Trapping a Two-level atom near a planar surface

Trapping and guiding atoms close to surfaces
- Tight confinement and strong coupling between atoms & photons
- Cavity QED with microcavities and photonic crystals – high Q, low mode volume
- Large scale elements replaced by miniaturized devices

Harness surface forces to build a trap by flipping the sign of the attractive potential

Constraints for Levitation
Extension of Earnshaw’s theorem to Casimir forces (Rahi et al, 2010) – repulsive interaction possible for
- Magnetic response
- Permittivities of the interacting objects asymmetric with respect to the surrounding medium
- Equilibrium
- Drive the atom to an excited state

Level shifts and spontaneous emission for different surfaces

Scattering from the surface
- Atom treated as a classical point dipole radiating in front of a planar surface
- Scattered part of the Green’s function can be determined from the reflection properties of the surface
  - Imaginary part corresponds to the power dissipated by the dipole, gives corrections to the spontaneous emission rate
  - Real part corresponds to the atomic level shifts in the presence of the surface

Excited Atom-Graphene interaction

Surface Plasmon contribution dominates spontaneous emission for chemical potential larger than the critical value in the near-field regime

Atom-Surface Interactions – Fluctuation forces

- Casimir Force (1947) – Quantized EM field modes in the presence of a surface lead to modification of zero point energy
- Vacuum forces – Fluctuation induced electromagnetic forces between neutral bodies

Off-resonant and Resonant energy level corrections coming from interaction with the vacuum EM field

II. ATOM NEAR DIFFERENT PLANAR SURFACES

Driving the atom externally with an far-detuned drive
- Drive frequency tuned such that the material has a resonant response for the Rayleigh scattered light from the atom

Dielectric Half-space

- For a dielectric, the Resonant potential in the near-field regime goes as
- Large resonant shift close to the surface limited by the loss parameter $U_{\text{loss}}^{\text{max}} = \frac{\pi^2 \kappa^2}{m^* \omega^2}$
- Vacuum modes lead to attractive off-resonant potential in the far and near field regimes

Far detuned drive becomes resonant for some distance from the surface

Trap Mechanism

- Atomic resonance frequency function of distance from the surface because of level shifts
- Mostly ground for close and far-off distances from the surface
- Increased probability of being in the excited state near resonance – atom experiences large resonant potential
- Trap seen near resonance!

“Eternal nothingness is fine
If you happen to be dressed for it”
- Woody Allen