

ARTICLE

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Bethe-hole polarization analyser for the magnetic vector of light

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20120106
Seoncheol Cha

Electromagnetic Wave

Maxwell's Equation

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

Electric Field

$$\nabla^2 \vec{B} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

Magnetic Field

$$\vec{E} = \vec{E}_0 e^{i\vec{k}\cdot\vec{r}-\omega t-\delta} n$$

Amplitude
Polarization

Electromagnetic Wave

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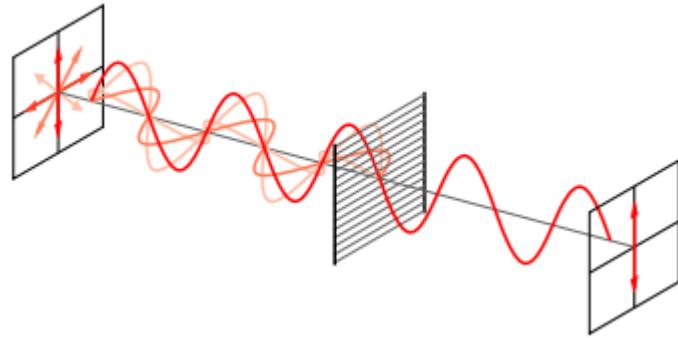
$$\nabla^2 \vec{B} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

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Electric Field

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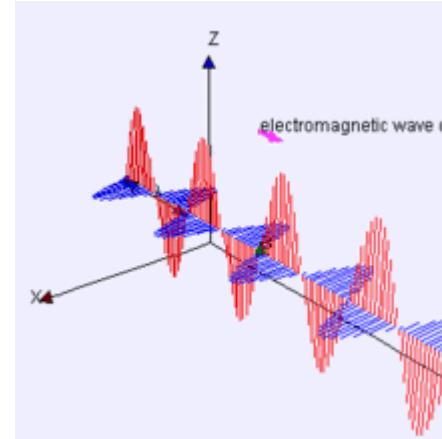
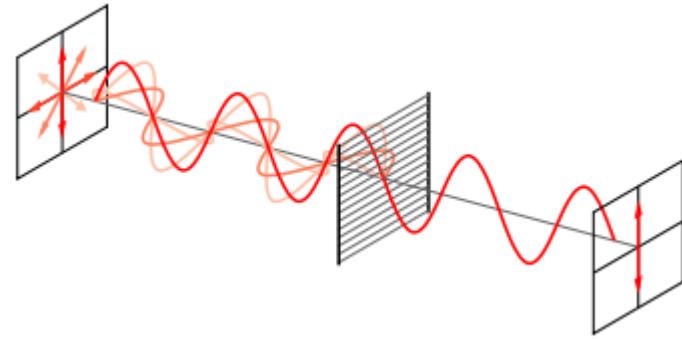
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Electric Field

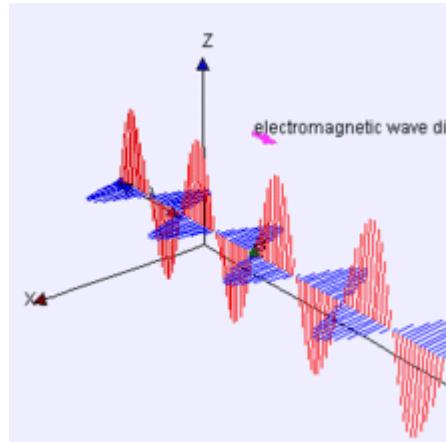
Magnetic Field

$$\vec{E} = \vec{E}_0 e^{i\vec{k}\cdot\vec{r}-\omega t-\delta} n$$

Amplitude
Polarization



$\vec{E} \perp \vec{B}$?



