Molecular Quantum Tunneling Devices for Nanoscale Attonewton Force Sensing

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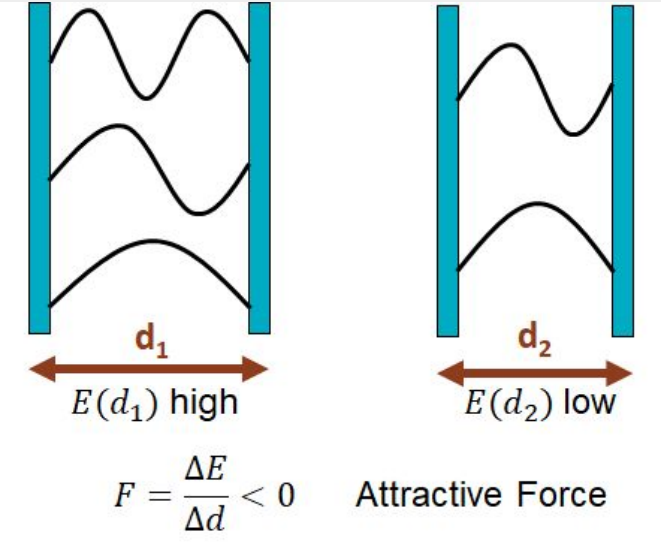
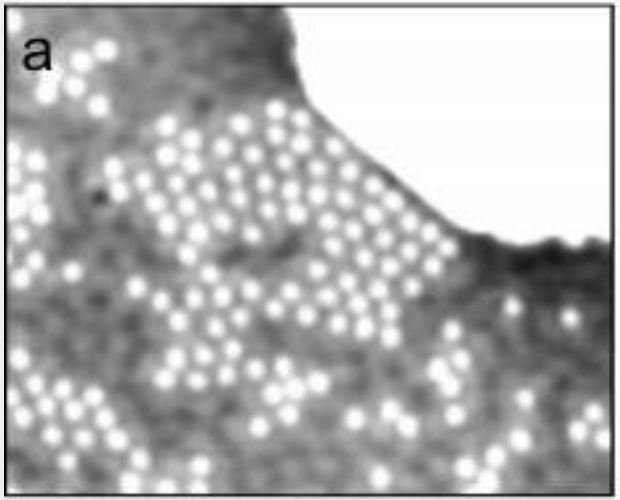
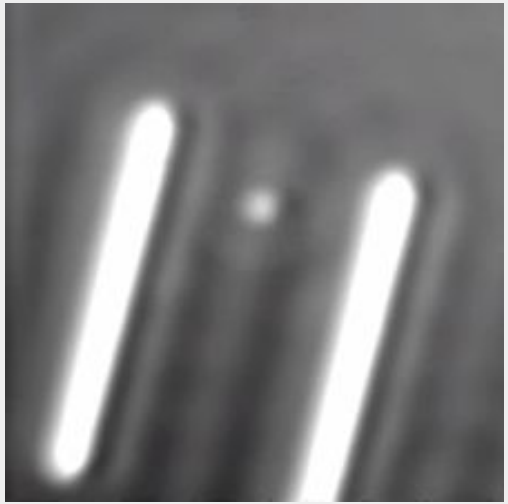
Electron-Mediated Casimir Forces





PRL 85, 2981 (2000)



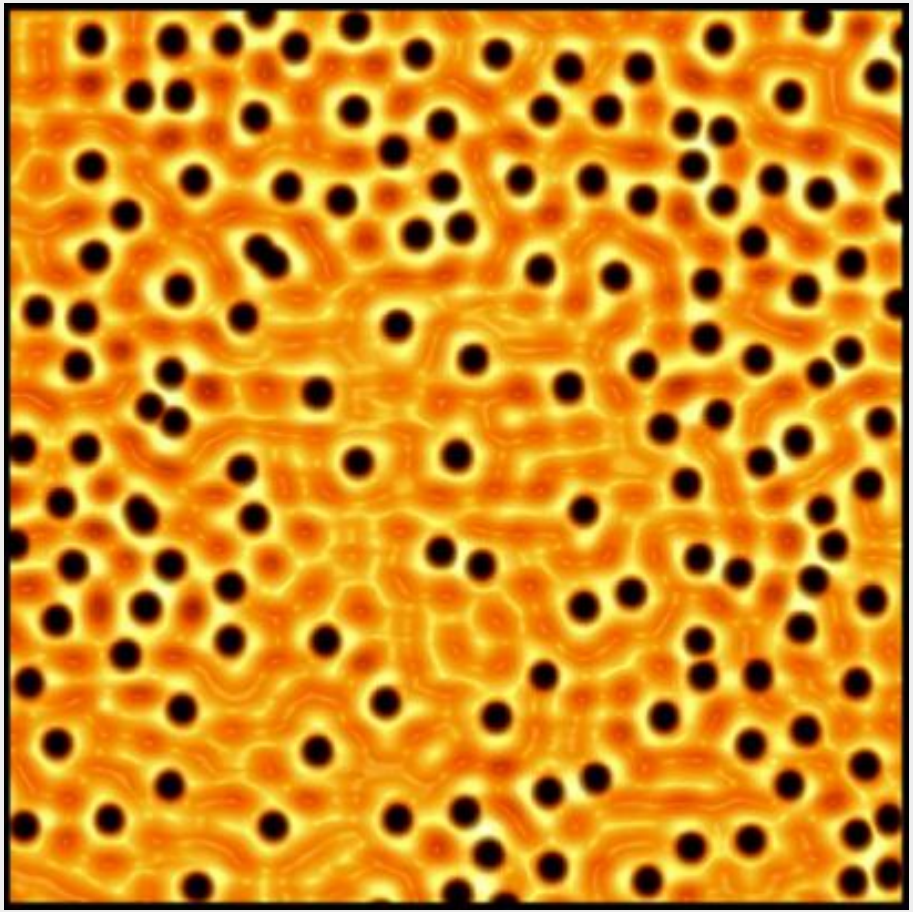
PRL 101, 226601 (2008)

- Observed long-range (~$1/d^2$) oscillatory interaction with period $\lambda_F/2$.
- Adatom separation statistics, no local information.

