Dispersion Forces on Graphene Systems

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Shielding a substrate with a graphene sheet

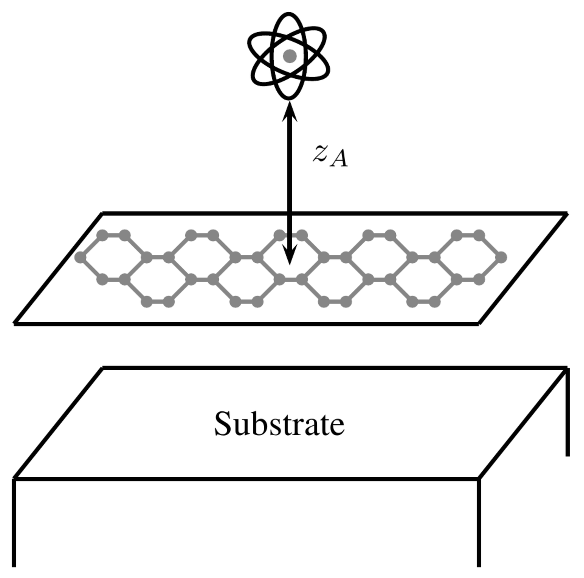
Graphene was been showned to be a strong absorber of electromagnetic radiation [1], it interacts strongly with light over a wide wavelength range, particularly in the far infrared and terahertz parts of the spectrum.

With graphene's absorbing properties in mind, we study the possibility of graphene systems to work as a shield of the effects of a substrate placed underneath it.

We adopt the ***Dirac model*** [2,3] for graphene and calculate the Casimir–Polder interactions, based on ***macroscopic QED formalism***. At zero temperature and for planar structures the CP potential can be written as [4]

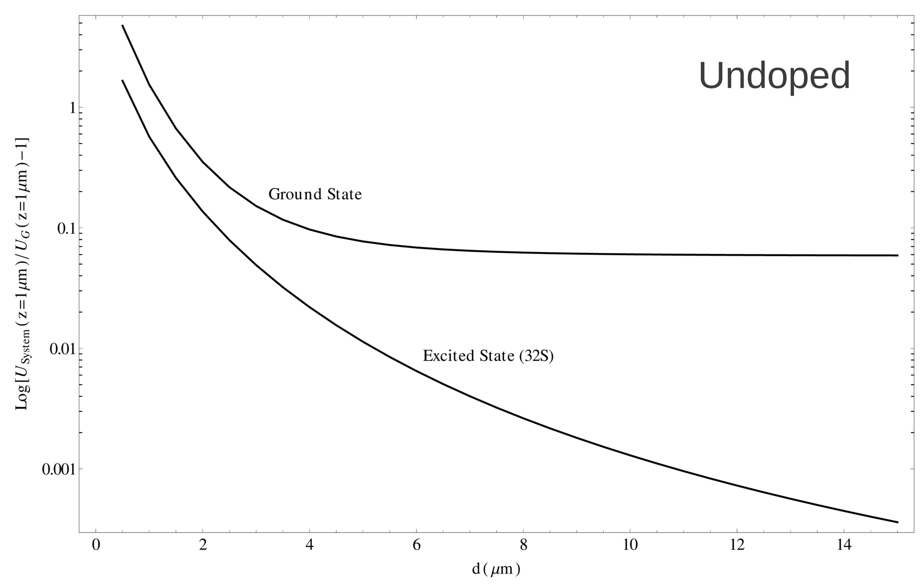
$$U_{\mathrm{CP}}(z_A)=\frac{\hbar\mu_0}{8\pi^2}\int_0^\infty d\xi\,\xi^2\alpha_n(i\xi)\int_0^\infty dk_\parallel\frac{e^{-2k_\parallel\gamma_{0z}z_A}}{\gamma_{0z}}\left[\mathrm{R}_{\mathrm{TE}}+\mathrm{R}_{\mathrm{TM}}\left(1-\frac{2k_\parallel^2\gamma_{0z}^2c^2}{\xi^2}\right)\right]$$
$$+\frac{\mu_0}{4\pi}\sum_{k\neq n}\omega_{nk}^2\,\mathbf{d}_{0k}\otimes\mathbf{d}_{k0}\int_0^\infty d\kappa_{0z}e^{-2\kappa_{0z}}\,\mathrm{Re}\left[\mathrm{R}_{\mathrm{TE}}+\mathrm{R}_{\mathrm{TM}}\left(1+\frac{2\kappa_{0z}^2c^2}{\omega^2}\right)\right]$$

