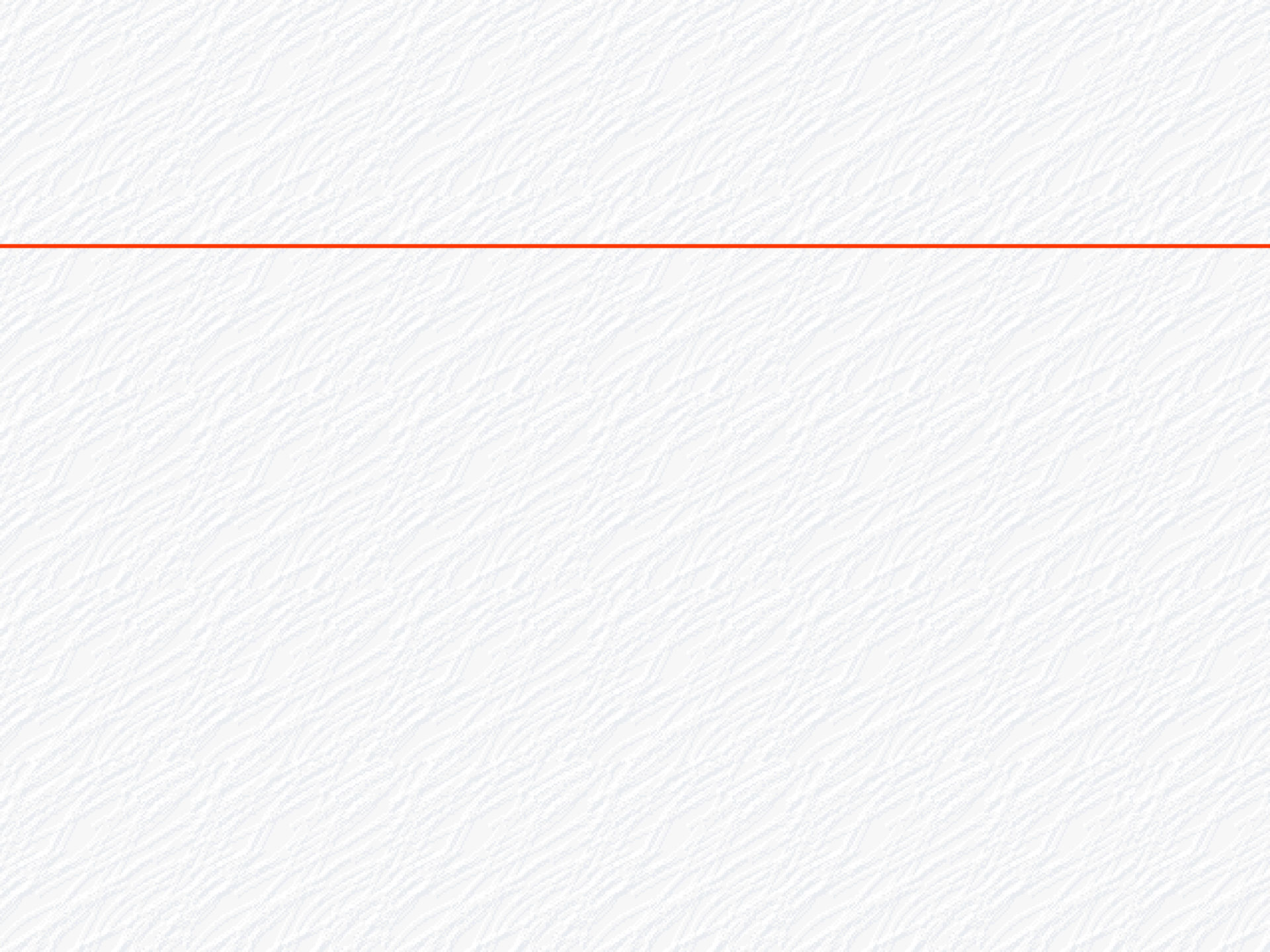
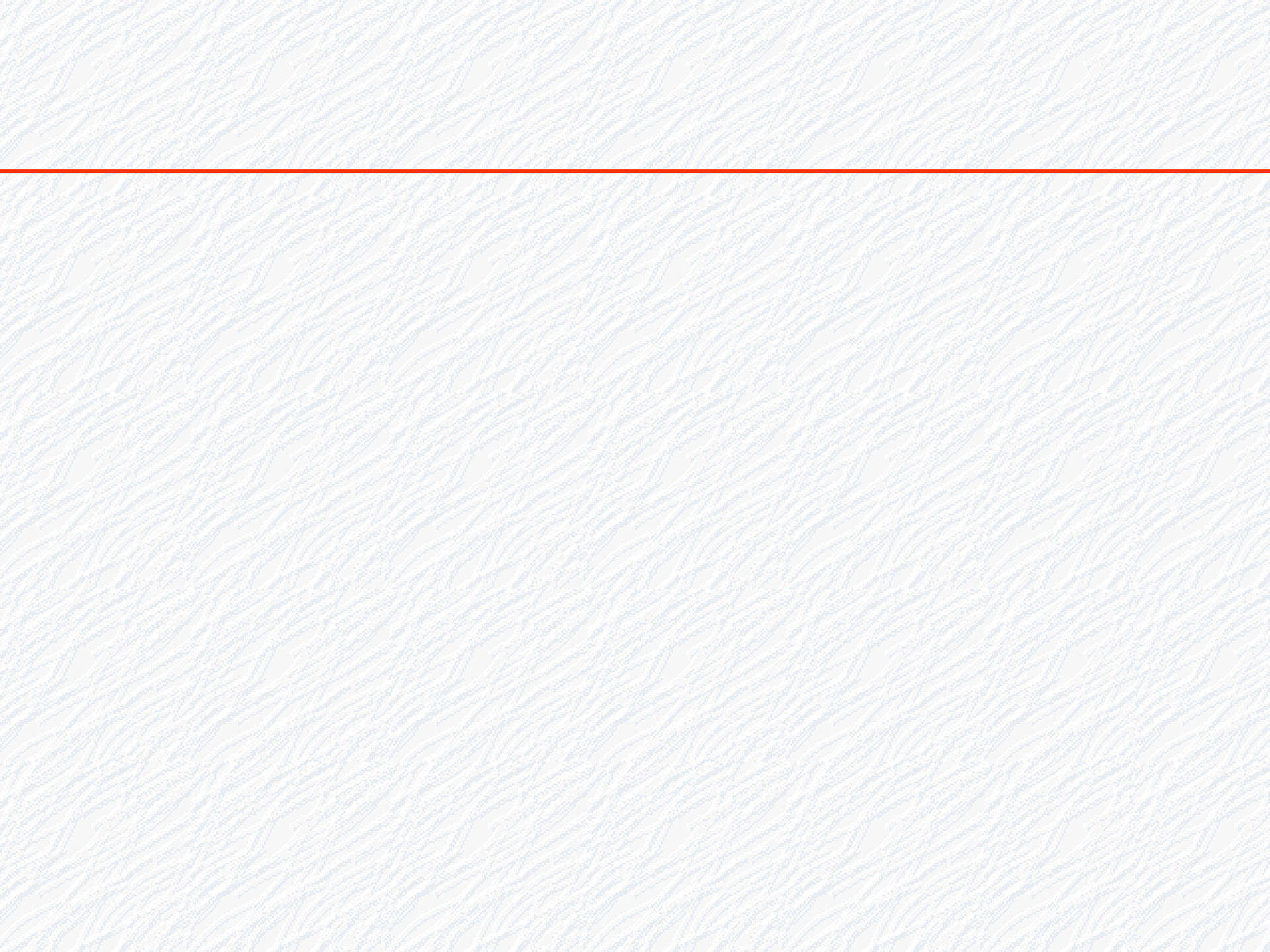
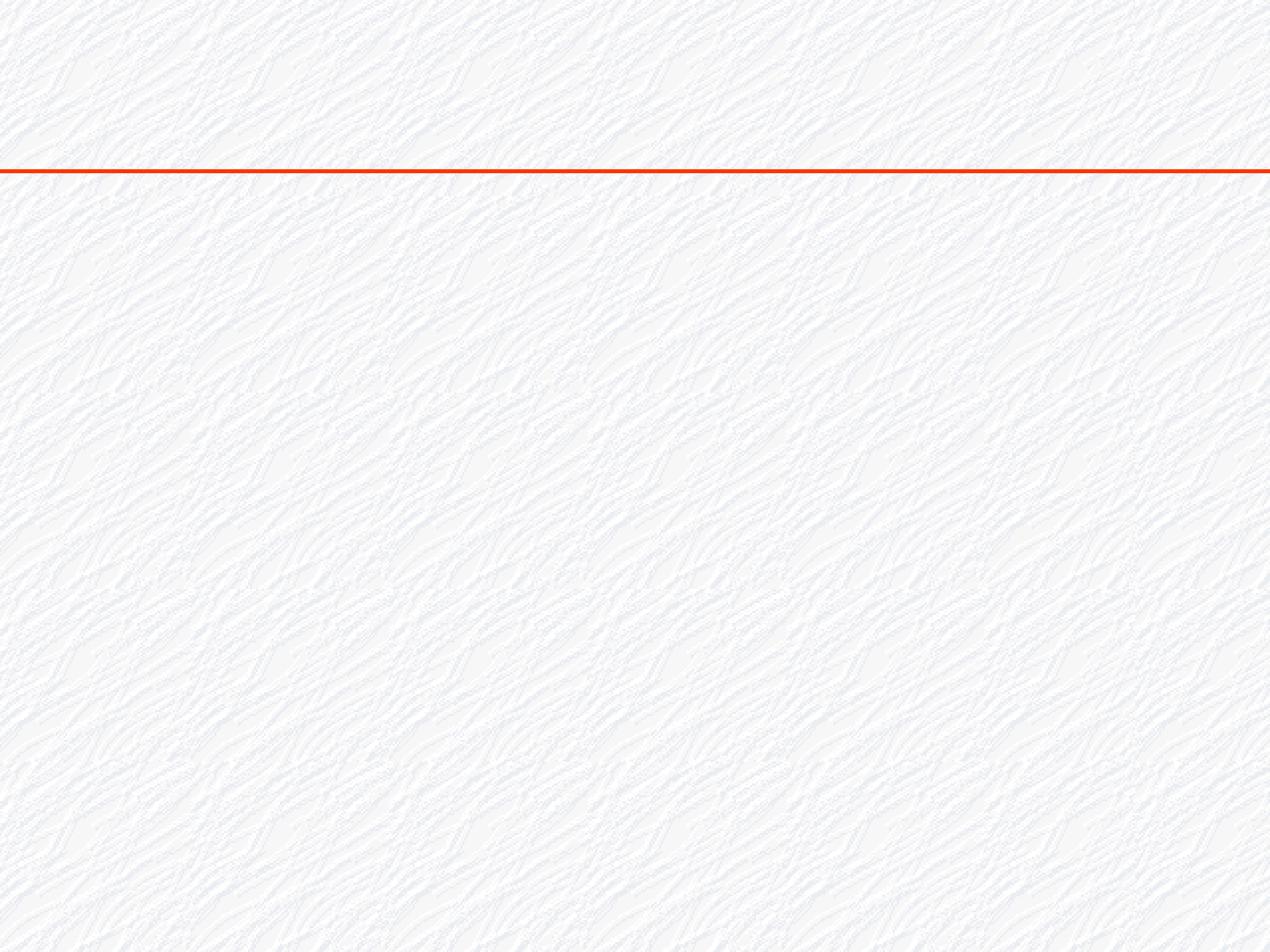