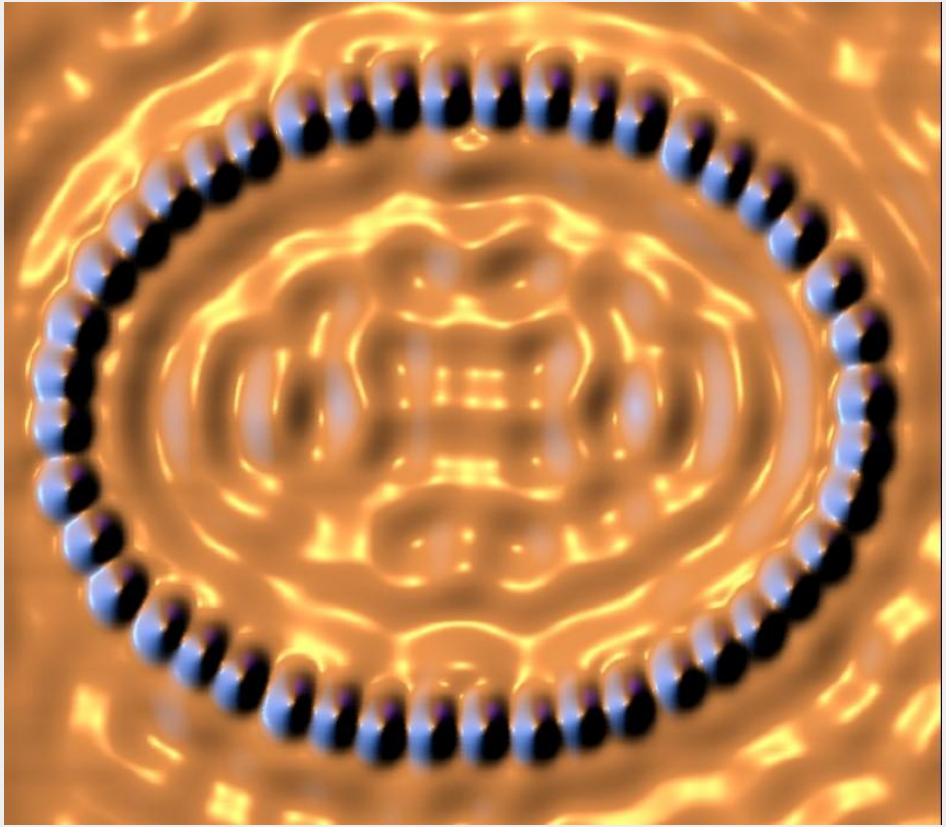
- Nanoscale resonator to study surface state confinement, control impurity diffusion.
- Long (~19 h) measurement times, averaged data.

Impurities Within an Electron Gas

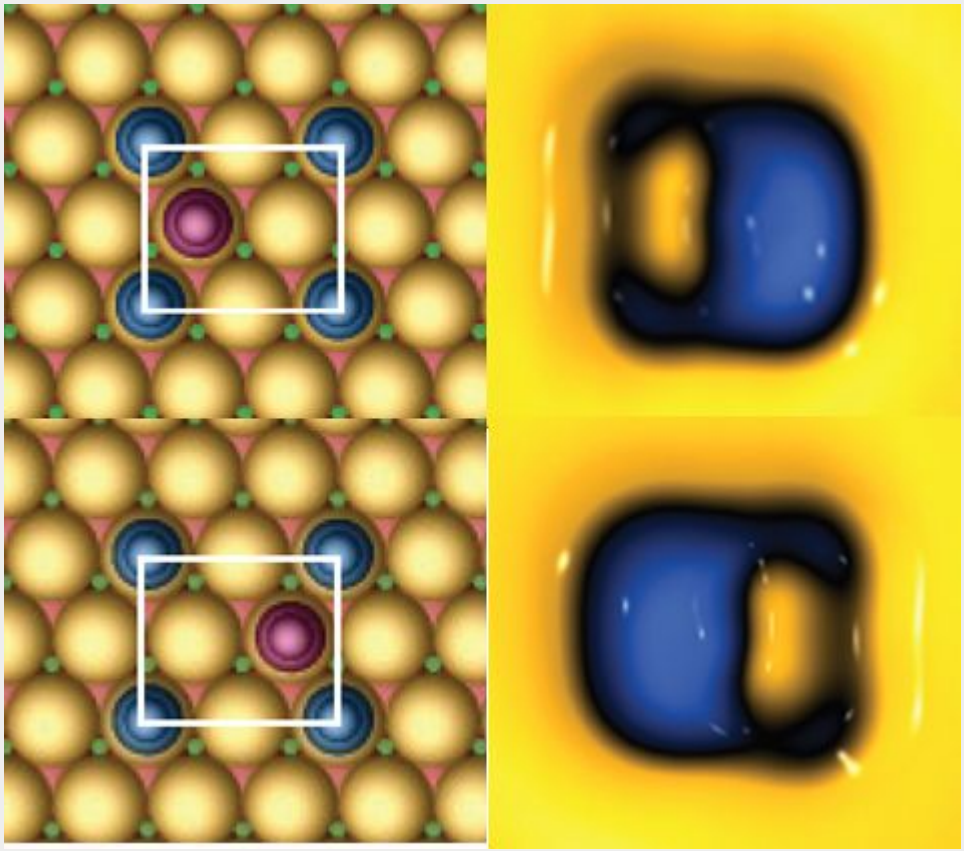
- CO on Cu(111).
- Impurities are “walls” that set wavefunction boundary conditions.
- 2DEG influences formation of defects on the surface.