THE
PHYSICAL REVIEW

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OCTOBER 1 AND 15, 1944

Theory of Diffraction by Small Holes

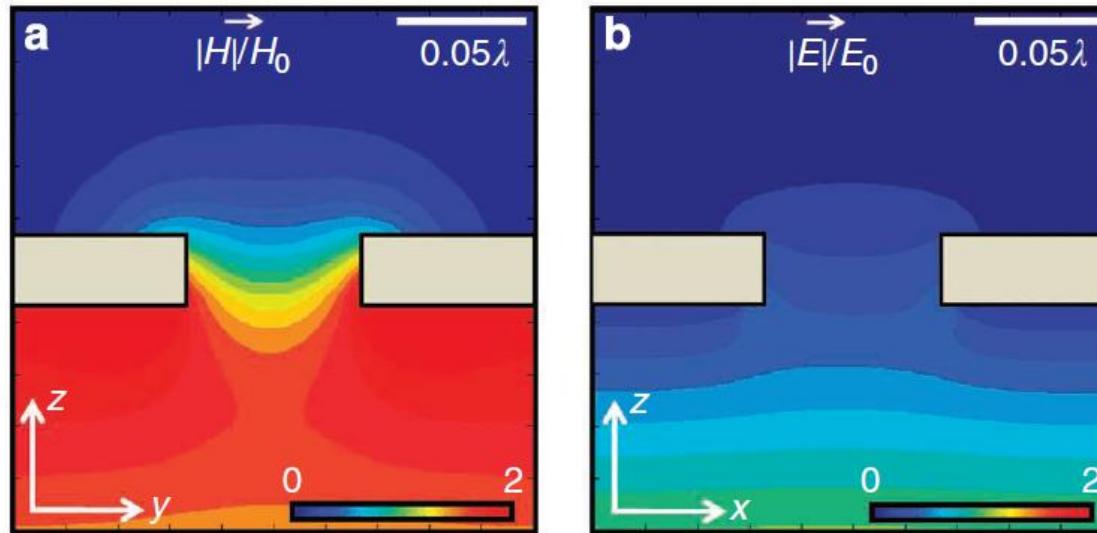
H. A. BETHE

Department of Physics, Cornell University, Ithaca, New York

(Received January 26, 1942)

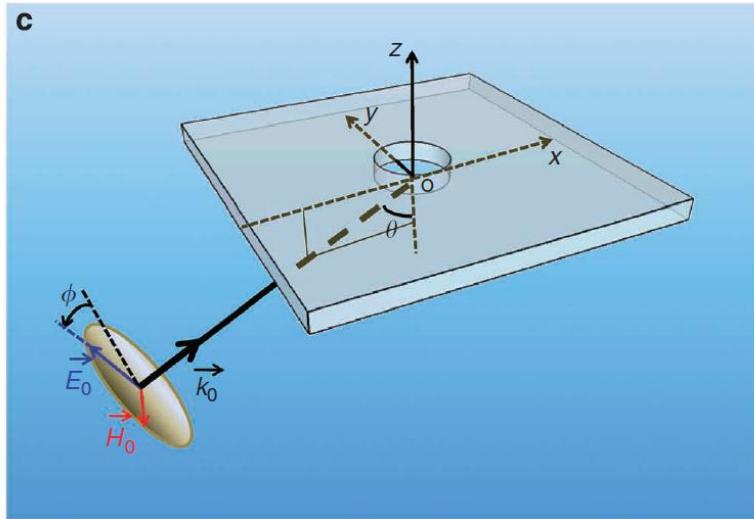
Small hole as the Magnetic Polarizer at evanescent field

Metallic film
(large dielectric constant)



Tangential magnetic field enters
Tangential electric field reflected

Small hole as the Magnetic Polarizer at oblique incident angle

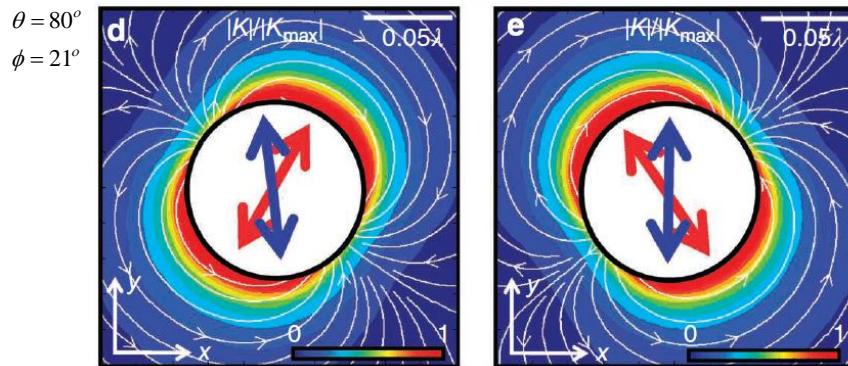
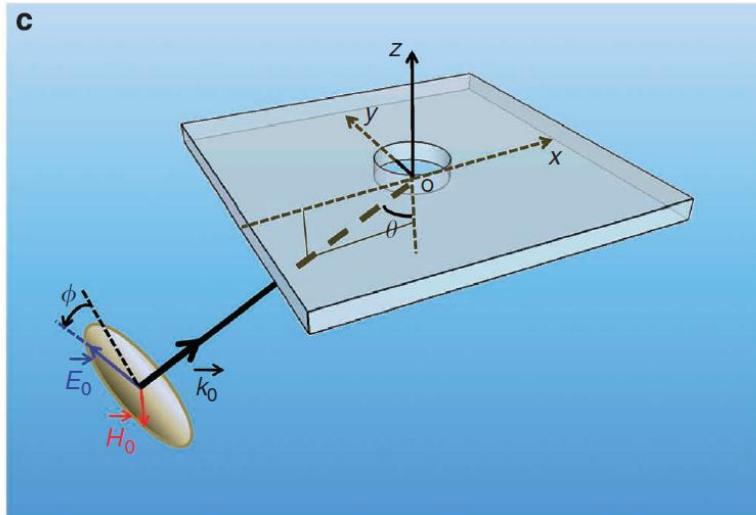