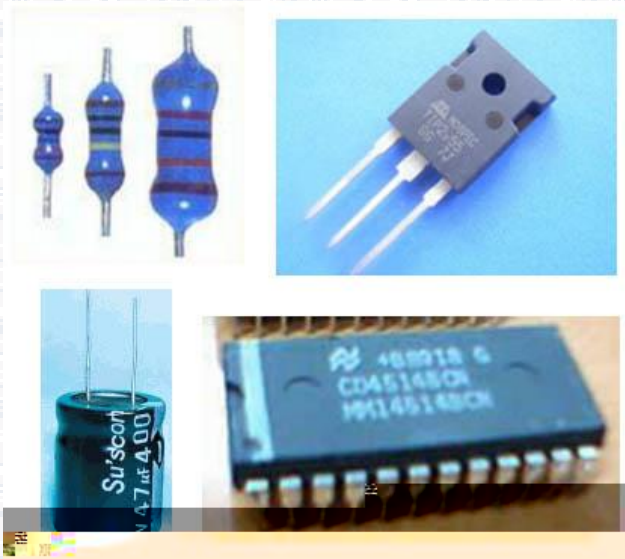
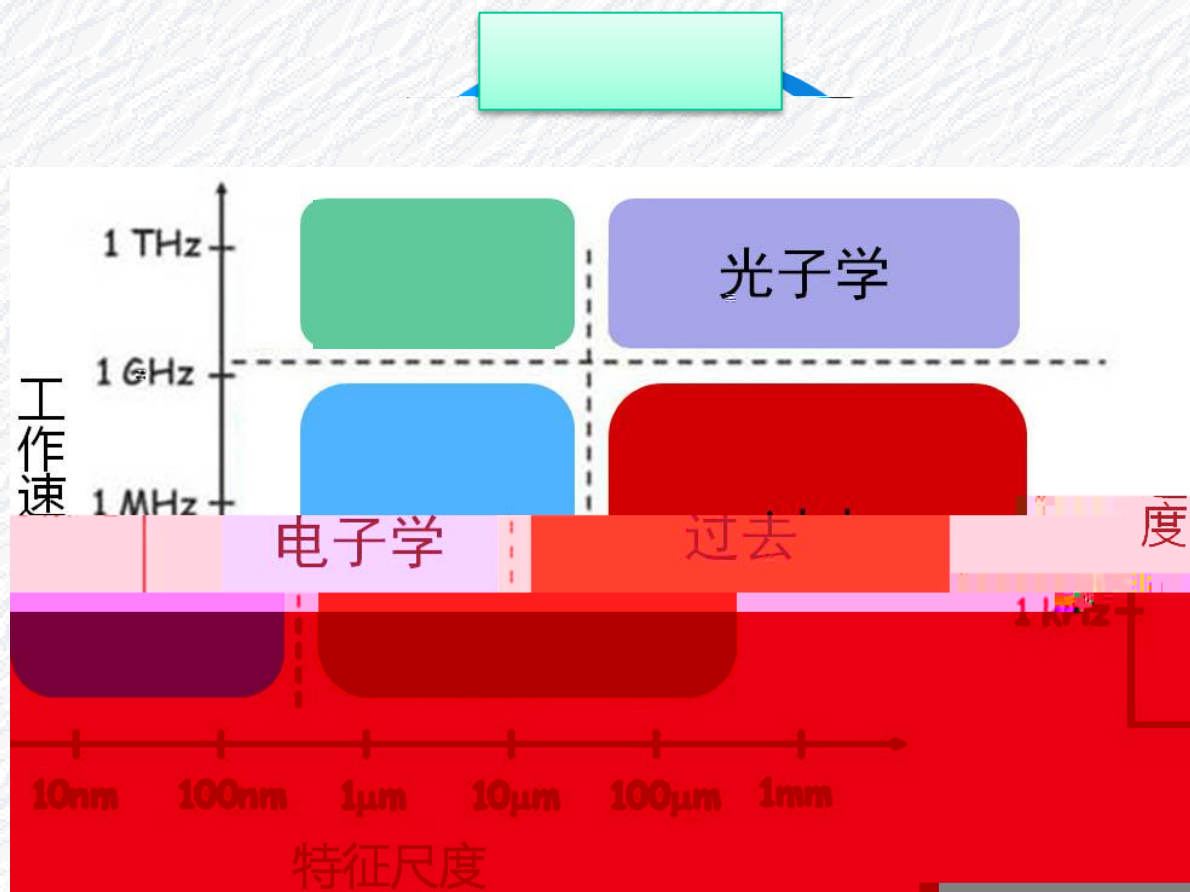








