Analysis of the Green's Function of a Metallic Slab in Different Media

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1 Methodology

The Green's function of a metallic slab characterizes the electromagnetic response of the system and depends on frequency (w), slab thickness (t), and observation (calculation) distance from the slab (z). This report presents the results of the analysis of the real and imaginary components of the Green's function for different surrounding media (vacuum and silica) The dielectric function of the metallic slab is modeled using the Drude model:

$$\varepsilon(\omega) = \varepsilon_b - \frac{\omega_p^2}{\omega^2 + i\gamma\omega}, \tag{1}$$

Here, $\varepsilon_b = 9.5$, $\omega_p = 9.06$ eV, and $\gamma = 0.071$ eV. Given the layering of the system along the z-axis, the nonzero components of the Green's function are G_{xx}, G_{yy}, and G_{zz}, with $G_{xx} = G_{yy}$ due to in-plane symmetry. So only G_{xx} and G_{zz} were computed numerically via integration using Python (SciPy) with adjustments to ensure convergence while handling singularities. Two different medium configurations were considered: (a) vacuum above and below ($\varepsilon_1 = \varepsilon_3 = 1$), and (b) vacuum above with silica below ($\varepsilon_3 = 4.2$). For each configuration, the variation of G_{xx} and G_{zz} was analyzed with ω ranging from 2 to 6 eV, t ranging from 1 to 20 nm, and z ranging from 1 to 20 nm. These values were decided for clearer features and conversion to S.I units were done when plotted.

2 Results and Discussion

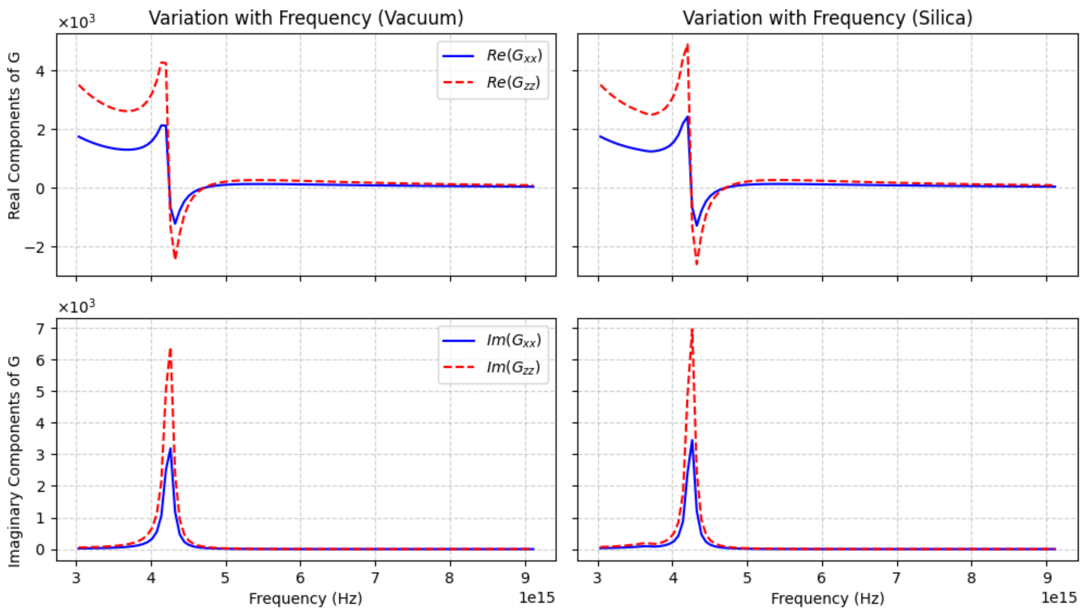

Figure 1: Variation of G components with ω for vacuum as an upper layer and vacuum and silica, respectively, as lower layers

Figure 1 shows the real and imaginary components of G_{xx} (blue) and G_{zz} (red), as a function of frequency for two different lower media: vacuum and silica. In the top row (the real components), a sharp resonance is observed around 4×10^{15} Hz, where both G_{xx} and G_{zz} show significant peaks. The resonance is higher in G_{zz}. The peak is sharper and the amplitude is higher in the case of silica, but the the resonance frequency does not differ. This suggests thatthe plasmonic response is affected by the metallic slab rather than the underlying medium.
At higher frequencies, the components stabilize in line with the expected Drude model behavior, where the metallic response transitions towards a dielectric-like system. The imaginary components (the lower row) show a similar resonance behavior, with a sharp peak at the same frequency, which shows strong dissipative effects near the plasmon

resonance.