Detector placed along z direction

$$\vec{E}_t = \vec{E}_0 - (\hat{z} \cdot \vec{E}_0) \hat{z} = E_0 (-\cos \theta \sin \phi, \cos \phi, 0)$$

$$\vec{H}_t = H_0 (-\cos \theta \cos \phi, -\sin \phi, 0)$$

Small hole as the Magnetic Polarizer at oblique incident angle



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$$\vec{H}_t = H_0 (-\cos \theta \cos \phi, -\sin \phi, 0)$$

$$\vec{k} \perp \vec{B}$$

$$\vec{k} \not\perp \vec{E}$$

Experimental realization

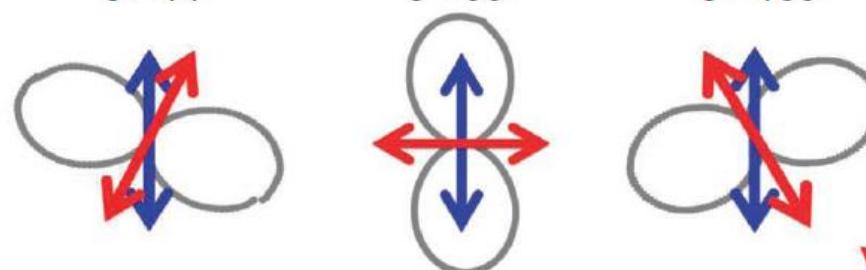
780 nm laser

80 nm diameter circular aperture in an 80 nm thick gold film (sapphire substrate)

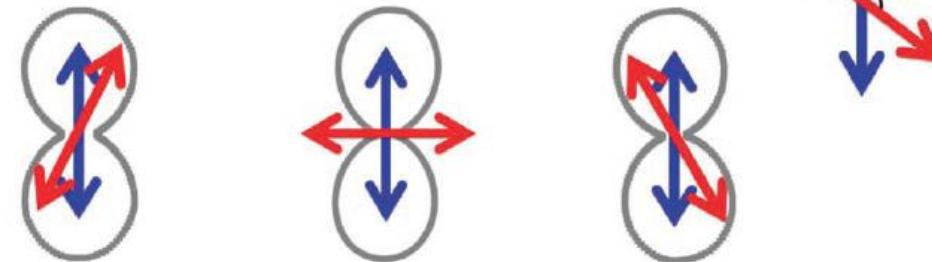
$$\cos \psi = \frac{-\frac{1}{2} \sin 2\phi \sin^2 \theta}{\sqrt{1 - \sin^2 \theta + \frac{1}{4} \sin^2 2\phi \sin^4 \theta}}$$