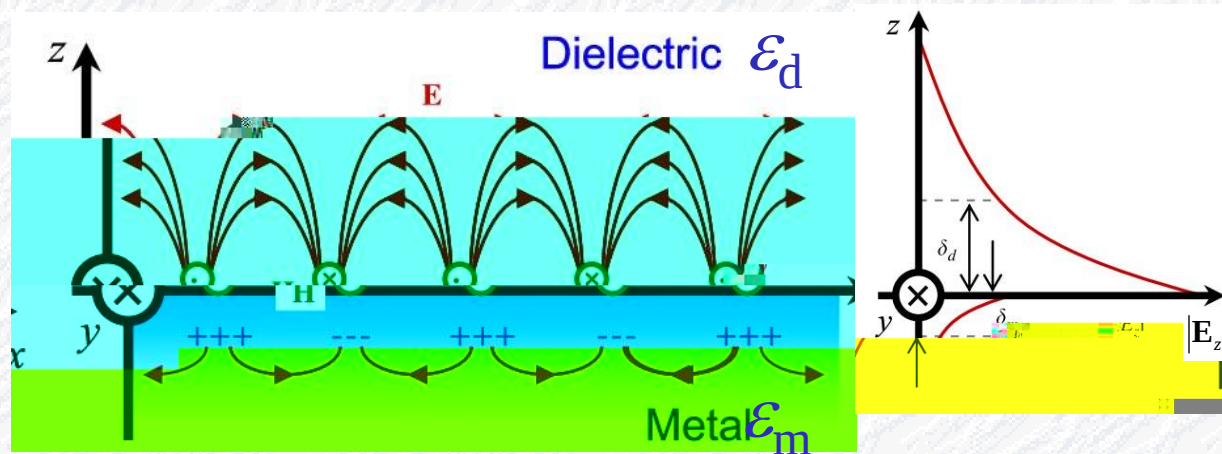




① 表面等离激元和光子的相互耦合

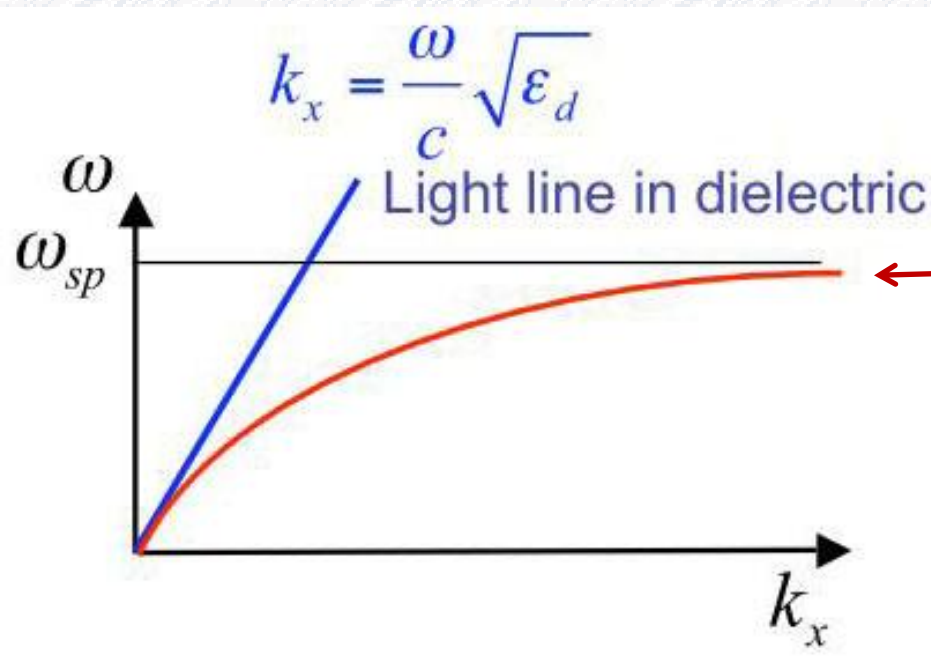


$$\epsilon_d \epsilon'_m < 0 \quad \epsilon_d + \epsilon'_m < 0$$



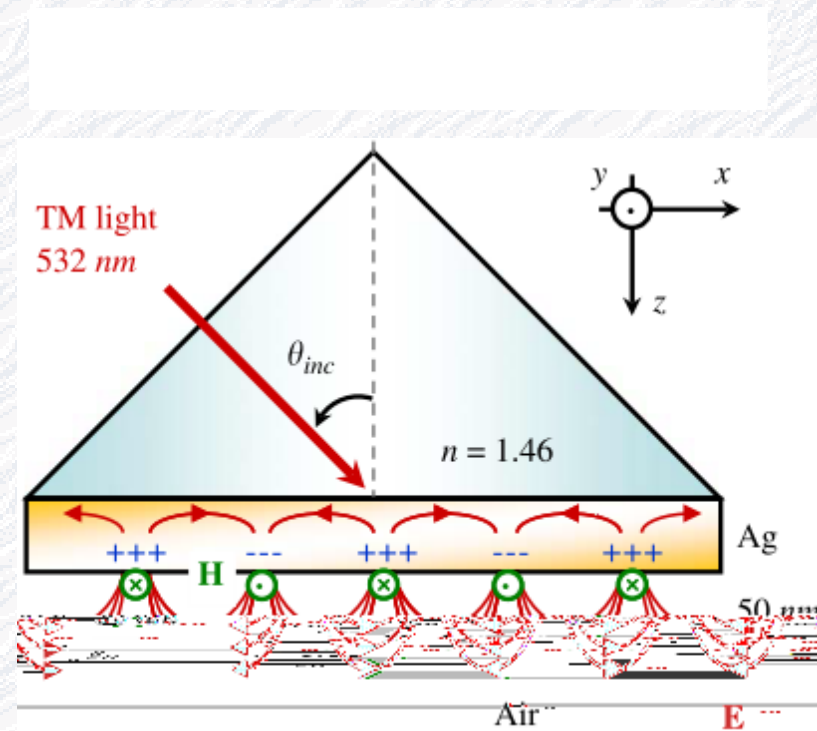
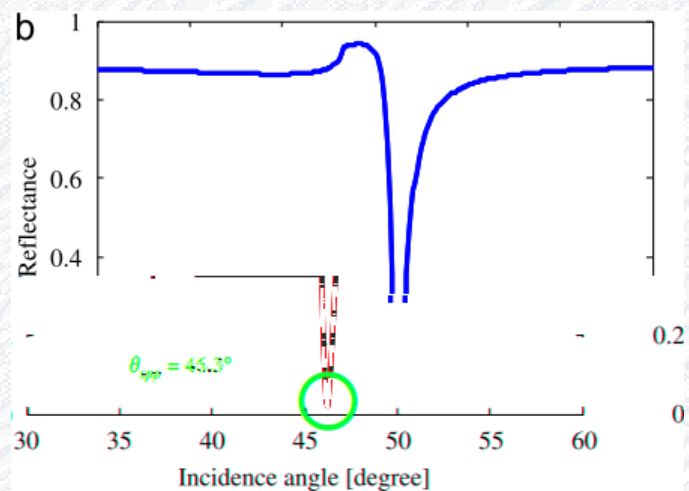
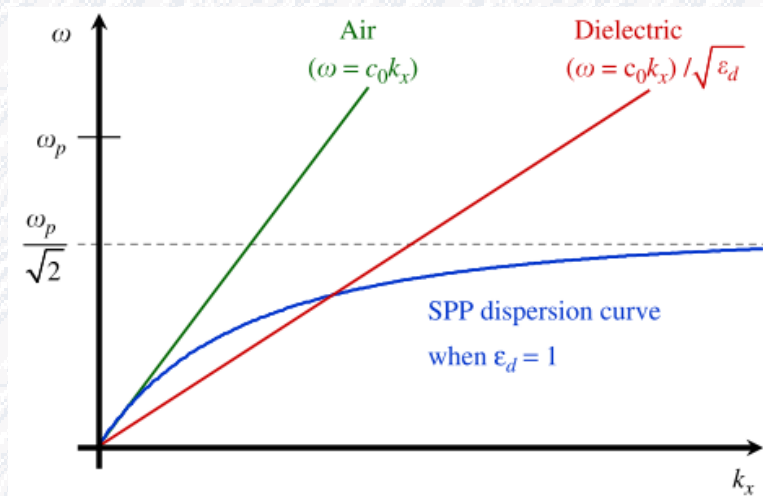
$$\begin{aligned} \mathbf{E}_{\parallel} &= \mathbf{E}_x + \mathbf{E}_y \\ \mathbf{E}_{\perp} &= \mathbf{E}_z \\ |\mathbf{E}_{\perp}| &> |\mathbf{E}_{\parallel}| \end{aligned}$$