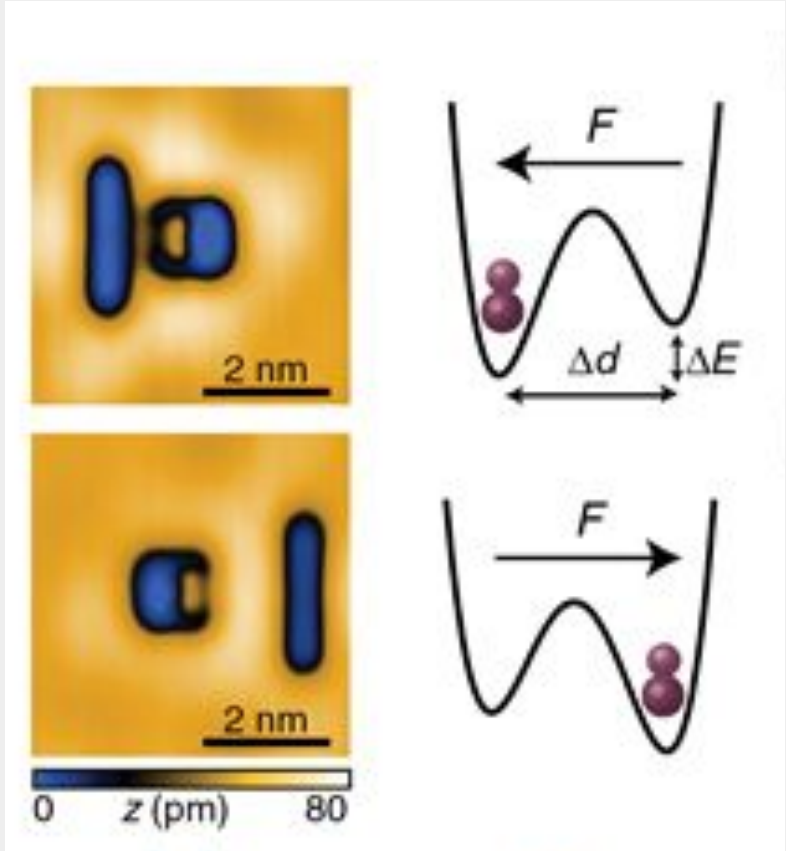


Atomic Manipulation with STM



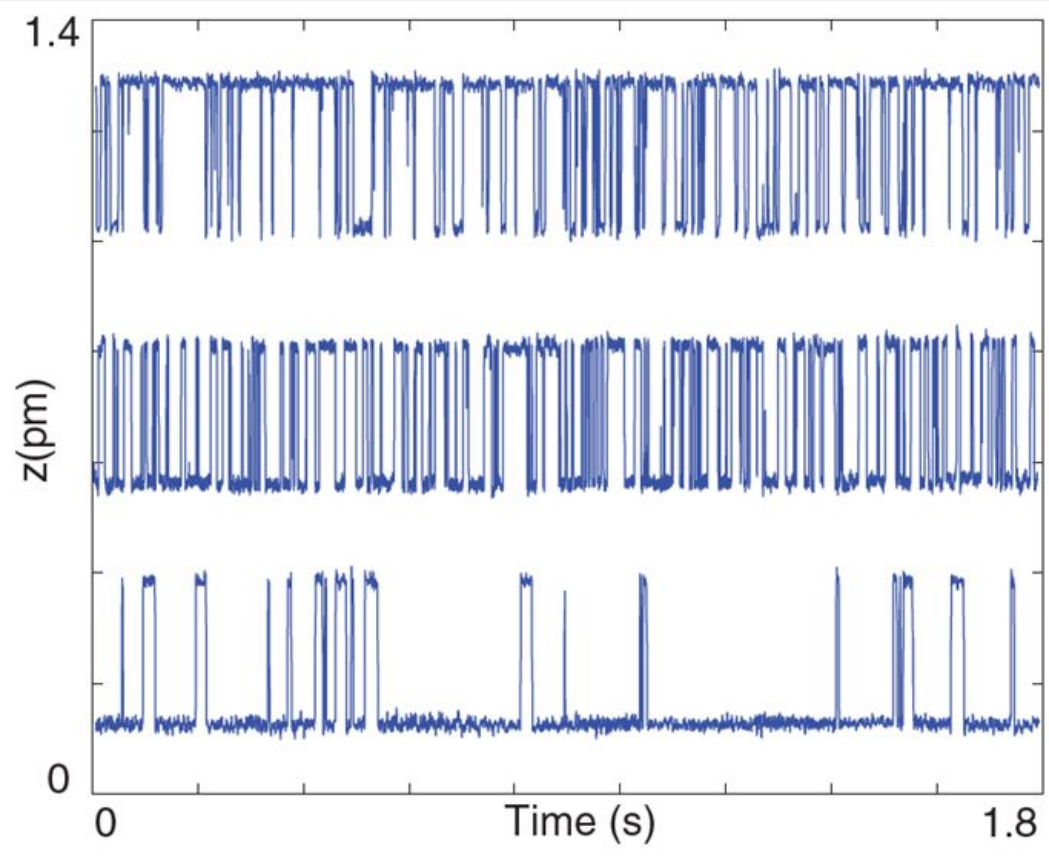
Quantum Force Sensors

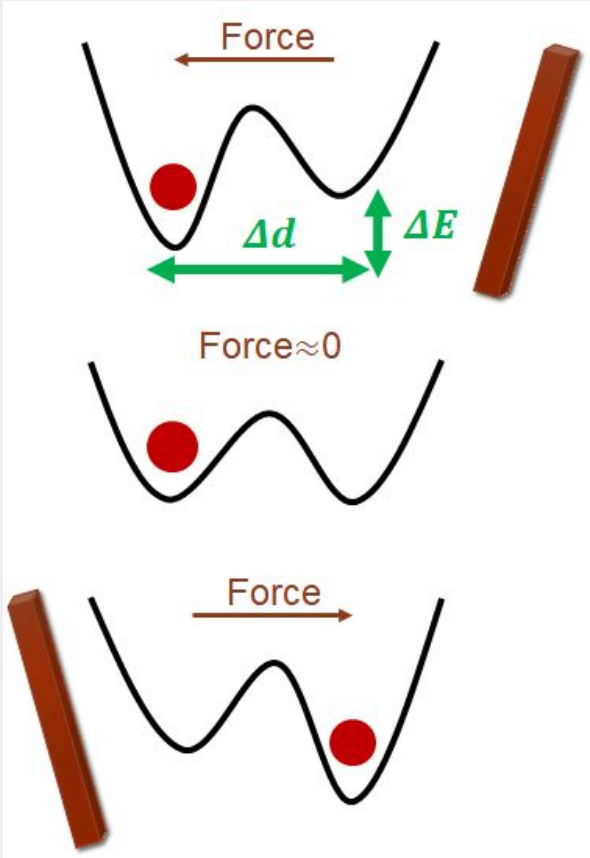