80 nm aperture **a**

$\Psi = 14^\circ$ $\Psi = 90^\circ$ $\Psi = 166^\circ$



80 nm nano ptl **b**



↔ Electric field

↔ Magnetic field

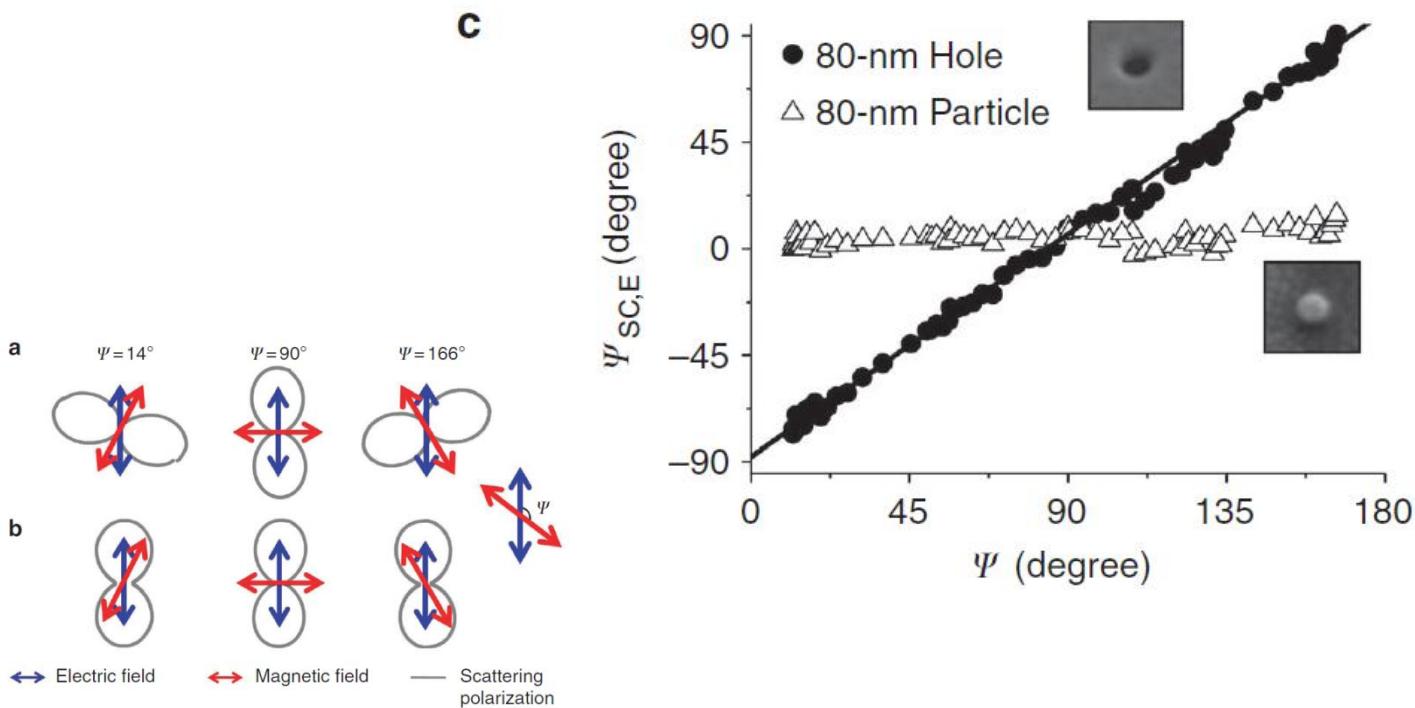
— Scattering polarization

Experimental realization

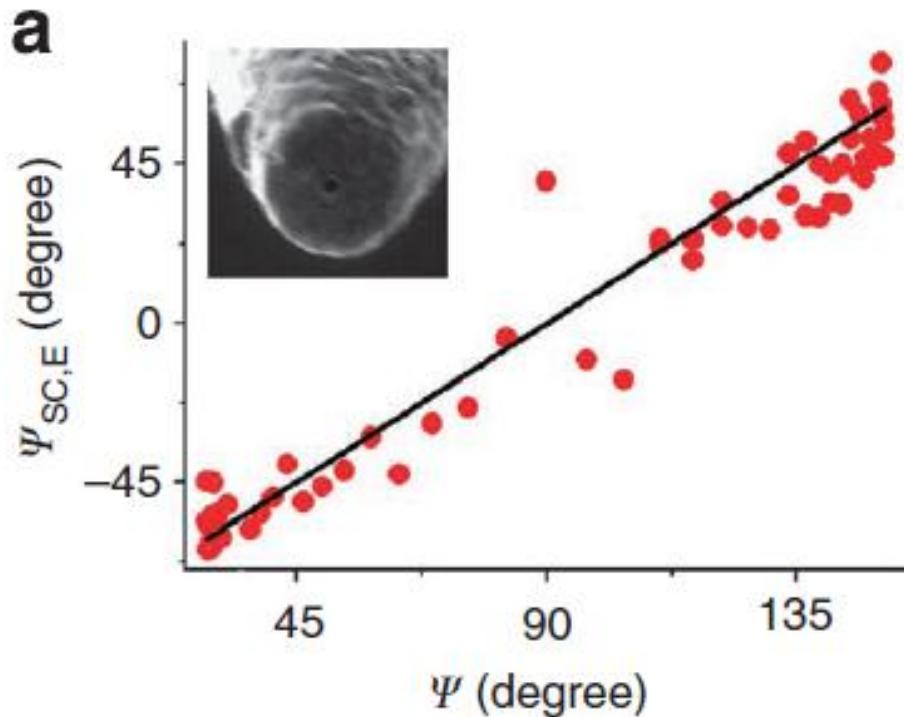