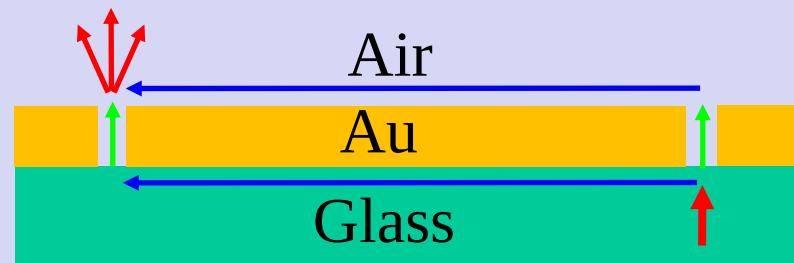
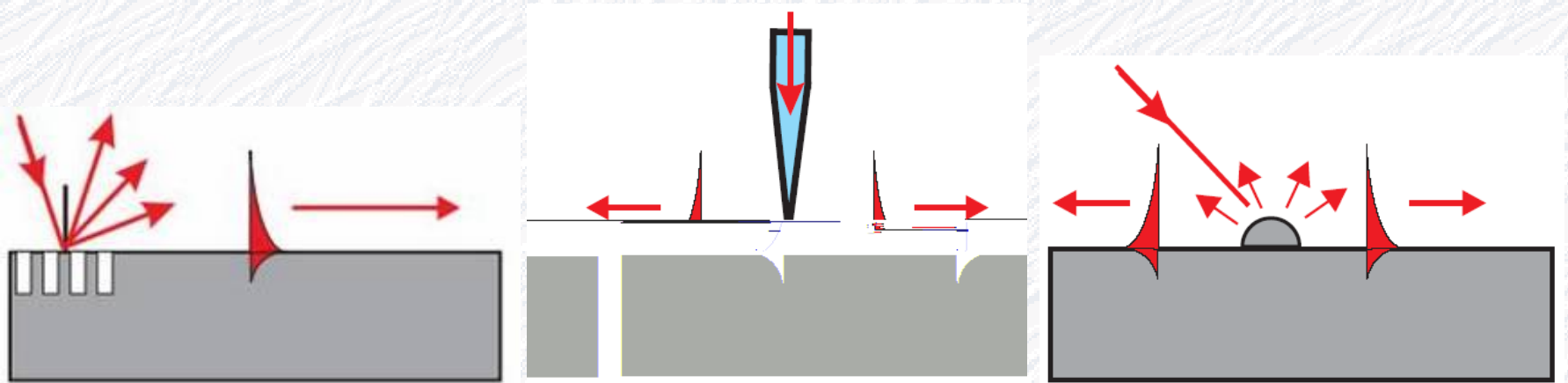
$$|\mathbf{E}_{\parallel}| > |\mathbf{E}_{\perp}|$$



$$k_{sp} = \frac{\omega}{c} \sqrt{\frac{\epsilon_m \epsilon_d}{\epsilon_m + \epsilon_d}}$$

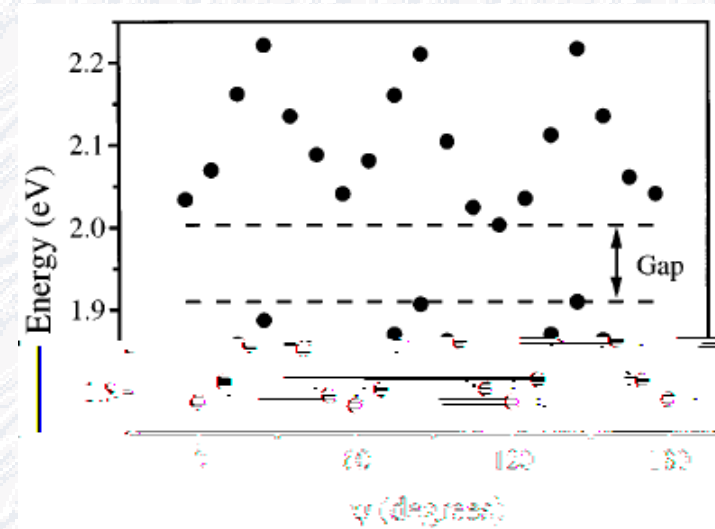
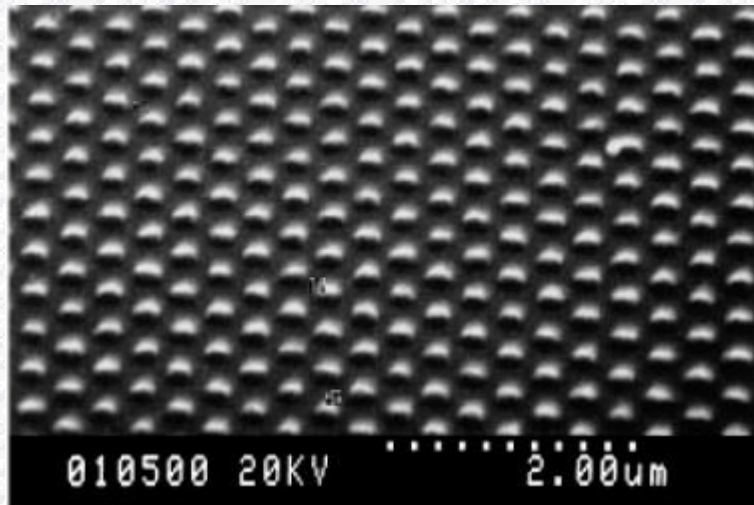




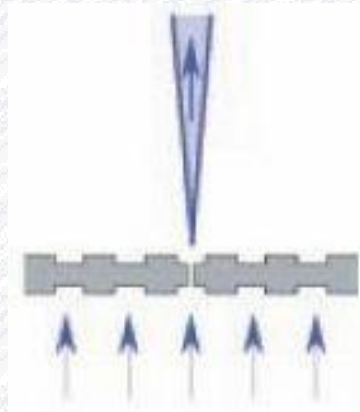
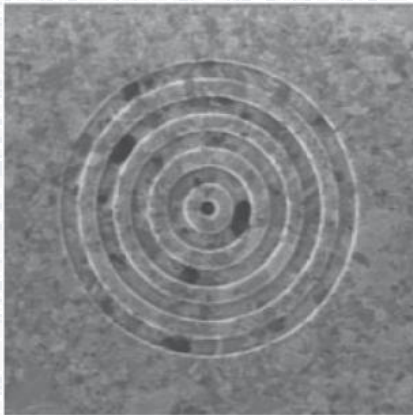


Xiaofei Wu et al., Opt. Lett. 34, 392 (2009).

