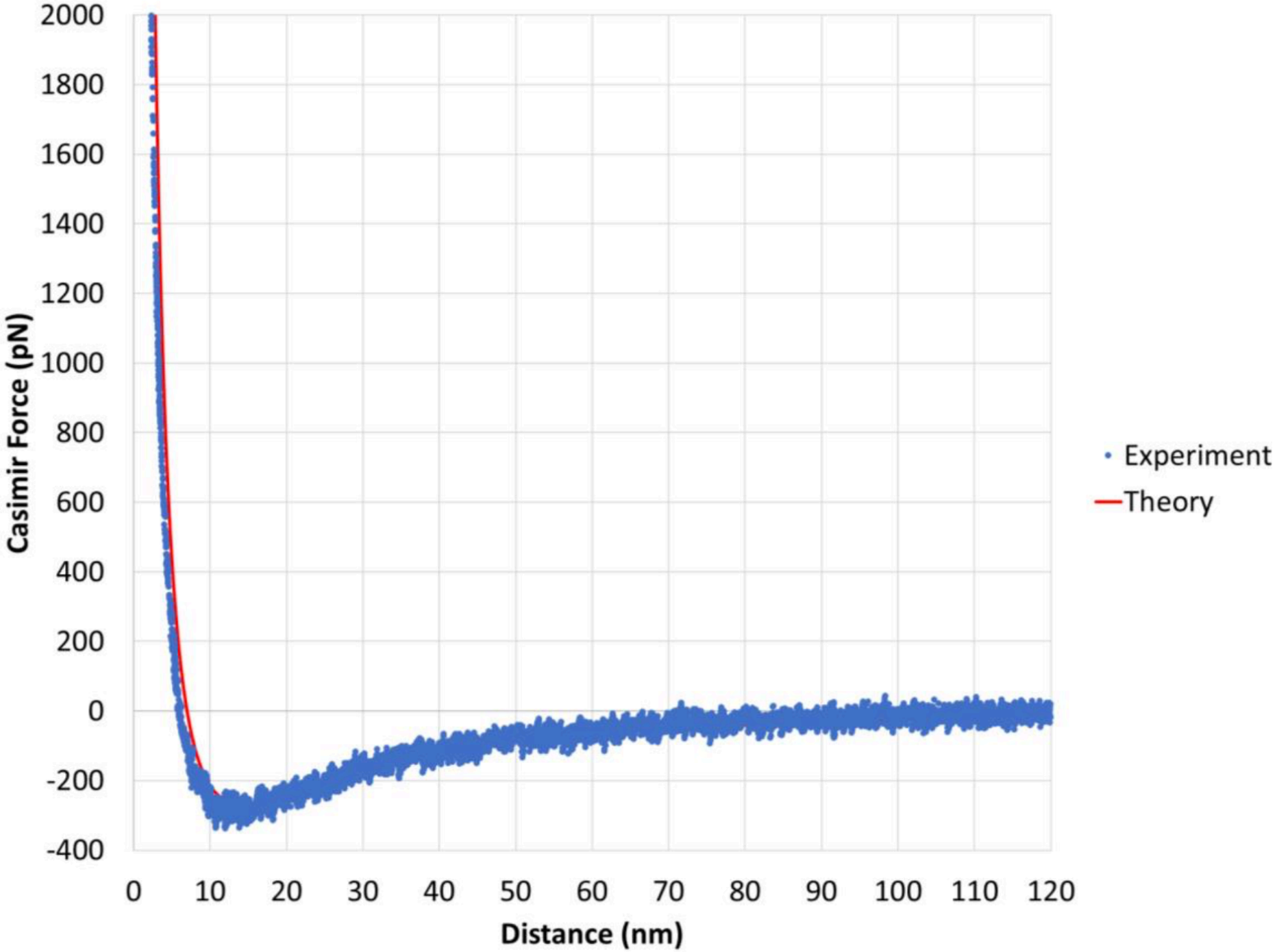


Result

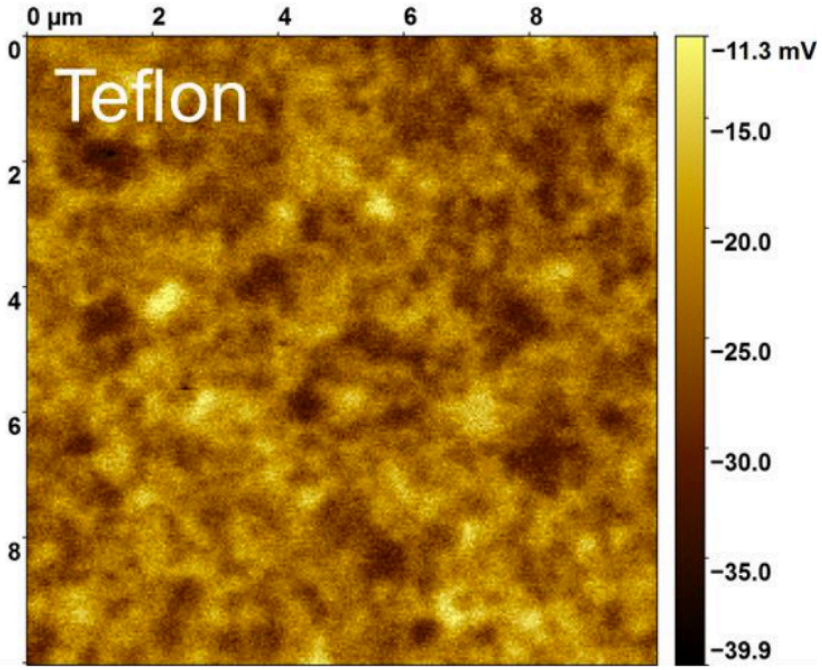

1500
1000
500
0
Casimir Energy (eV)
$d_0 \cong \delta/2$
0
50
100
150
200
Distance (nm)

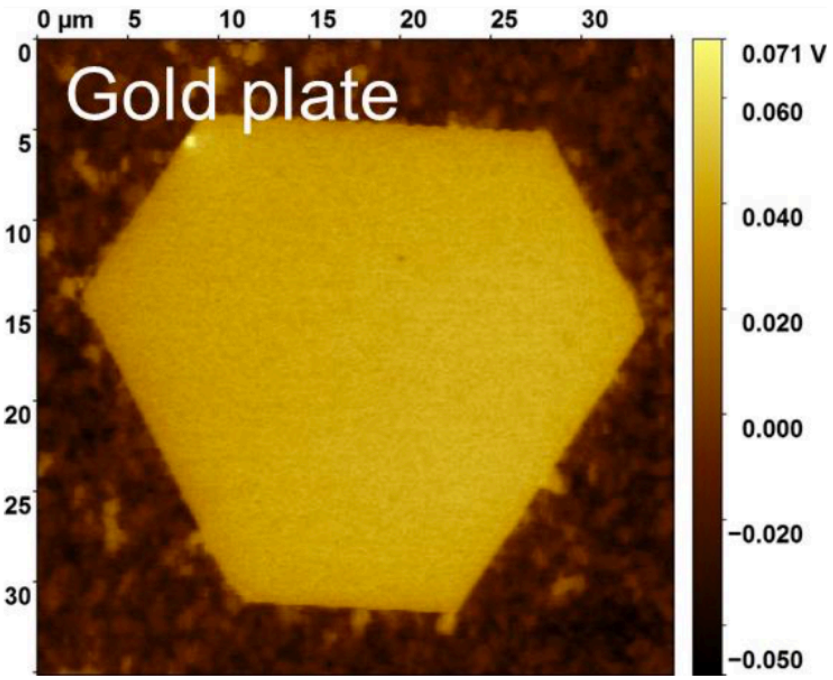

5
4
3
2
1
0
iξ (eV)
d
$d = d_0$
0
1
2
3
$k_{||}d$ (rad)
Repulsive
0
Attractive


d
d
d
$d \ll d_0$
$d = d_0$
$d \gg d_0$
Repulsive
Attractive
iξ (eV)
$k_{\parallel}$ (rad m^{-1})
x 10^7


