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Super Lenses by QED

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***Abstract* – Evanescent waves in meta-materials thought to enhance the quality of diffraction-limited images is superseded by a simple form of QED inducing sub-diffraction-limited quality in a superlens comprising a nanoscale silver film.**

I. INTRODUCTION

Conventional lenses create images by capturing the propagating light waves all objects emit, the optical threshold of which is called the diffraction limit. Evanescent waves are also emitted, but cannot be observed because they move only tangential to surface and exponentially decay into the lens thickness. In transformative optics, evanescent waves are proposed [1] to explain how a superlens comprising a thin lens of a metamaterial having a negative index of refraction allows the evanescent wave to grow instead of decreasing as it travels through the lens to exit the lens and form sub-diffraction images. However, sub-diffraction limited imaging may be more simply achieved [2] with a nanoscale thick silver film, the analysis of which is presented in [3].

By classical physics, the existence of evanescent waves in a conventional lens requires [4] a thermal origin. But in a nanoscale thick superlens, the thermal history of images is lost as QM denies temperature changes as the heat capacity of the atom vanishes. QM stands for quantum mechanics, the Planck law [5] shown in Fig. 1.

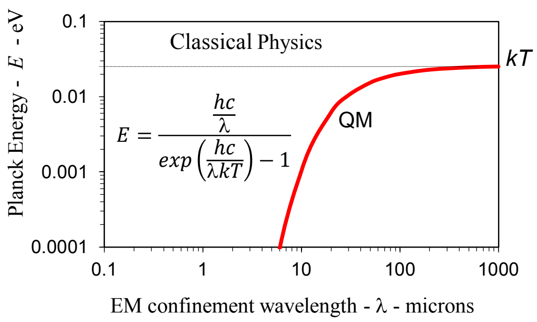


Fig. 1 Planck law of the Atom at 300 K
In the inset, E is Planck energy, h Planck's constant, c light speed,
k Boltzmann's constant, T temperature, and λ EM confinement wavelength

By QM, Fig. 1 shows for heat capacity of the atom to vanish, the atoms in the superlens must be placed under nanoscale EM confinement at wavelengths $\lambda < 100$ nm. But nanoscale films having high S/V ratios. S/V stands for surface-to-volume. Hence, the diffraction-limited P* image is almost entirely confined to the superlens surfaces, the high S/V ratio providing momentary EM confinement of silver atoms over nanoscale wavelengths.

II. THEORY

Sub-diffraction imaging by a nanoscale thick superlens is proposed [3] to be a natural consequence of a simple QED induced light-matter interaction upon the absorption of light emitted from a diffraction limited P* image. QED stands for quantum electrodynamics, but is a simplified form of light-matter matter interaction of QED proposed by Feynman [6] and others.

Briefly stated:

Absent heat capacity, simple QED conserves diffraction-limited images by creating standing waves of light confined by high S/V ratios inside the nanoscale superlens having half-wavelength λ/2 = nd, where n and d are the refractive index and thickness of the superlens.

III. APPLICATION

Consider the superlens configuration [2] comprising a 35 nm silver film in contact with a 40 nm PMMA spacer under UV illumination at λ* = 365 nm shown in Fig. 2(a). PMMA stands for polymethylmethacrylate.