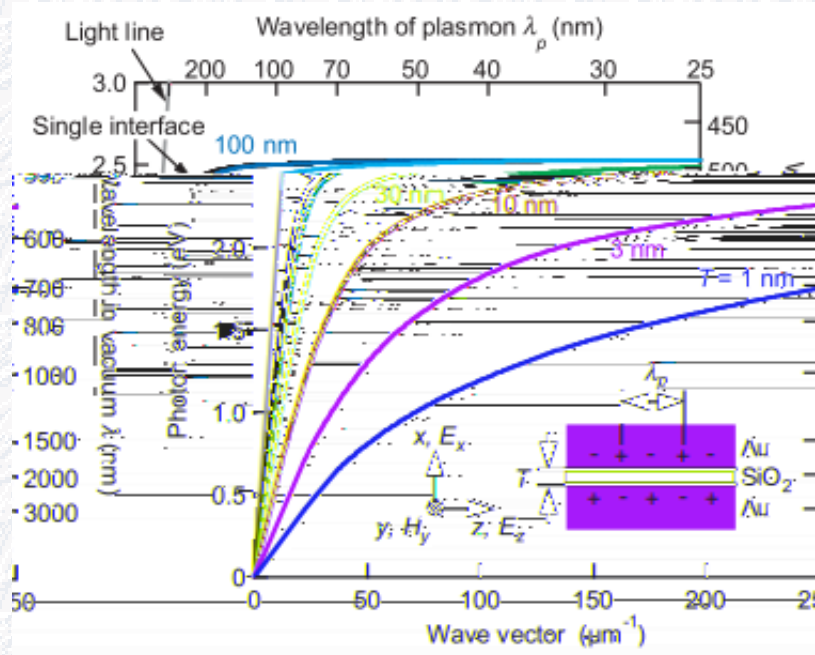




Kitson et al., Phys. Rev. Lett. 77, 2670 (1996)

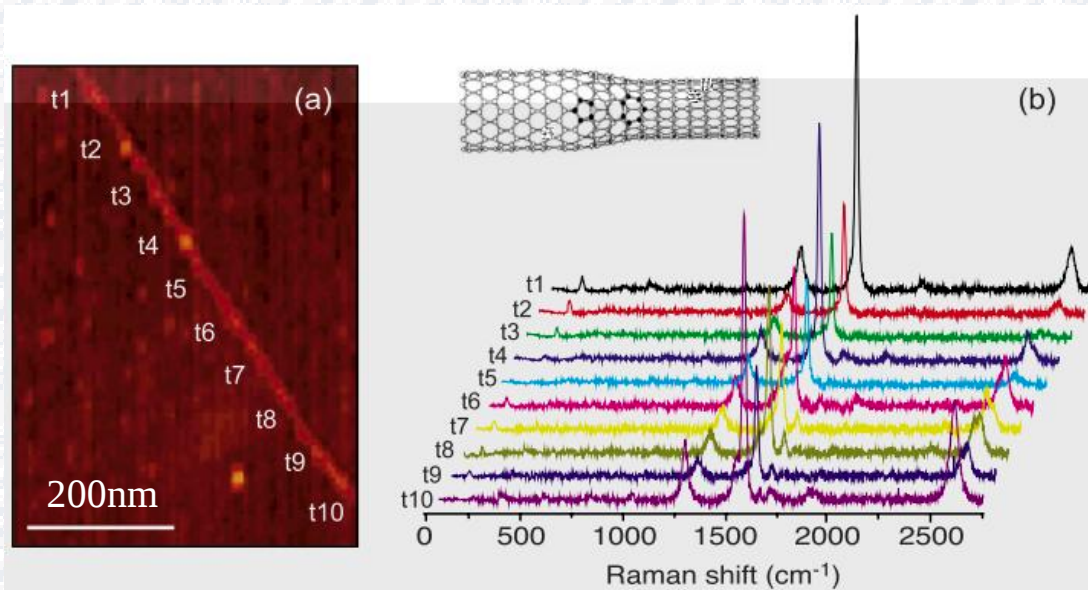


Ebbesen et al., Science 297, 820 (2002)



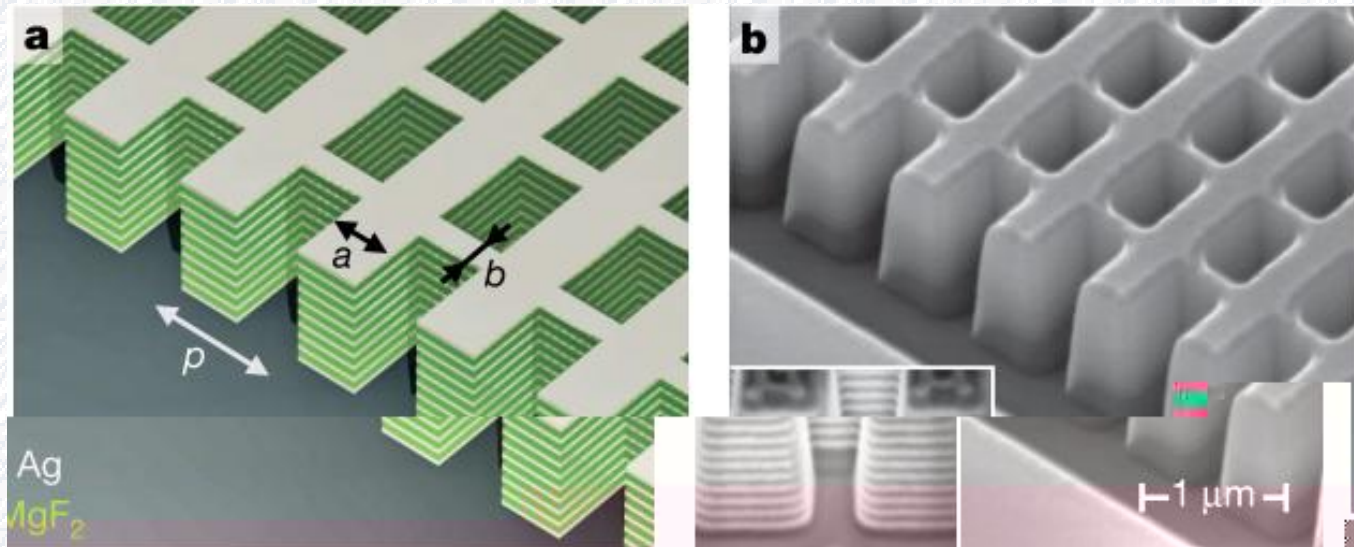
λ

Miyazaki et al., Phys. Rev. Lett.
96, 097401 (2006)

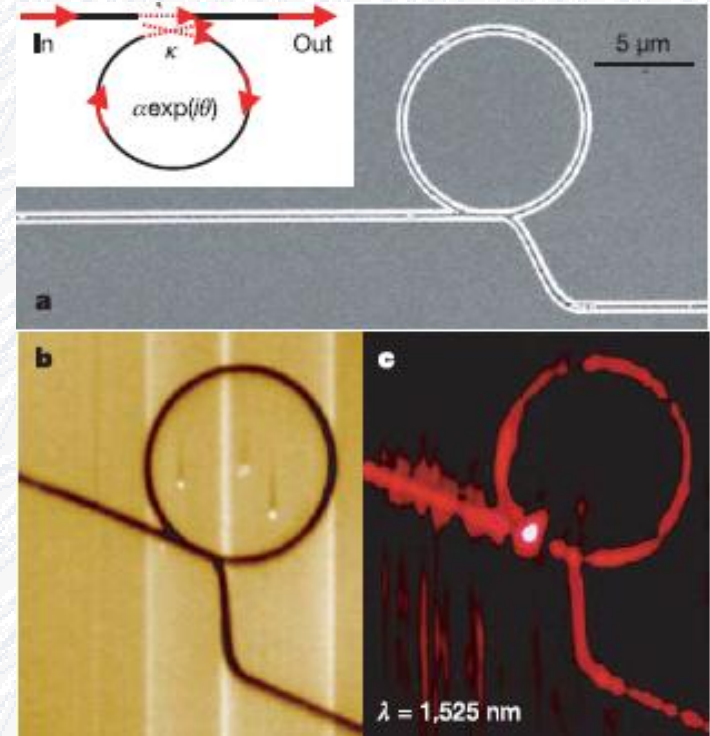
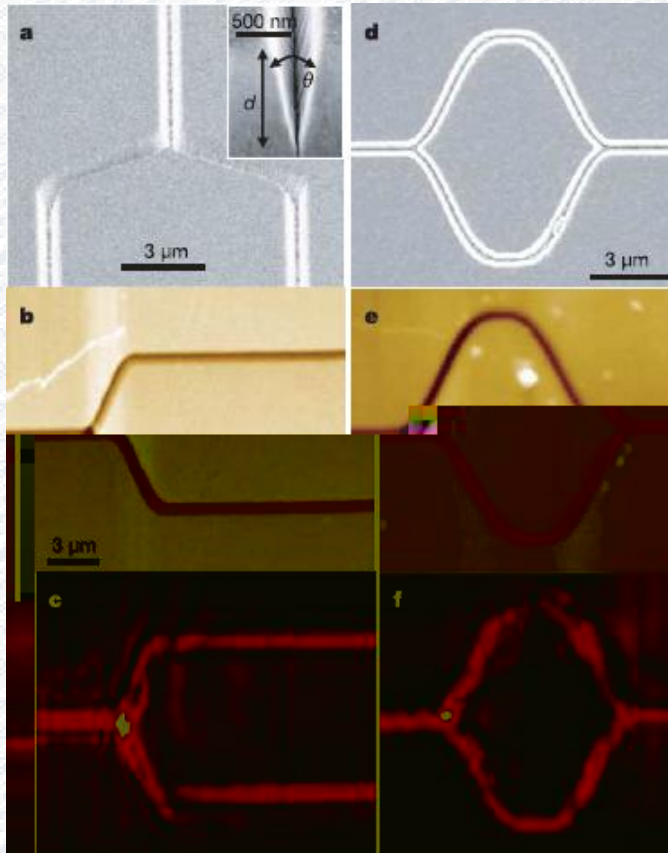