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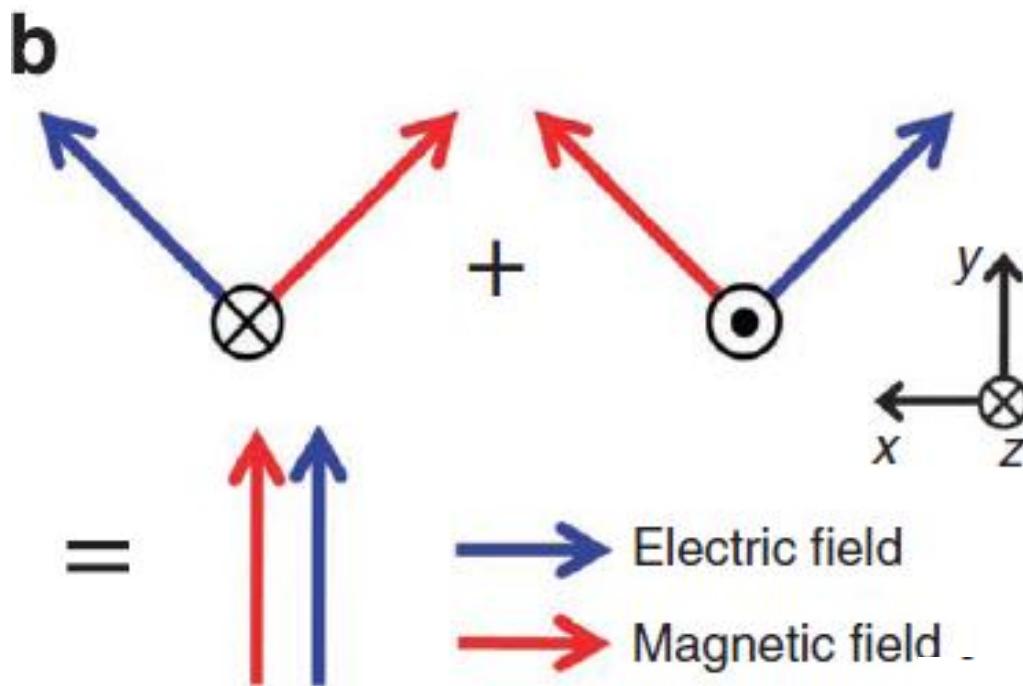


NSOM probe for determining magnetic field



NSOM probe : 0.6λ
Aperture diameter : 0.1λ
 $\lambda = 780 \text{ nm}$

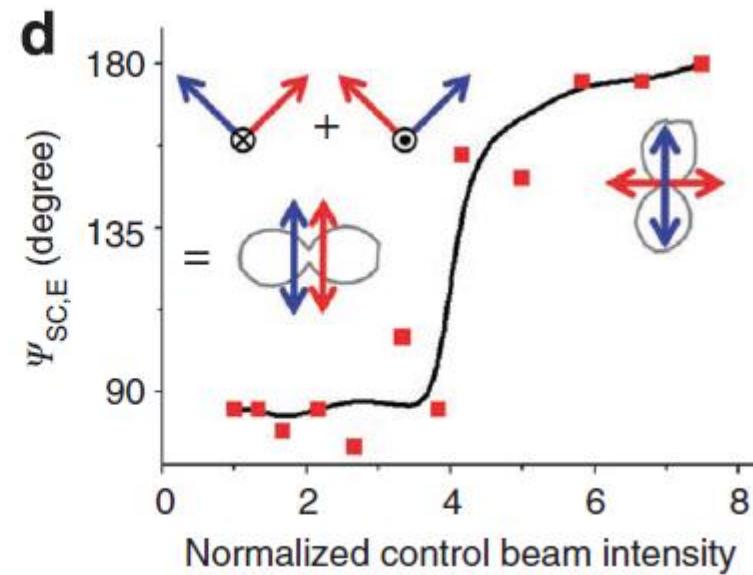
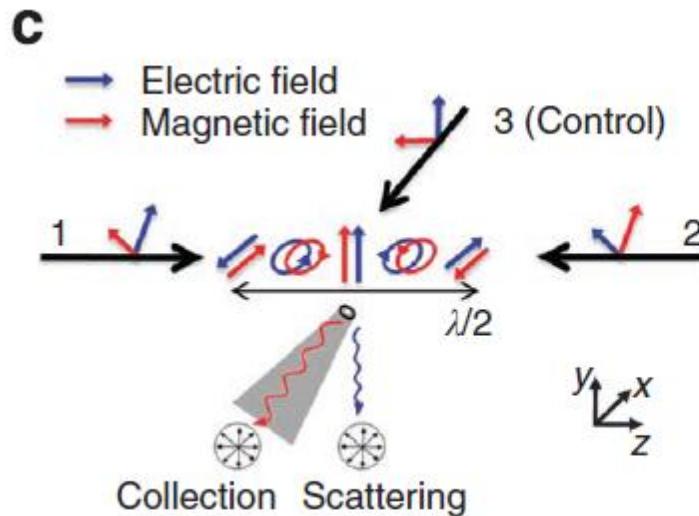
$E // B$