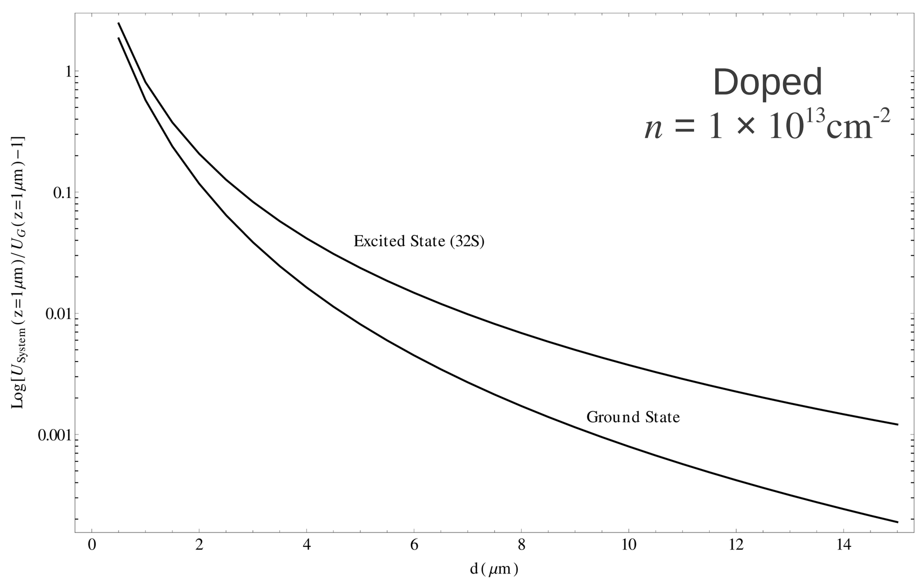
The first term describes the nonresonant part of the CP potential, recognisable by the integration along the imaginary frequency axis and the second term is related to resonant photon exchange between the atom and the graphene sheet. R_{TM} and R_{TE} are the reflection coefficients for the transverse magnetic (TM) or transverse electric (TE) modes of the layered system under investigation.



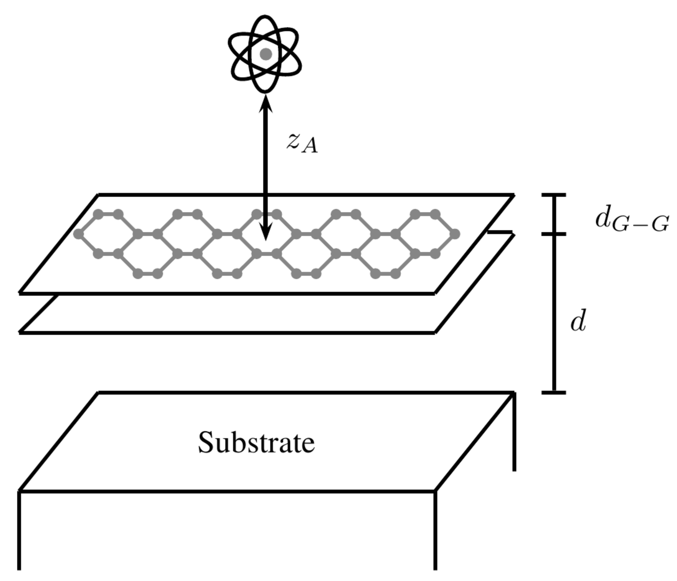
Scheme of an atom near a free-standing graphene sheet close to a dielectric substrate

For our simulations, we considered a gold substrate described by the Drude Model.