Tip-enhanced Raman spectroscopy of a single-walled carbon nanotube

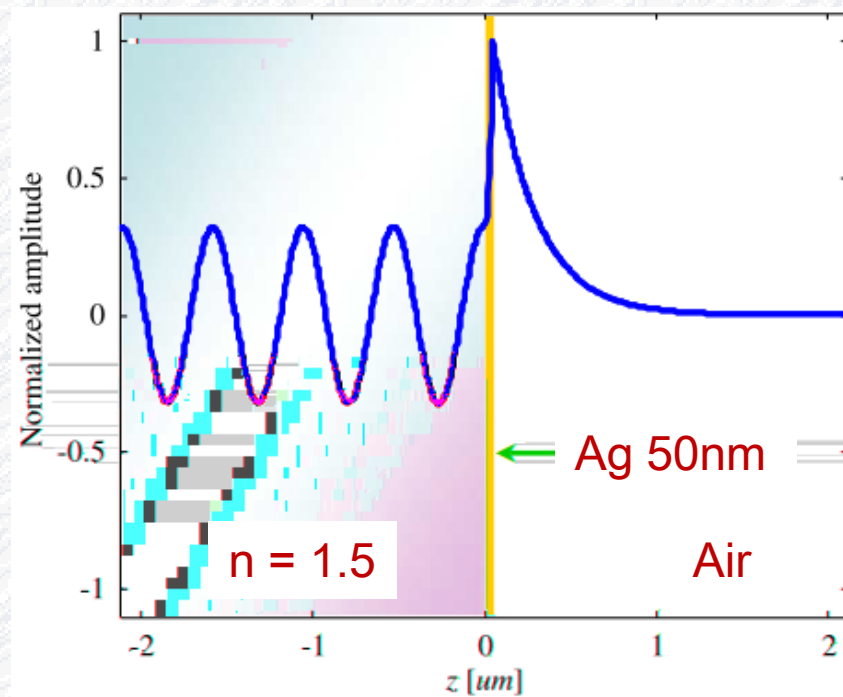
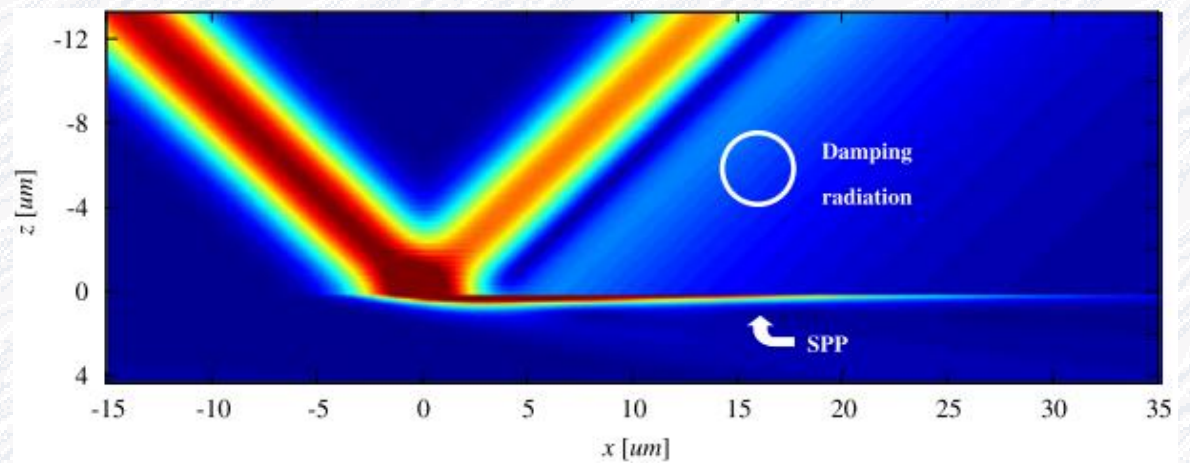
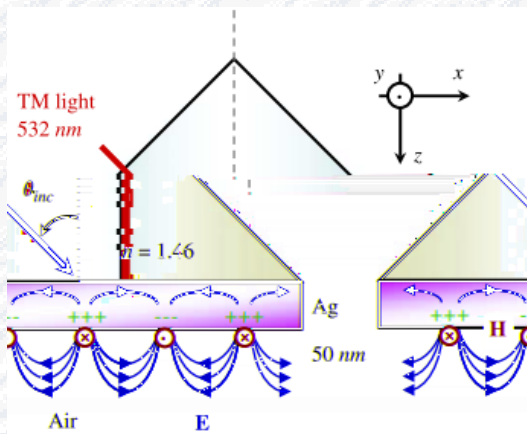
Anderson et al., Nano Lett. 7, 577–582 (2007)

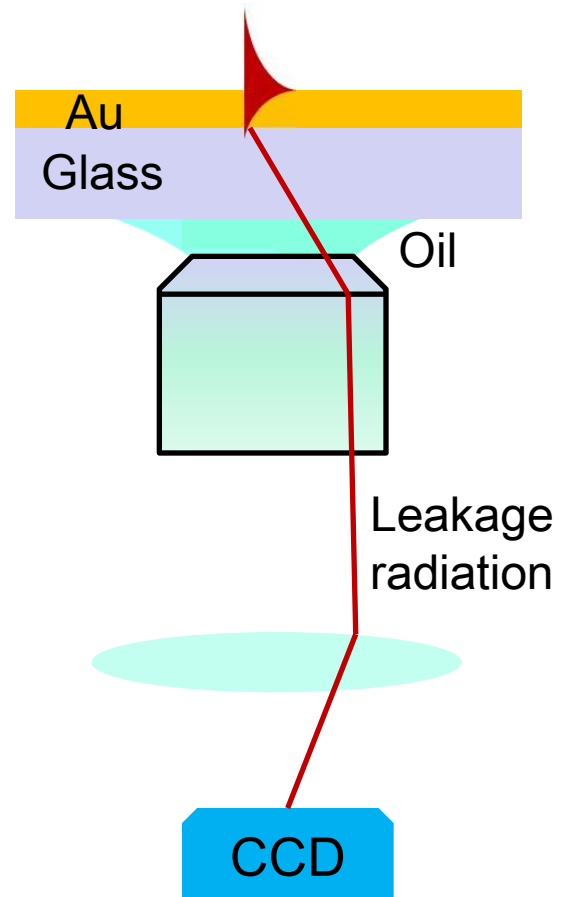
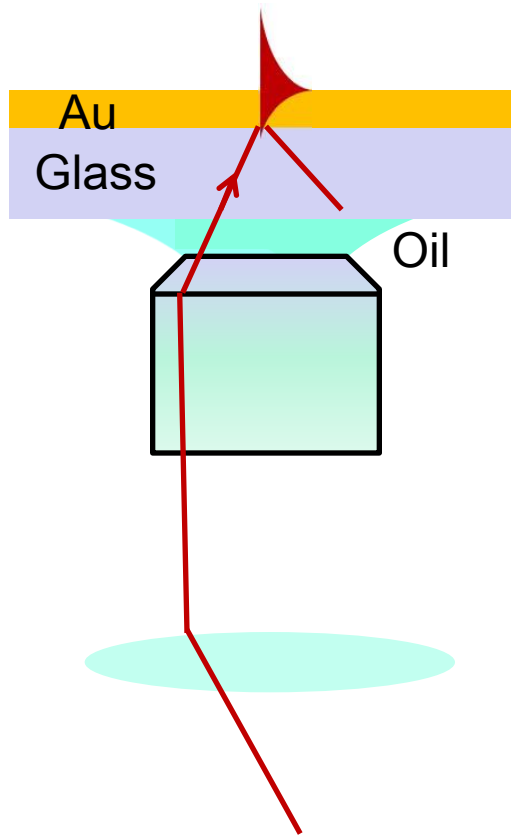