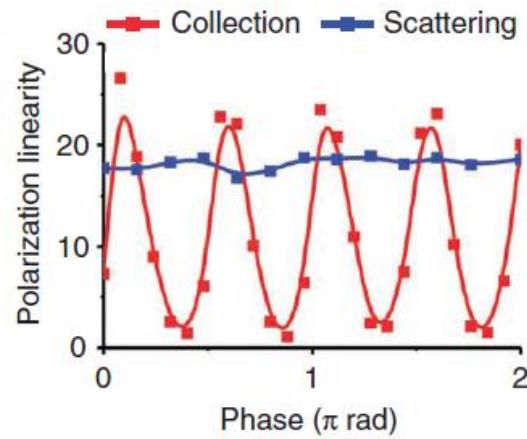
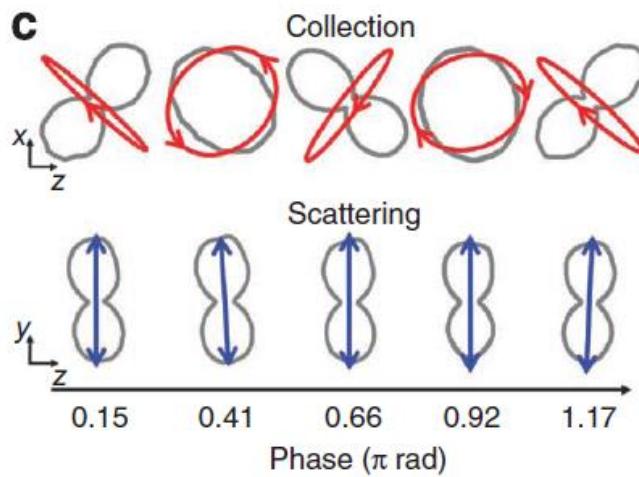
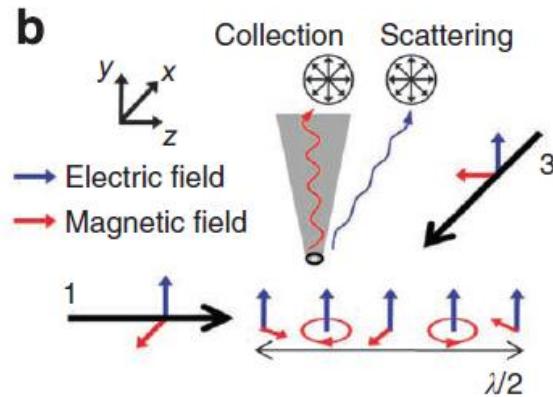
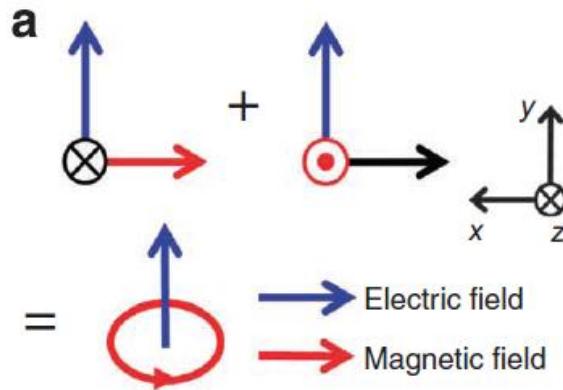
$$E = \sqrt{2} E_0 \left(i \sin(k_0 z + \frac{\varphi}{2}), \cos(k_0 z + \frac{\varphi}{2}), 0 \right) e^{-i(\omega t - \frac{\varphi}{2})},$$

$$H = \sqrt{2} H_0 \left(-i \sin(k_0 z + \frac{\varphi}{2}), \cos(k_0 z + \frac{\varphi}{2}), 0 \right) e^{-i(\omega t - \frac{\varphi}{2})},$$