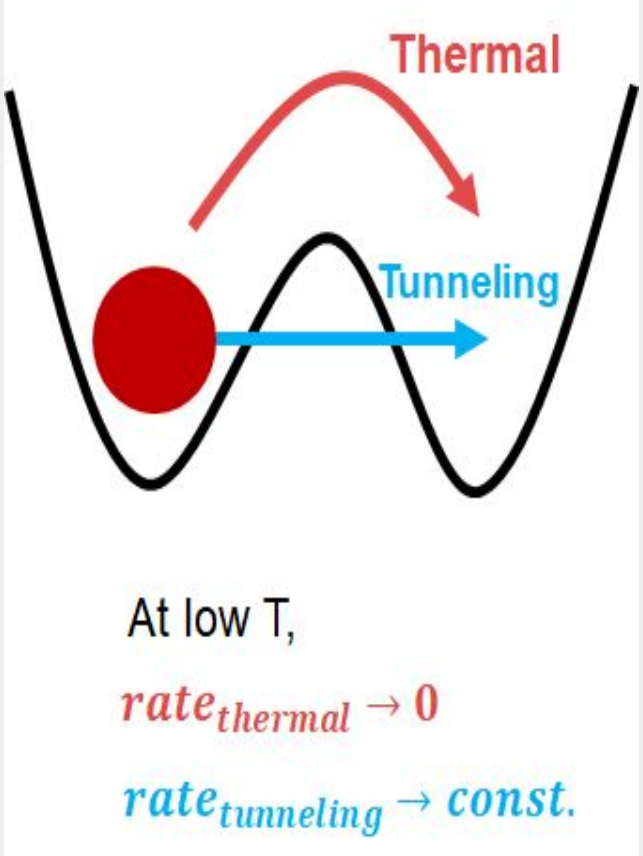
Quantum Force Sensors

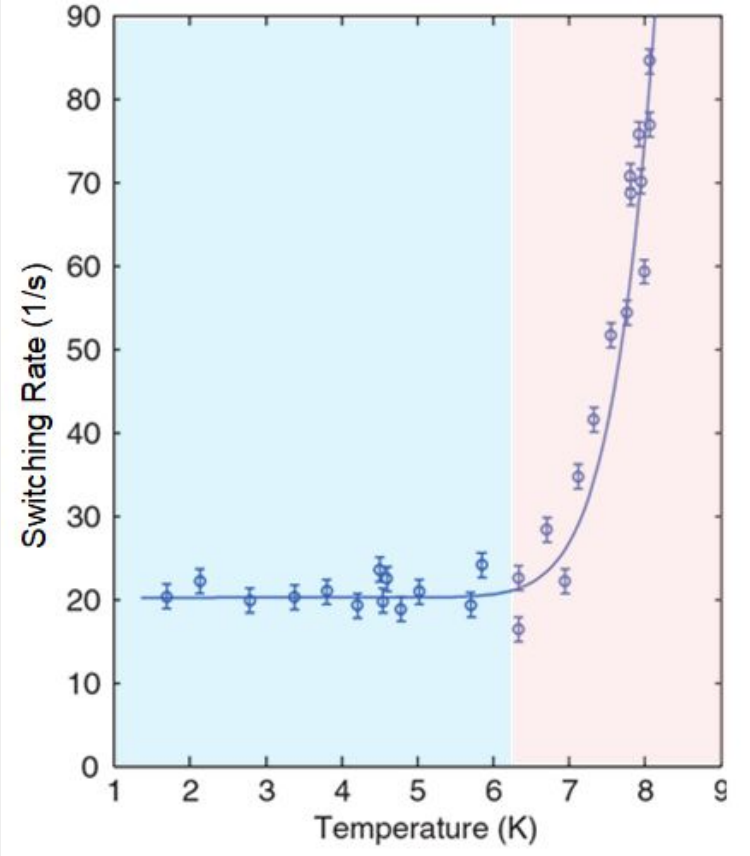
$$F = \frac{\Delta E}{\Delta d} \approx -\log\left(\frac{t_1}{t_2}\right)$$