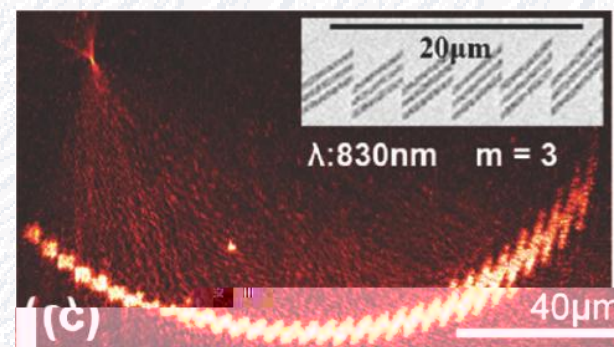
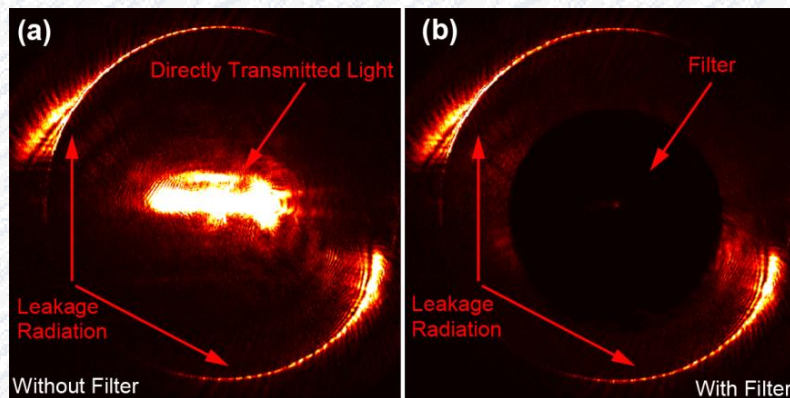
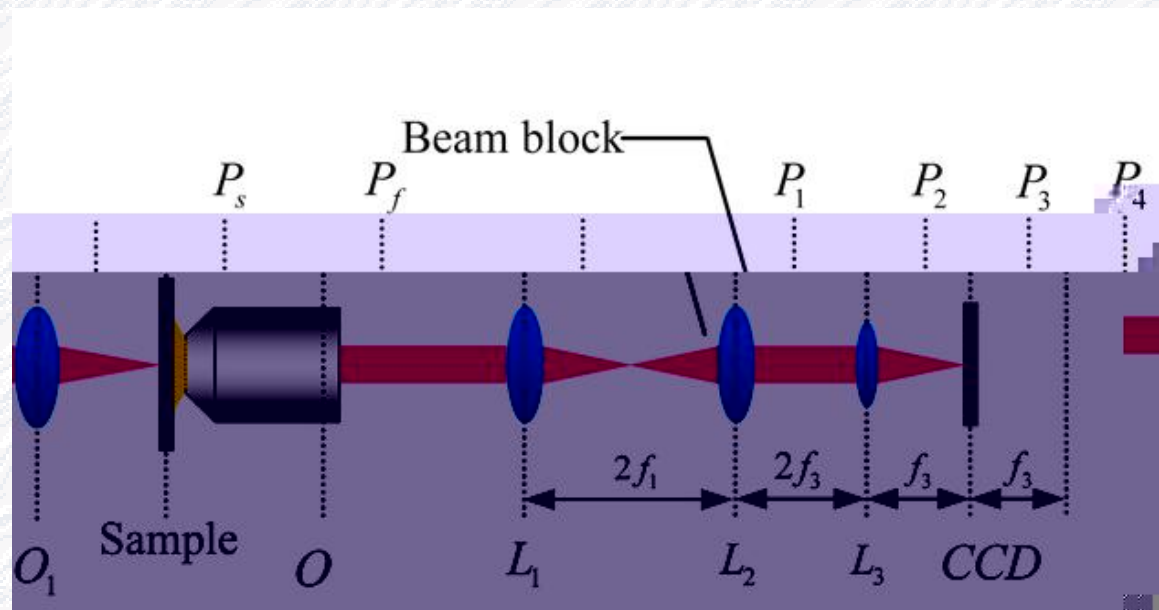
Valentine et al., Nature 455, 376-379 (2008)

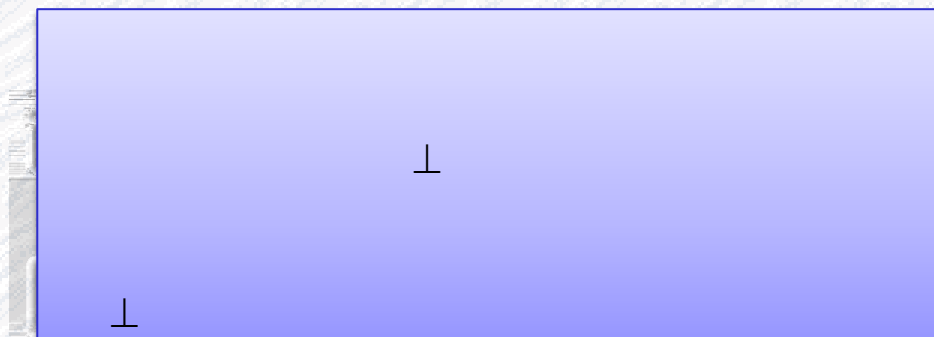
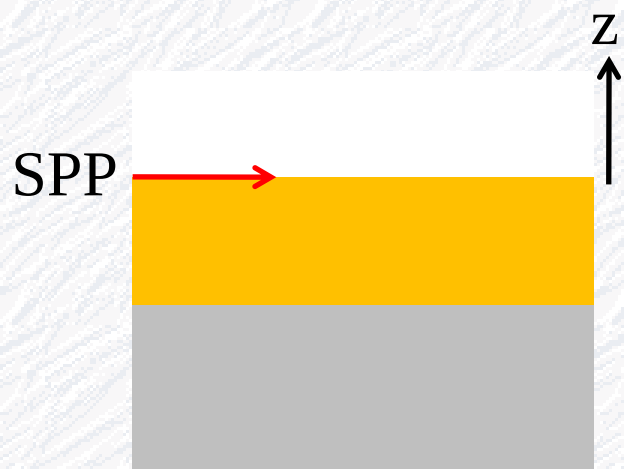


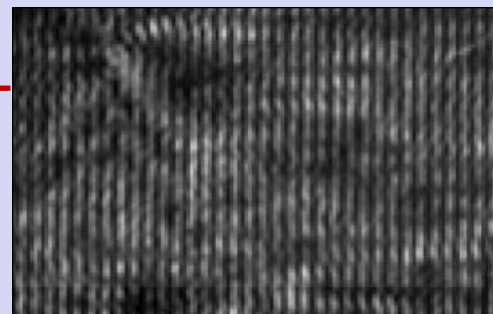
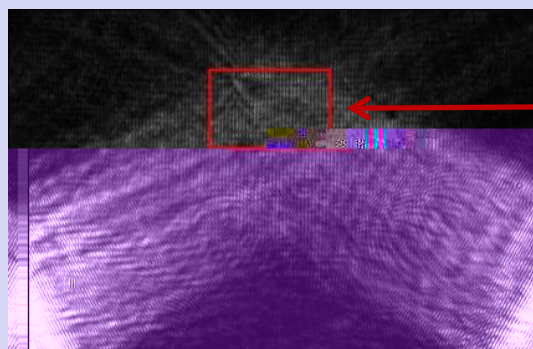
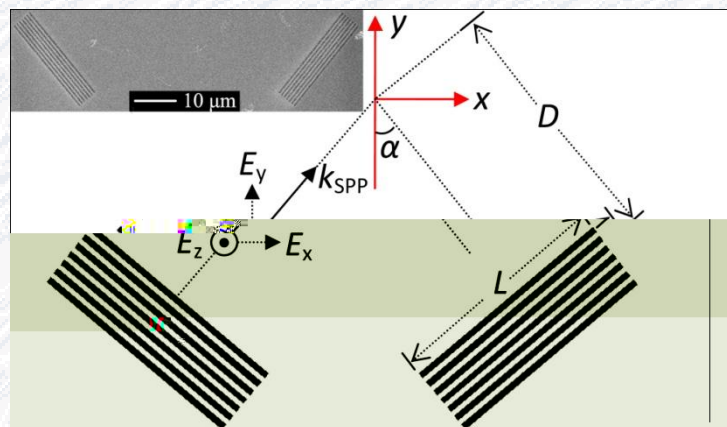
Nature 440 508 2006