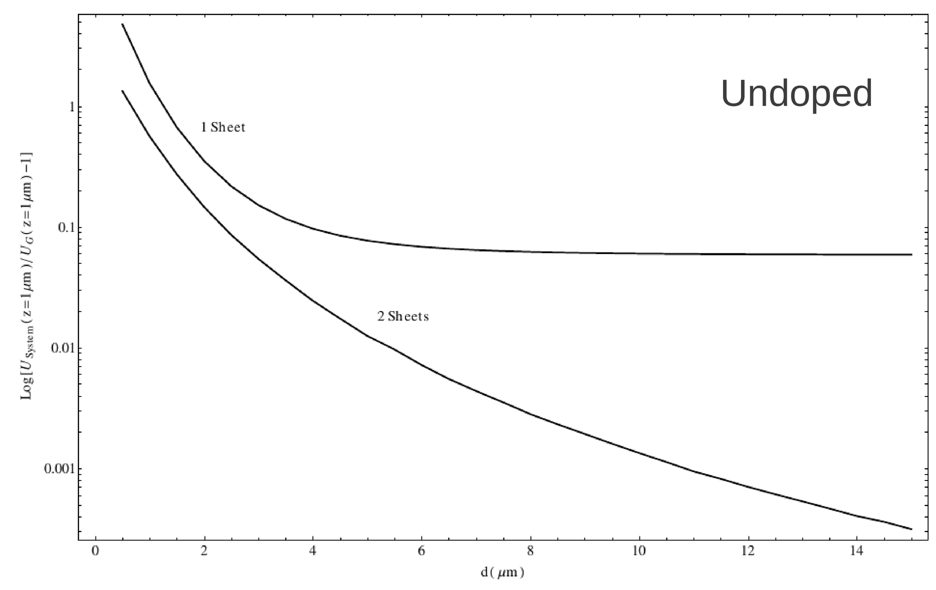




Normalized CP potential of a Rubidium atom (in the ground and 32S Rydberg state) at $z_A = 1\mu\mathrm{m}$ for different distances d between the graphene sheet and gold.



Scheme of an atom near two free-standing graphene sheets close to a dielectric substrate



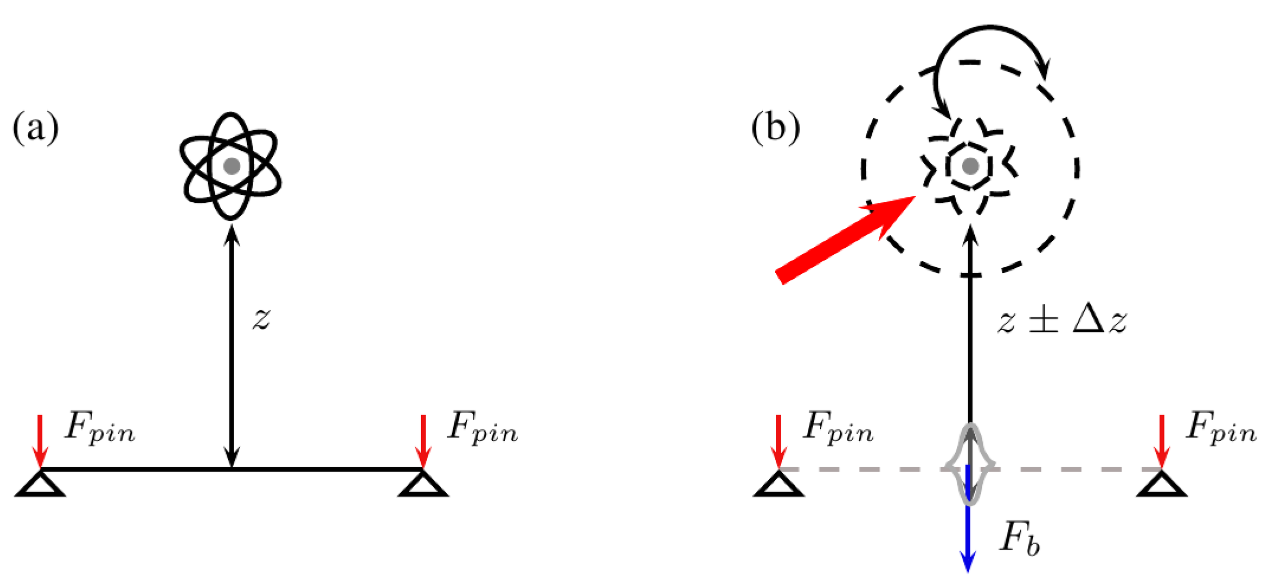
Normalized CP potential of a Rubidium atom at $z_A = 1\mu\mathrm{m}$ for different distances d between the graphene sheet and gold.