2000
1800
1600
1400
1200
1000
800
600
400
200
0
-200
-400
Casimir Force (pN)
0
10
20
30
40
50
60
70
80
90
100
110
120
Distance (nm)
Experiment
Theory

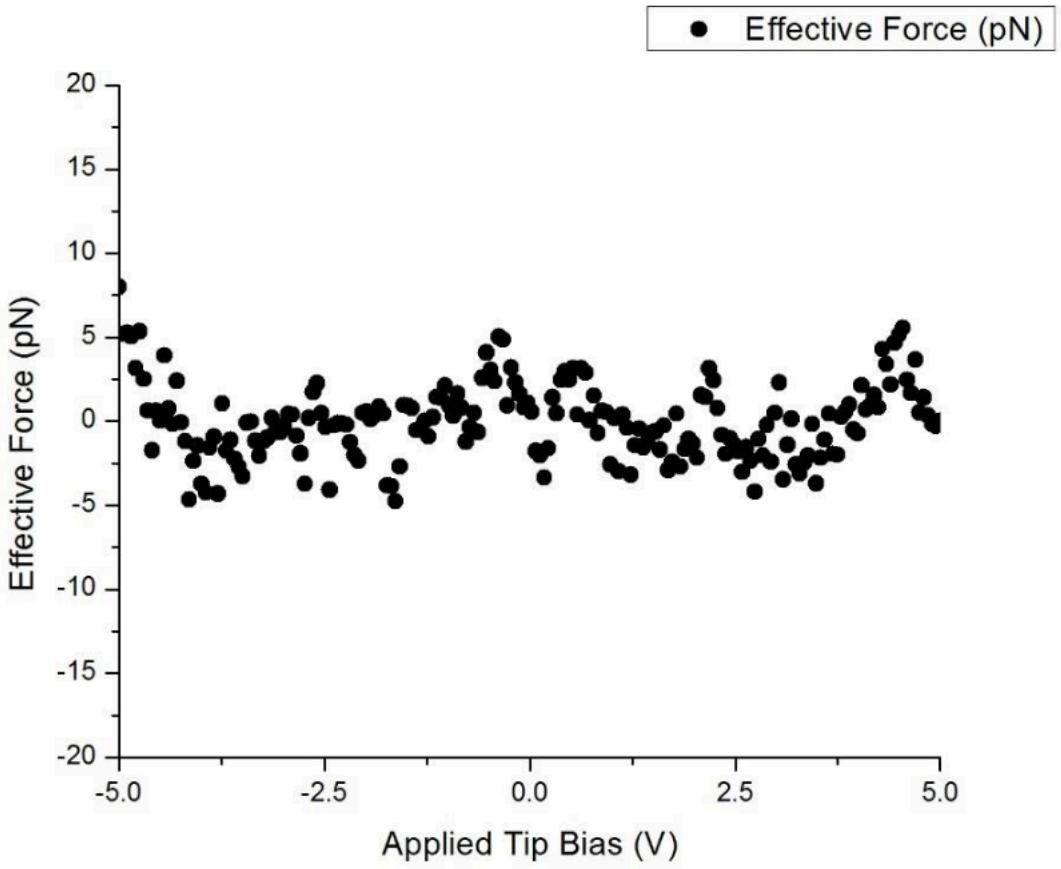
Surface potential





Small surface potential variation → low surface charge (negligible)

Effective force induced by applied bias voltage in ethanol solution



Zeta potential

Samples	Zeta potentials (mv)	Std (mv)
Gold Nanoplates	-8.31	4.87
Teflon film	-13.57	1.73