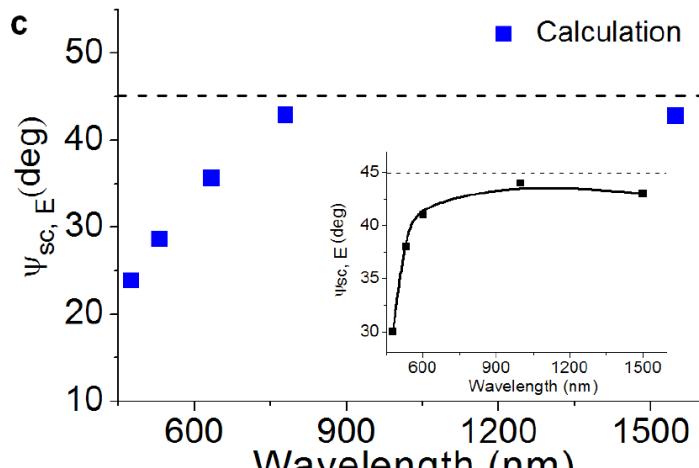
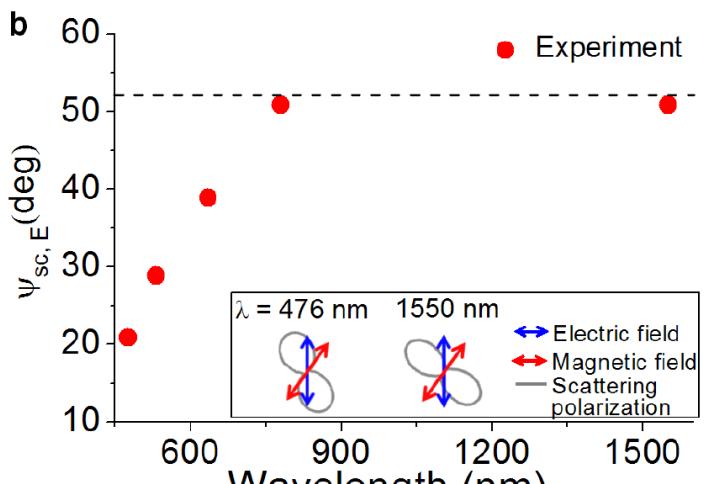
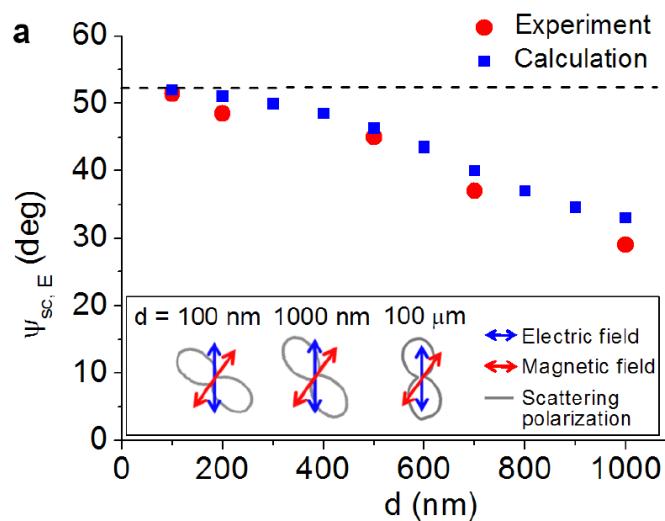
E // B



