Heat transfer of Nanoholes as inside-out Nanoparticles

Thomas Prevenslik
QED Radiations, Berlin, Germany

Abstract Nanoscale heat transfer of nanoholes (NHs) in solids is presented as the inside-out version of solid nanoparticles (NPs) in air. However, classical light-heat interaction in electromagnetic (EM) modes of NPs and NHs is not valid and requires consideration of the Planck law of quantum mechanics that denies atoms in NHs and NPs the heat capacity to conserve heat by an increase in temperature. Simple QED is a nanoscale heat transfer process (nothing to do with Feynman's QED) that is based on the Planck law by conserving heat in local nanoscale regions of a structure by the emission of EM radiation instead of temperature. Unlike elastic Mie scattering, simple QED is similar to inelastic Raman scattering that includes changes the emission frequency of absorbed light, but differs in that conservation occurs in size dependent EM quantum states E of the nanostructure. Since both NHs and NPs are presumed small compared the wavelength of incident light, simple QED assumes light is absorbed over NH and NP surfaces. Since the Planck law precludes conservation of absorbed light by a temperature increase, simple QED assumes standing EM radiation is created inside the NH or NP, the absorbed surface heat itself providing the EM confinement to constrain standing EM radiation inside the NH and NP. In effect, simple QED conserves heat from light in nanoscale regions by creating EM radiation - not temperature. Examples are presented to illustrate how heat transfer of inside - out NPs is related to NHs.

Analysis

Currently, surface plasmons (SPs) are thought to be intrinsic EM modes that enhance light near nanoscale metal features, e.g., strong EM enhancement with NPs and NHs, although the source of SPs is not well understood. In contrast, simple QED is proposed to define size dependent states E for the NP and NH in terms of the respective refractive index n and spherical or cylindrical diameter d, i.e., $E = hc/\lambda$ with $\lambda = 2nd$, where h is Planck's constant and c the velocity of light.

Simple QED is not only the source for exciting SPs, but also as the E state fluoresces down to lower levels molecular states are exited in the NP or the NH. Nanotechnology is commonly characterized by light excited SPs on NP surfaces, but less known is enhanced light transmission through NHs. But SPs cannot explain how heating air in a 200 nm NH in a thin Au film with a 532 nm laser [1] produced a significantly shorter ~ 475 nm circular fringes around the NH.

A simple QED comparison of a spherical 200 nm gold NP with a cylindrical 200 nm NH in a gold film is presented as shown in Fig. 1.

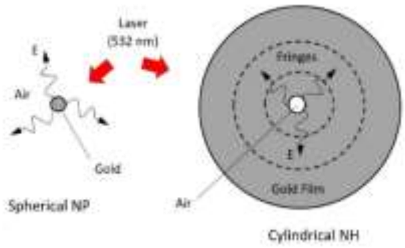

Figure 1. NP in Air vs. Air in NH

The 200 nm gold NP of diameter d is shown in air surroundings that extend to a spherical region of infinite extent. In contrast, air in the NH of a gold film is limited to the 200 nm diameter d of the NH. A 532 nm laser is shown irradiating the NP and NH. By simple QED, the state E is given in both NP and NH as $\lambda = 2nd$, where n is the refractive index of gold in the NP and air in the NH, both having the same diameter d. For air having index n = 1, simple QED produces $\lambda = 400$ nm standing EM radiation inside the NH, but upon entering the film is redshift by the gold index before emission to the surroundings. The index of gold films [2] is sensitive to wavelength from 450 to 500 mm, giving n = 1.2 at 480 nm consistent with the experimental fringes at ~ 475 nm. In contrast, the gold NP emits EM radiation at ~ 475 nm directly into the surroundings.

Conclusions

By simple QED, the enhanced transmission of light through NHs in gold films is the inside-out variant of gold NPs, both emitting ~ 475 nm EM radiation into the surroundings.

Simple QED is the proposed source of SPs and not evanescent waves.

The 532 nm laser only serves as a heat source to the air in the NH and the gold NP, neither of which have anything to do with SPs.

References

[1] Yin, L., *et al.*, 2004: Surface plasmons at single nanoholes in Au-films. *Applied Physics Letters* · **85**, 467.

[2] Refractive Index of Au, Gold for Thin Film Thickness Measurement, See Tabular data. https://www.filmetrics.com/refractive-index-database/Au/Go.