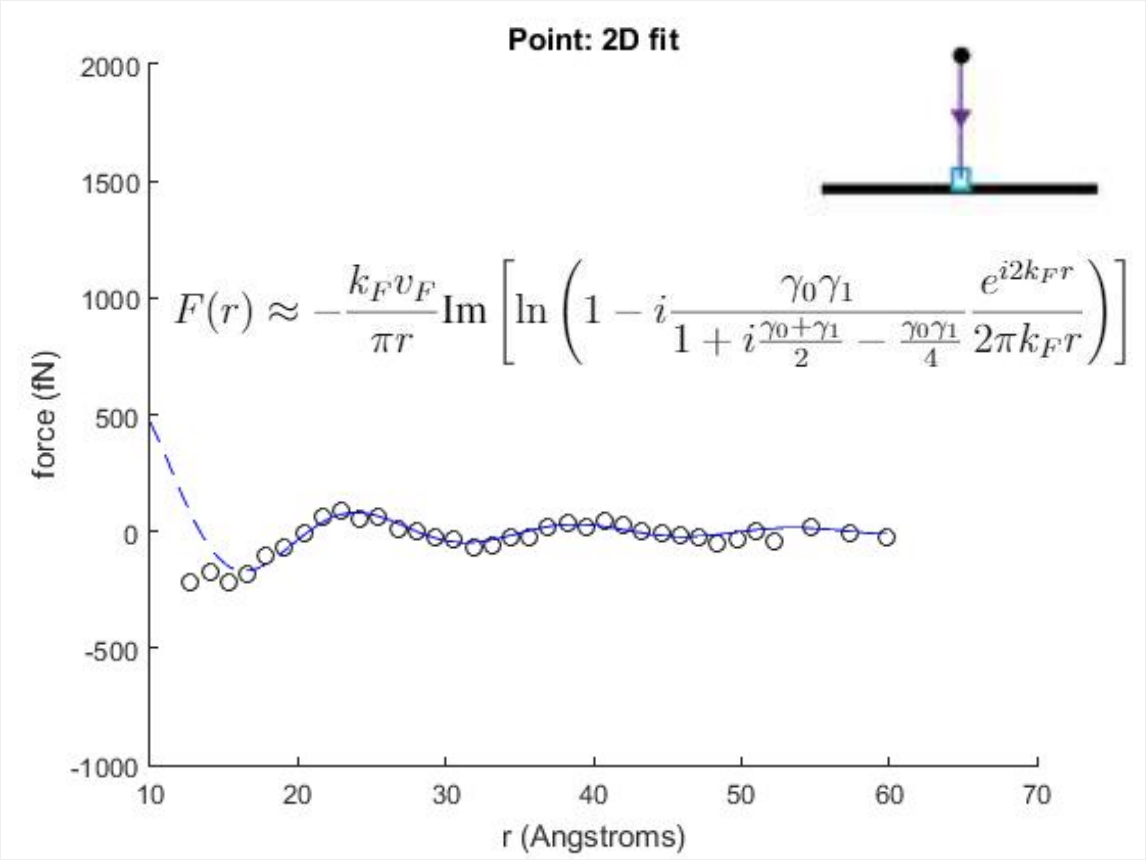


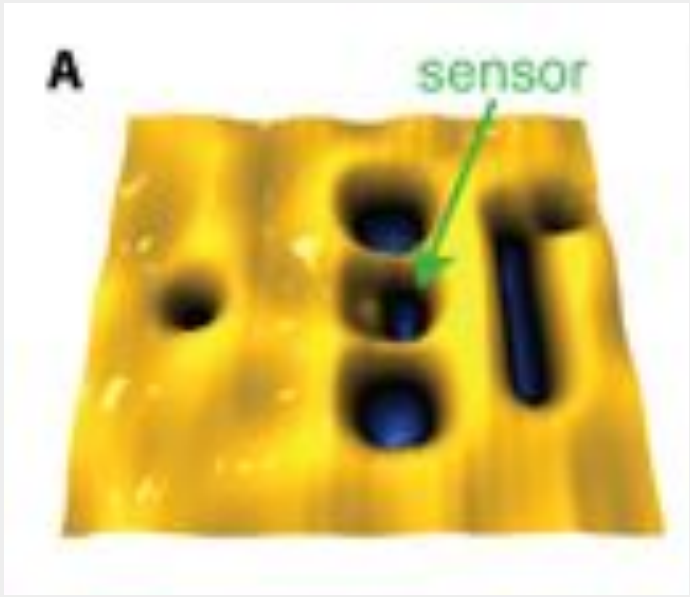
Quantum Force Sensors



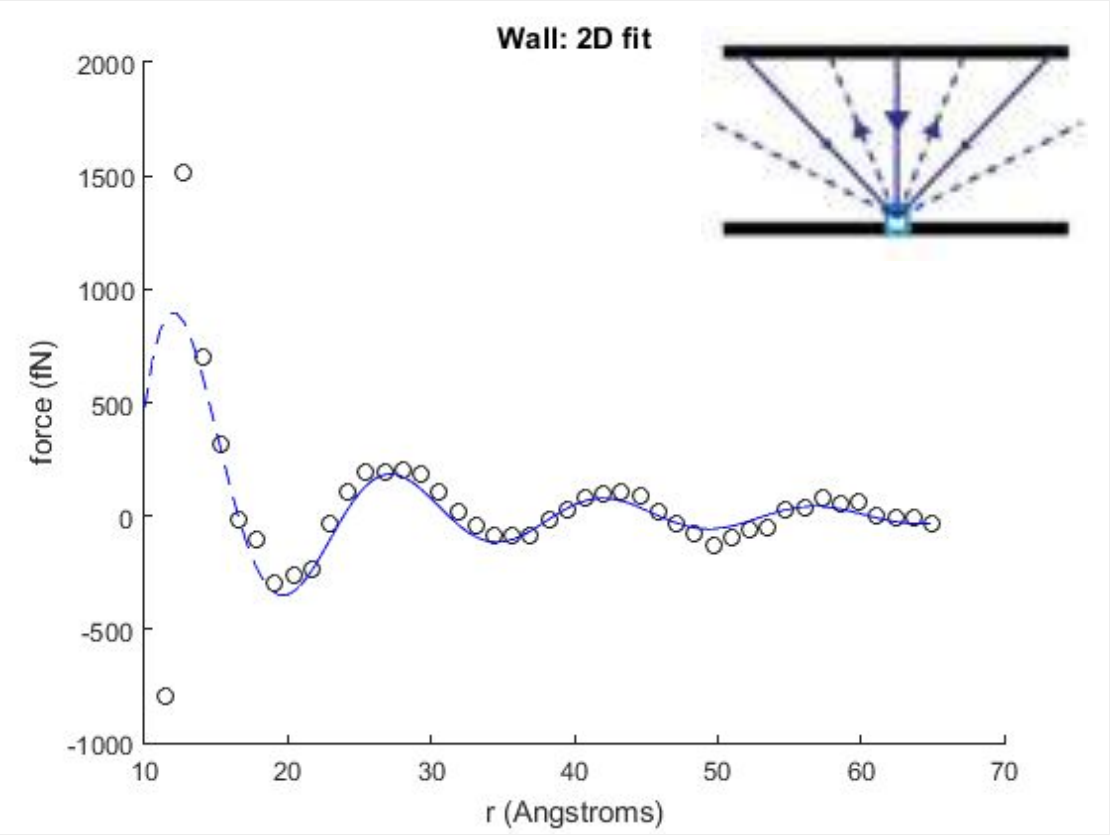


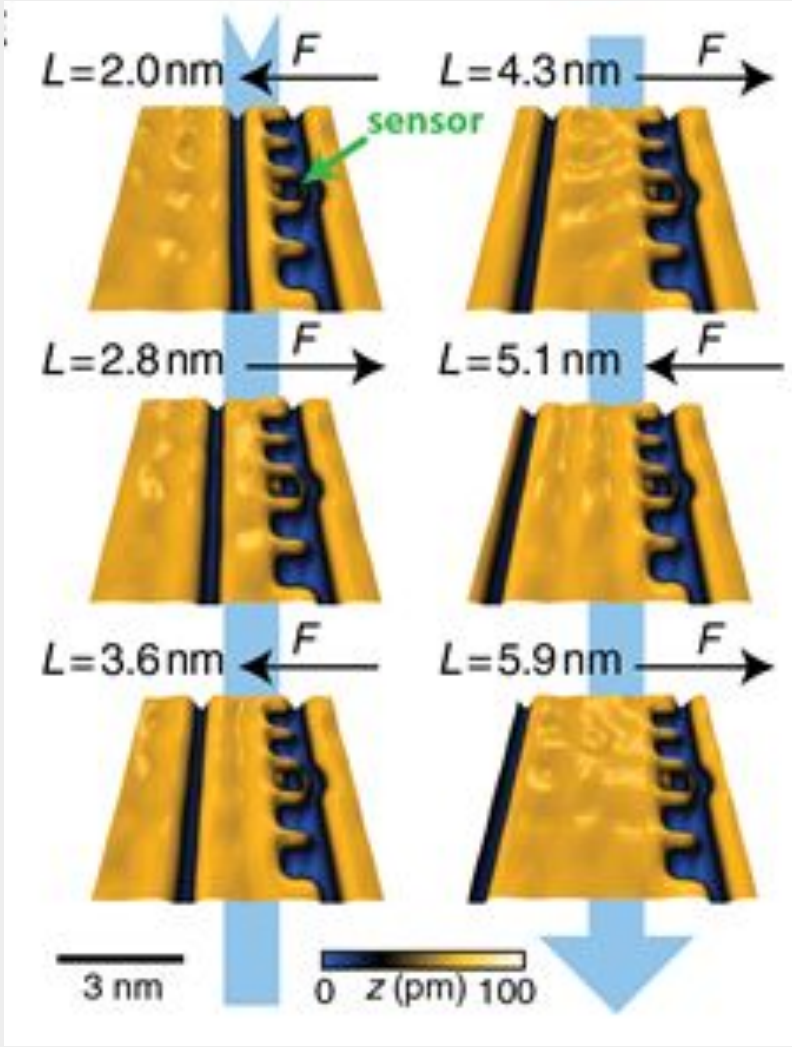