We kept fixed the distance between the two graphene layers at $0.5\ \mu\mathrm{m}$.

Controlled ripple texturing through Casimir-Polder force

We propose the possibility to create ***hybrid quantum systems*** which combine coherent cold atoms with graphene membranes. The atoms can couple to a graphene membrane via CP forces. Temporal changes in the atomic state changes the CP interaction which leads to the creation of a ***backaction force*** in the graphene sheet.

→ **controllable way to engineer ripples in a graphene sheet**



Schematic diagram (not to scale) showing an atom next to a suspended graphene membrane (distances in the order of a few hundred nanometers). The arrows indicate the two forces F_{pin}, F_b at interplay in the system.

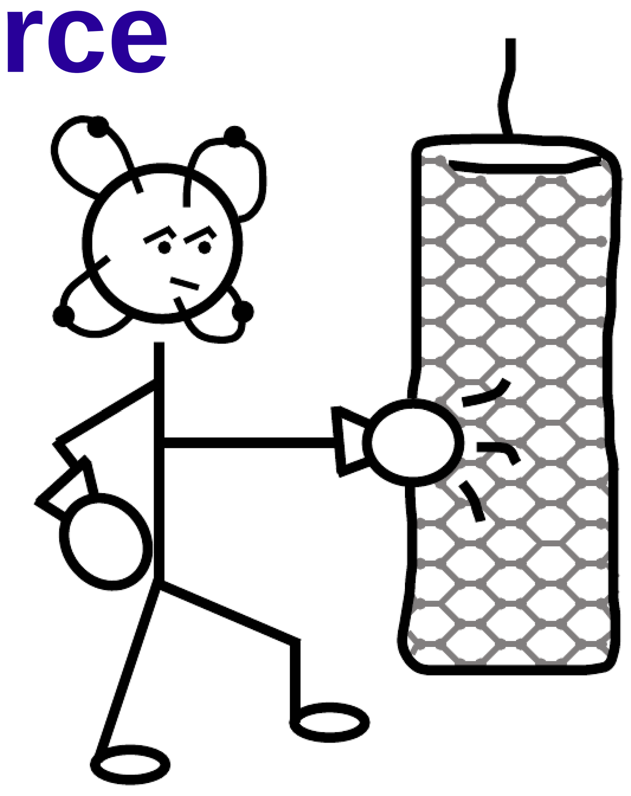
For mechanical resonators under tension T the fundamental resonance mode f_0 is given by [5]

$$f_0=\left\{\left[A\sqrt{\frac{E}{\rho}}\frac{t}{L^2}\right]^2+A^2 0.57\frac{T}{\rho L^2wt}\right\}^{1/2}$$

where E is Young's modulus, ϱ is the mass density; t, w, L are the dimensions of the suspended graphene sheet and A is a clamping coefficient (A is equal 0.162 for cantilevers).

To create a force necessary to produce a ripple of a determined amplitude one needs to excite N atoms of the condensate. The interplay between atom–surface distance and principal quantum number n is of crucial importance in this process.

$$N_{\min}(n)\gtrsim 1.2\times10^{-6}n^4$$



Atomic State	$z_{\min}(n)$	$N_{\min}(n)$
$\lvert 32S_{1/2}\rangle$	121 nm	2
$\lvert 43S_{1/2}\rangle$	218 nm	5
$\lvert 54S_{1/2}\rangle$	345 nm	11

Minimal number of atoms required to generate a ripple with 1 nm amplitude for a cantilever with T=16fN.

References

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