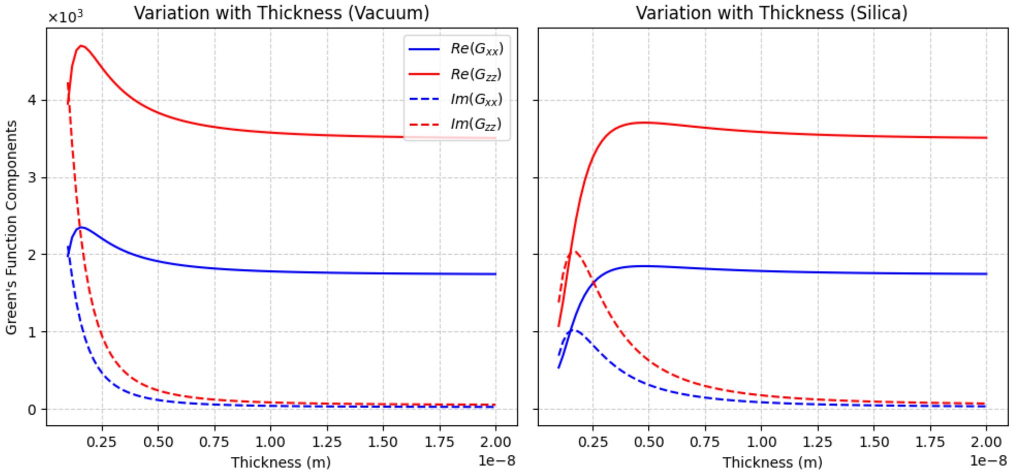

Figure 2: Variation of G components with t for vacuum as an upper layer and vacuum and silica, respectively, as lower layers

Figure 2 shows the components as a function of the slab thickness. For both cases, G_{zz} is consistently higher than G_{xx}. At smaller thicknesses, both components shows a variation and peaking before stabilizing, with a higher peak for G_{zz}. As the thickness increases, the response flattens which might suggest that the thicker the slab, the less sensitive to its surfaces. Where silica is added, the function starts at a lower value and increases with the increase of the thickness until it stabilizes, with the peaks are flattened. The imaginary components shows a decay pattern in the vacuum case, while in the silica case, they show a variation similar to that of the real components in the vacuum case but with lower magnitude. This suggests that dissipation is affected by the material contrast and less abrupt in the presence of silica. The overall trend is almost preserved and shows that dissipation is higher for thinner slabs between two layers of vacuum.

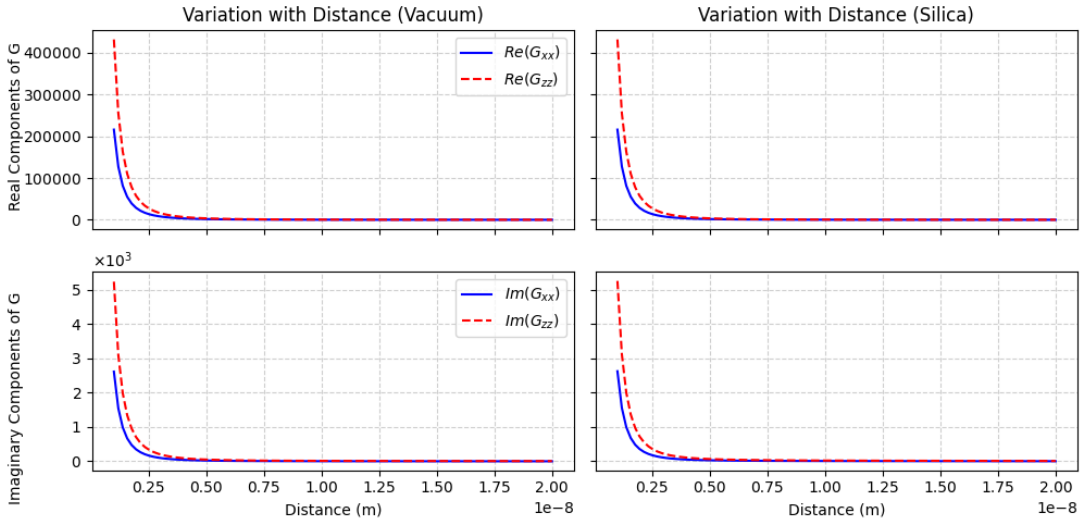

Figure 3: Variation of G components with z for vacuum as an upper layer and vacuum and silica, respectively, as lower layers

Figure 3 shows the variation of G_{xx} and G_{zz} as a function of observation distance. In both cases of vacuum and silica, all components show the same rapid decay. The values are higher at small distances and decrease as the distance increases. The decay behavior is nearly identical for vacuum and silica, which suggests that the components as a function of distance is not affected by the underlying medium. The overall trend shows that the field is confined near the slab and experiences a decay with distance. The imaginary components exhibit a similar decay trend and show strong dissipation effects near the slab. This shows that field confinement is strongest at small distances and that dissipation diminishes at larger distances.