Fermionic Casimir Forces: Point Source



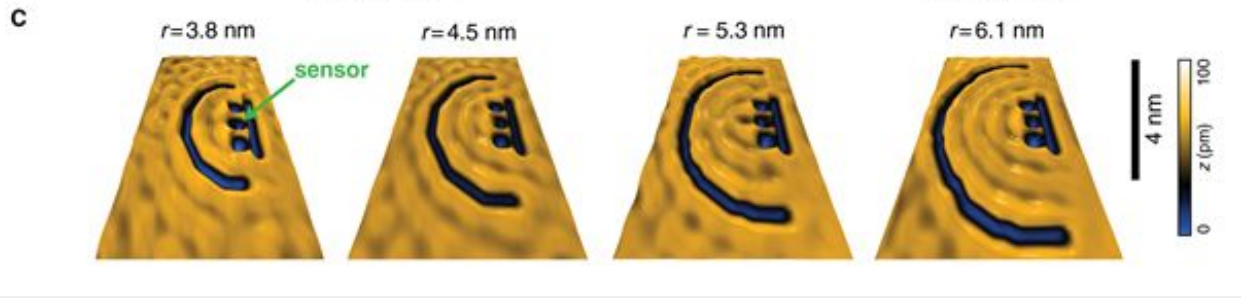


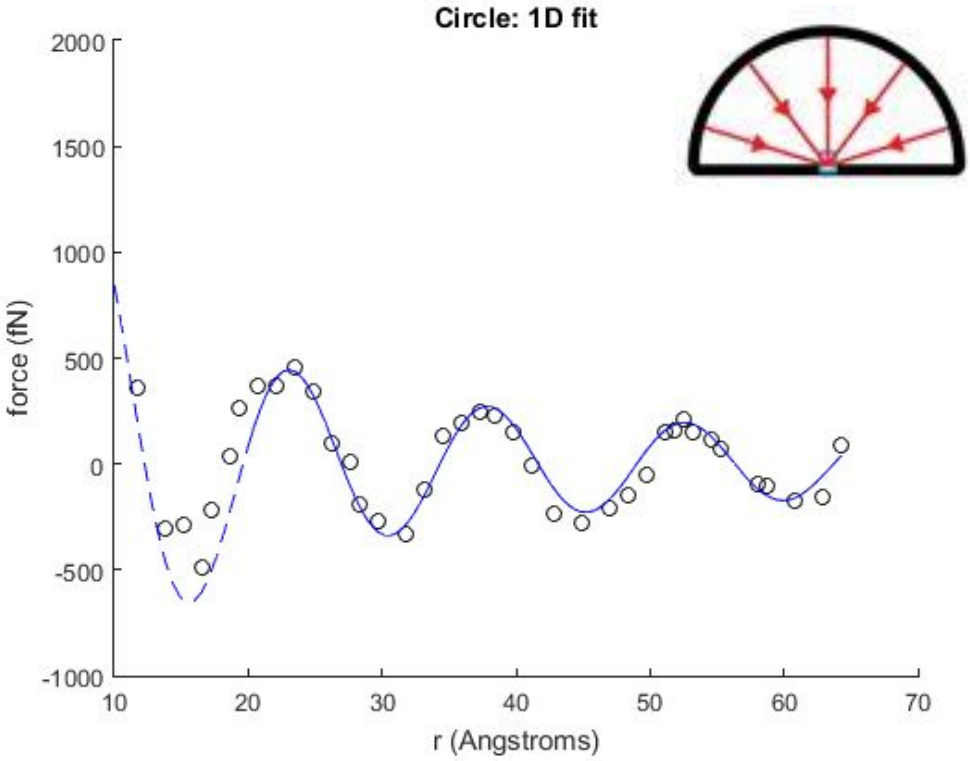
Wall Source


Wall: 2D fit
force (fN)
r (Angstroms)
2000
1500
1000
500
0
-500
-1000
10
20
30
40
50
60
70

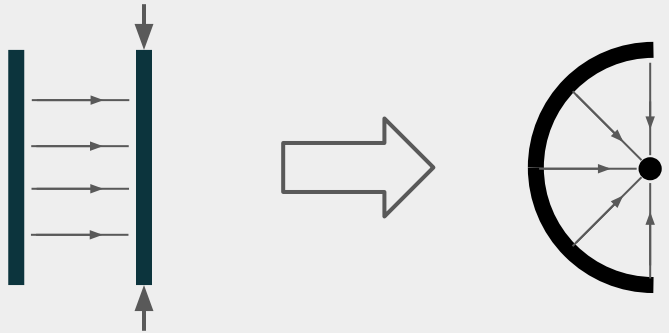

L=2.0nm
F
L=4.3nm
F
sensor
L=2.8nm
F
L=5.1nm
F
L=3.6nm
F
L=5.9nm
F
3 nm
0 z (pm) 100

