Superlens by transformative optics or QED?

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Transformative optics suggesting diffraction-limited image resolution may be restored by evanescent fields in a silver film is superseded by QED inducing sub-diffraction-limited quality from diffraction-limited images

INTRODUCTION

In conventional optics, image quality depends on the diffraction limit. Recently, Transformative Optics (TO) using a superlens was proposed to restore image quality below the diffraction limit – the restoration not possible with conventional optics. TO theory [1] explains the superlens by evanescent waves in meta-materials having negative permittivity in contact with a dielectric with a permittivity of equal and positive sign, although a superlens of nanoscale silver film somehow obviates the need for complex permittivity matching.

In classical physics, evanescent waves [2] in the surface of materials require a thermal origin, but the Planck law of QM precludes temperature fluctuations in nanoscale films because the heat capacity of the atom vanishes. QM stands for quantum mechanics. What this means is TO cannot explain the enhanced image quality of a silver superlens not only because matched permittivity is not required but because evanescent waves cannot exist [3] in nanoscale thin films. An alternative TO theory is required to explain the superlens.

In this regard, consider the superlens configuration [1, 4] comprising a 35 nm silver film in contact with a 40 nm PMMA spacer under UV illumination at $\lambda^* = 365$ nm resolving sub–diffraction-limited etched chromium objects down to 60 nm shown in Figure 1(a).

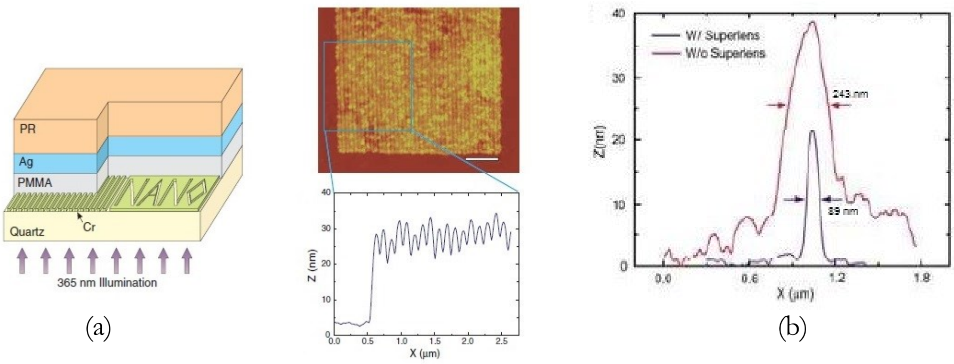

Figure 1. Superlens Configuration and Enhanced Image Quality

Absent the silver film, the diffraction-limited wavelength P* = λ* / n is controlled by the refractive index n of PMMA, i.e., for n = 1.5, P* = 243 nm. With the silver film, the superlens was found to resolve the average cross section of the etched chromium objects to a line width of 89 nm. The diffraction-limited and enhanced image quality shown in Figure 1(b).

THEORY

Imaging below the diffraction-limit using a superlens is proposed to be a natural consequence of simplified QED induced EM radiation created in the nanoscale silver film upon the absorption of light from the diffraction limited P* image. QED stands for quantum electrodynamics, but differs from the complex relativistic QED by Feynman and others.

Briefly stated: simplified QED conserves EM radiation (or light) supplied to a superlens absent heat capacity by creating light having half-wavelength $\lambda/2 = nd$, where n and d are the refractive index and thickness of the silver film. But the superlens must be absorptive at the diffraction-limited wavelength. P* consistent with silver and other noble metals.

The superlens having a vanishing heat capacity requires clarification. By classical physics, the nanoscale silver film conserves the light of the P* image by changing its temperature. QM differs as the Planck law requires atoms through the film thickness have vanishing heat capacity thereby precluding any change in film temperature. The Planck law at 300 K in relation to EM confinement wavelength is illustrated in Figure 2.

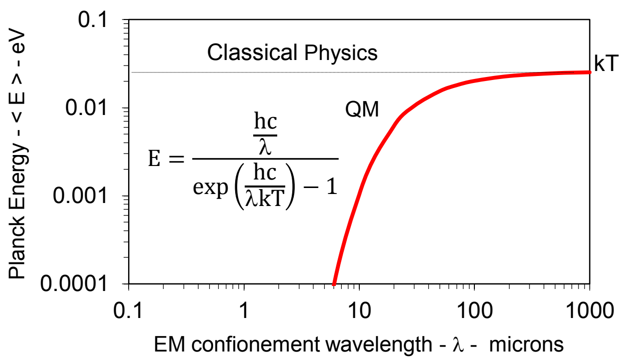

Figure 2 Planck law of the Atom at 300 K

In the inset, E is Planck energy, h Planck's constant, c light speed,
k Boltzmann's constant, T temperature, and λ EM confinement wavelength

For heat capacity to vanish, Figure 2 shows the silver atom in the film must be placed under nanoscale EM confinement wavelengths λ < 100 nm. But this a natural characteristic of nanoscale films having high S/V ratios as the absorbed P* image energy is almost entirely to confined to their surfaces, the surface energy itself providing momentary EM confinement of silver atoms over nanoscale wavelengths. S/V stands for surface-to-volume.

DISCUSSION

The diffraction-limited wavelength P* for PMMA [4] having n = 1.5 illuminated with UV at λ^* = 365 nm is, P* = 365/1.5 = 243 nm. Below P*, periodic spaced structures cannot be resolved as shown in Figure 1(b).

The superlens of a silver film interposed between the PMMA and the photoresist absorbs the light of the diffraction-limited image P*. Since QM precludes temperature changes in the nanoscale silver film, the energy of the P* diffracted image light is conserved by the emission of light at wavelength λ = 2 nd, where n is the refractive index and d is the thickness of the silver film. Unlike evanescent waves that cannot pass through the silver film, QED induces the silver films having thickness d = 35 nm to emit light at sub-diffraction wavelength λ that etches the photoresist. Consistent with Figure 1(b), silver at P* = 243 nm from [5] having n = 1.28, QED produces sub-diffraction-limited light at λ = 2 (1.28) 35 =89.6 nm.

CONCLUSIONS

QED induced enhancement of diffraction-limited images in silver superlens thicknesses < 100 nm is proposed as an TO alternative. QED does not rely on evanescent fields, but rather is a consequence of the size effect of QM that precludes conservation of light from the diffraction-limited image in the PMMA at wavelength P* by an increase in silver film temperature. Instead, simplified QED conserves the light from the diffraction-limited P* image to shorter wavelength λ < P* that enhances the quality of the diffraction-limited image. TO based on complex permittivity matching is not required. However, QED requires the superlens to be absorptive at the wavelength P* of the PMMA image light. Noble metals are therefore desirable, but not necessary.

REFERENCES

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