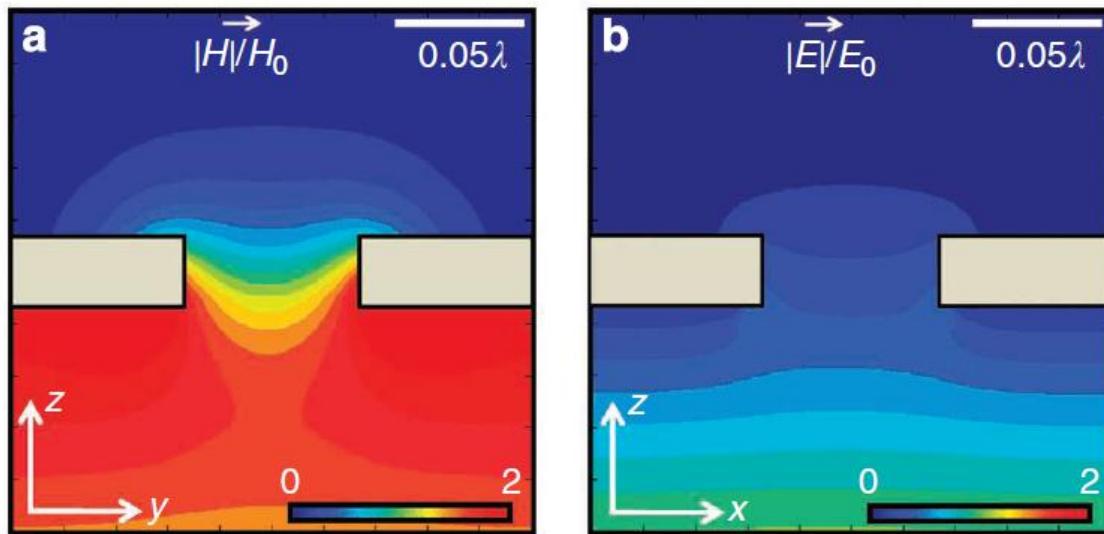
Linear E and circular B



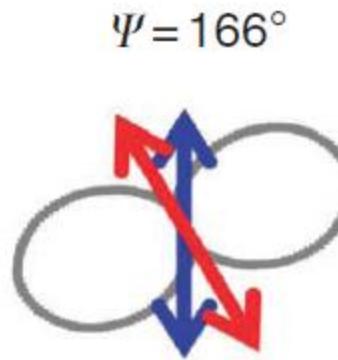
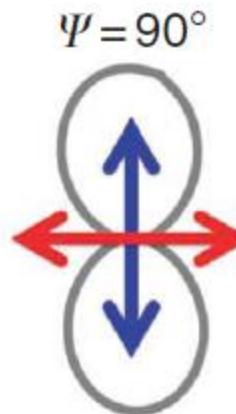
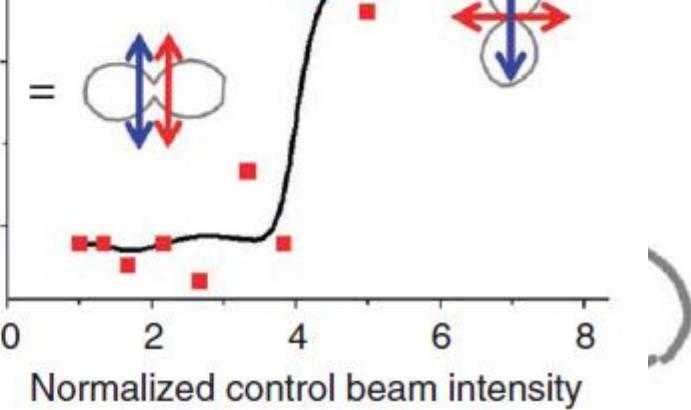
Linear **E** and circular **B**



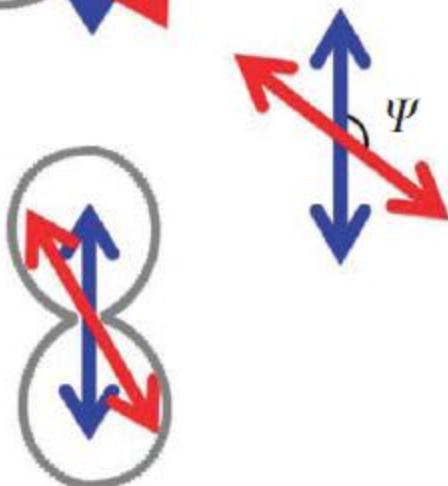
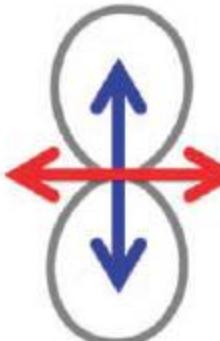
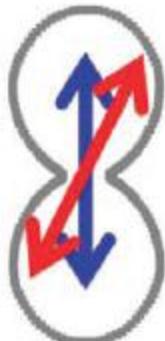
Small hole as the Magnetic Polarizer at evanescent field



See
Jackson 3rd
pp203-206



b



\leftrightarrow Electric field

\leftrightarrow Magnetic field

— Scattering polarization