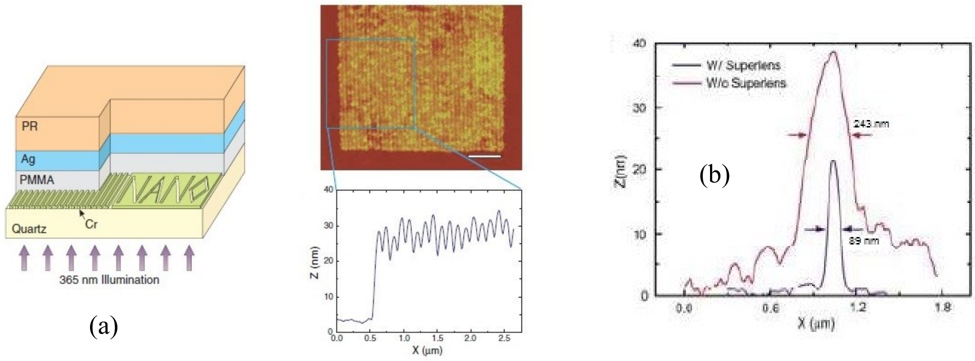


Fig. 2. Superlens Configuration and Enhanced Image Quality

For normal-incidence illumination the minimum spatial period that can be resolved with wavelength P* through a medium with refractive index *n* is λ*/ *n*, where *n* is given by the refractive index of PMMA, i.e., for *n* = 1.5, P* = 243 nm. With the silver film, the superlens was experimentally found [4] 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 are shown in Fig. 2(b).

IV. ANALYSIS AND RESULTS

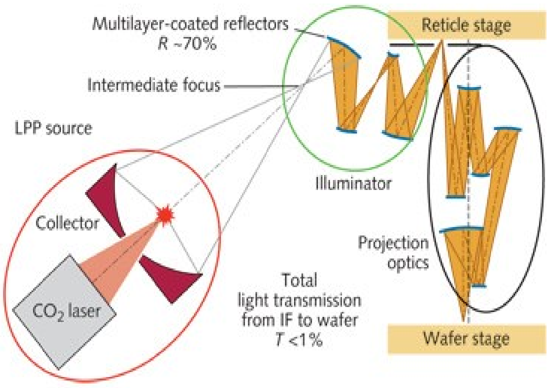
The superlens of a silver film interposed between the PMMA and the photoresist absorbs the light of the diffraction-limited image P*. Since QM precludes temperature changes [3] in the nanoscale silver film, the heat of the P* diffracted-image is conserved by the emission of light at wavelength λ = 2 *nd*. Unlike evanescent waves that cannot pass through the silver film, simple QED induces the silver films having thickness *d* = 35 nm to emit light at sub-diffraction wavelength λ that etches the photoresist. Silver at P* = 243 nm from [7] having index *n* = 1.28, simple QED produces sub-diffraction-limited light at λ = 89.6 nm.

V. EXTENSION

Difficulties in extending Moore's law to 13.5 nm may be traced to LPP lithography. LPP stands for Laser Produced Plasma. Based on classical physics, EUV light is produced [8] from the atomic emission upon ionization of atoms in solid and gas targets by a high power CO_2 laser. After reflection from a large 100 cm mirror, the EUV light is processed from the atomic emission. LPP systems are expensive and complex as shown in Fig. 3(a).

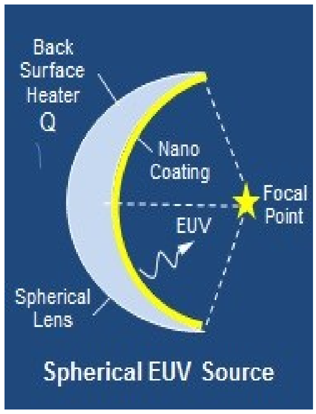
QED induced EUV lithography [9] based on QM offers a far simpler alternative and inexpensive way to extend Moore's law to 13.5 nm as illustrated in Fig. 3(b). The EUV source comprises an ordinary 10 cm spherical glass lens provided on the front surface with *d* < 5 nm silver coating. An ordinary heater on the back surface allows heat to flow into the coating, but QM precludes any increase in the coating temperature. Instead, QED converts the heat into the coating to a steady EUV light source. Lasers are not required.

(a)



LPP

(b)



QED

Fig. 3. LPP and QED lithography

In contrast to LPP, QED converts the heat supplied to the backside of the spherical lens to the EUV at 13.5 nm using a silver coating having refractive index n = 1.31 and a thickness, $d = \lambda / 2n$ = 5.1 nm.

VI. Conclusions

Simple QED explains sub-diffraction limited imaging without the need for evanescent waves, but requires the superlens to be absorptive at the wavelength of the diffraction-limited image P*.

QED avoids the complexity and cost of LPP lithography in allowing Moore's law to be extended to 13.5 nm. using a 5 nm silver coating on an ordinary 10 cm glass spherical lens.

References

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