Circular Source

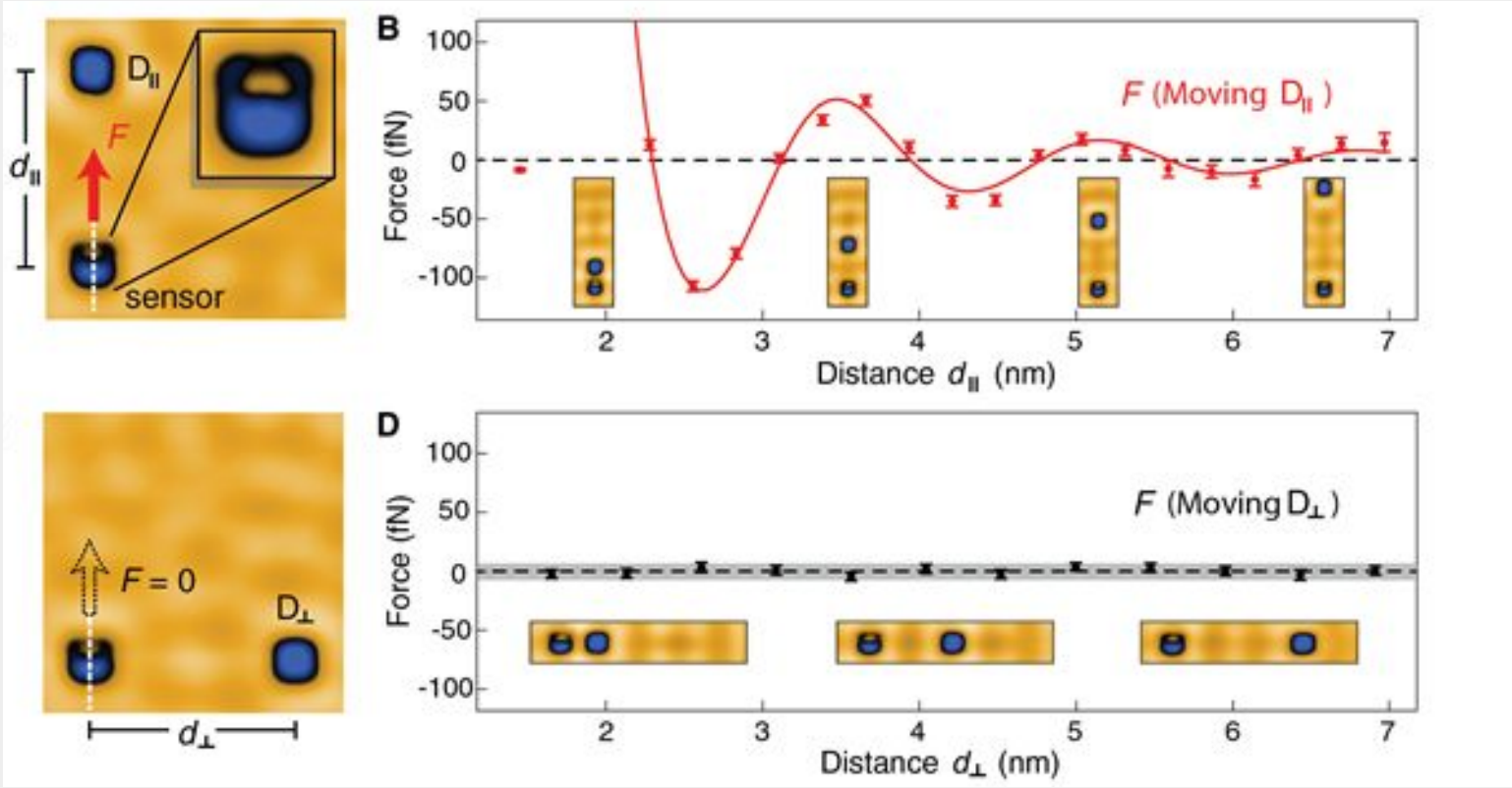




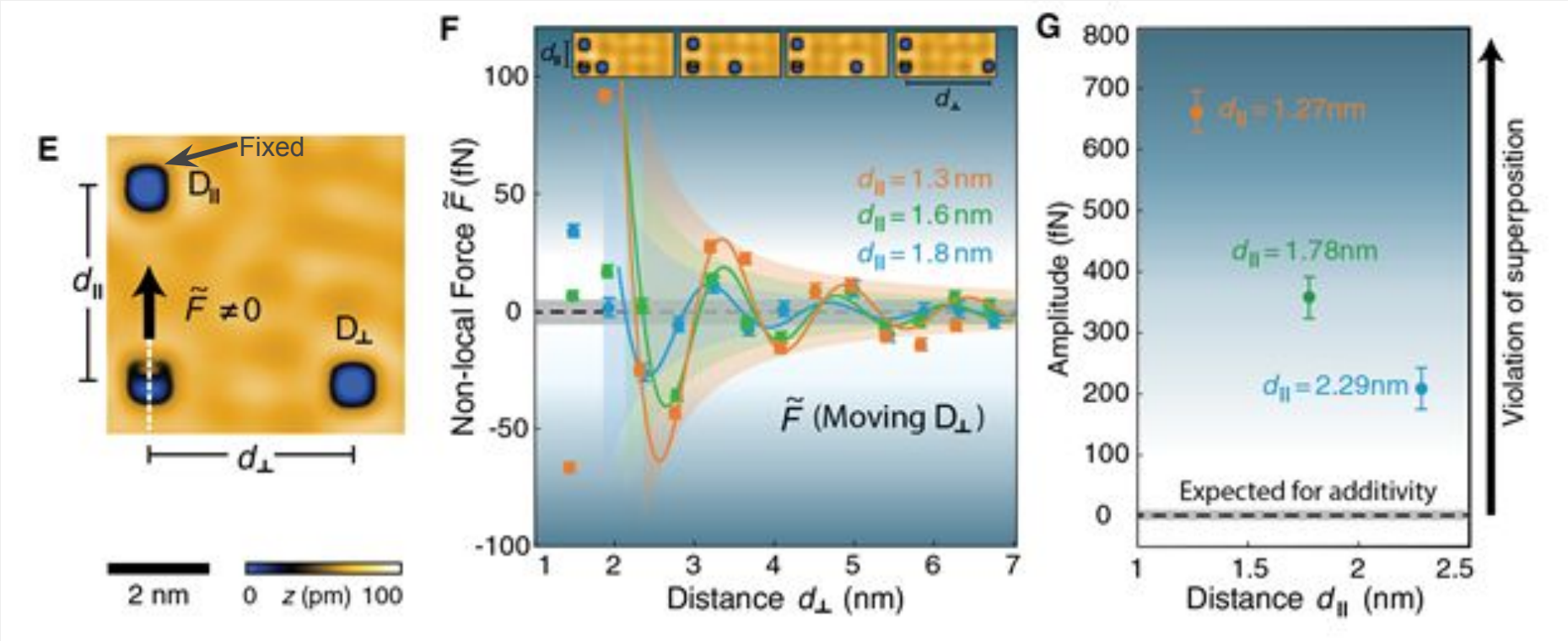
- True 1D case is line-to-line, collapsing source to a point maps conformally to circular source.



Non-Local Effects from Background Particle Fields

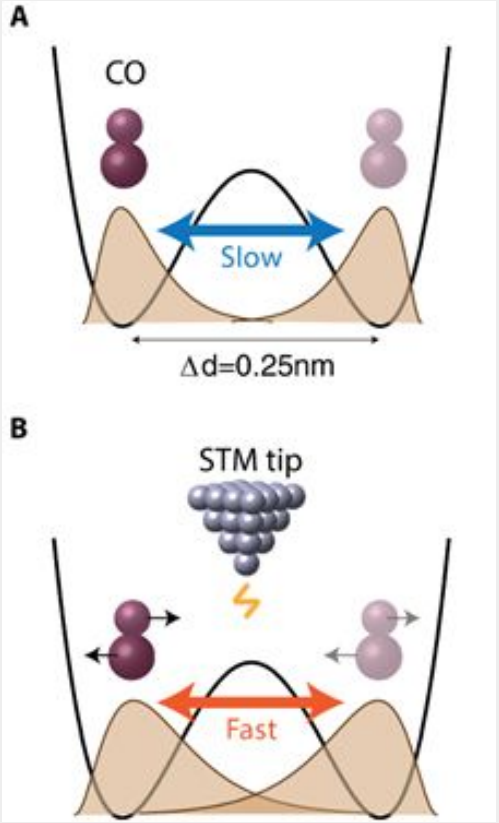


Non-Local Effects from Background Particle Fields



Increasing Force Sensitivity

- For 30 minute acquisitions we reach <1 fN sensitivity.
- Sensing resolution increased with faster switching rates, larger sampling time.
  - Driving sensor into excited state.
  - Molecular engineering of switching molecule.



Conclusions

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