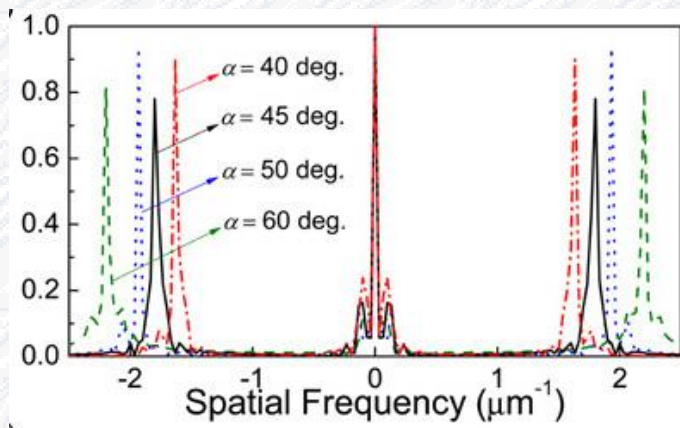




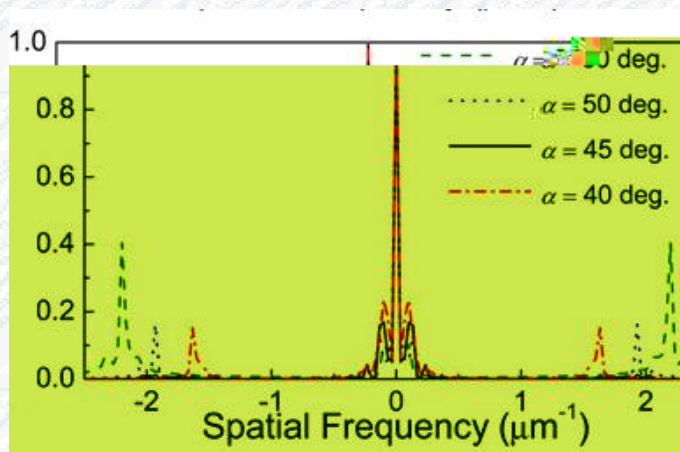




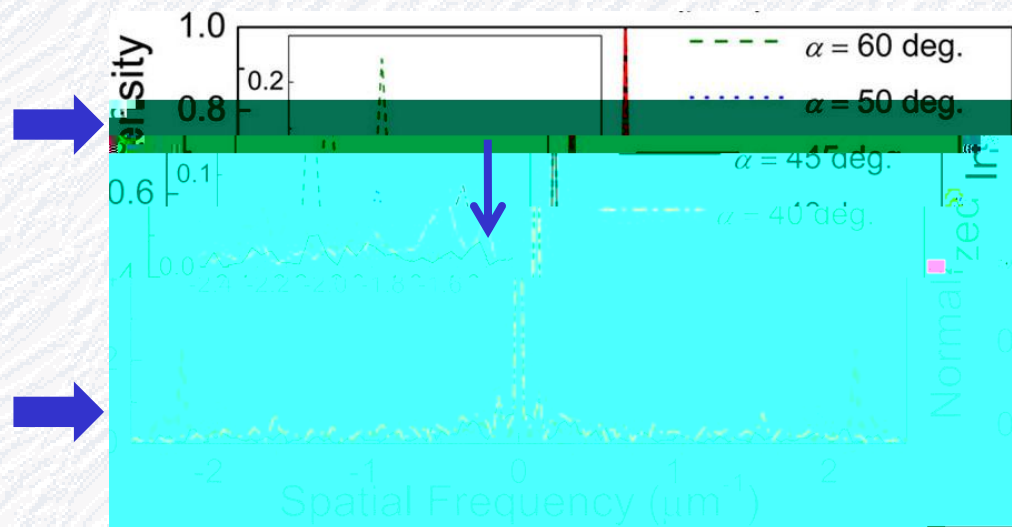
α

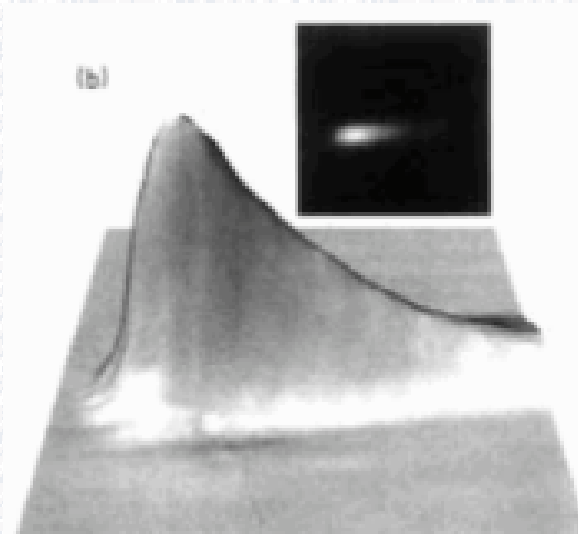
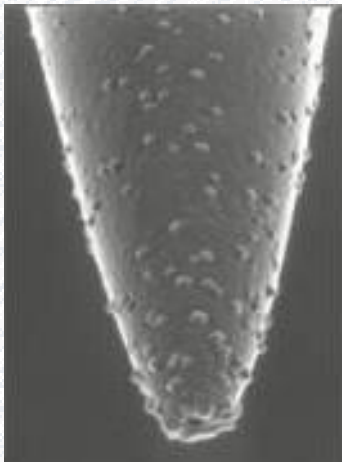
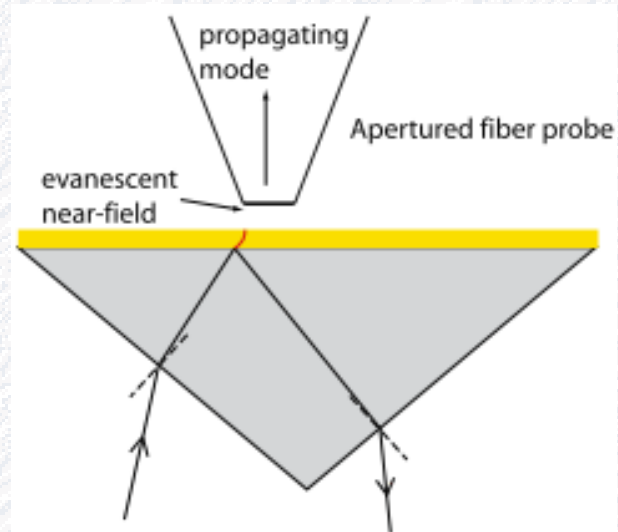
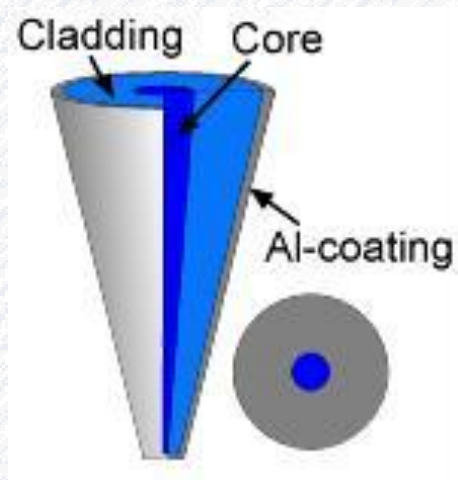


$$|E_{\perp}|^2$$

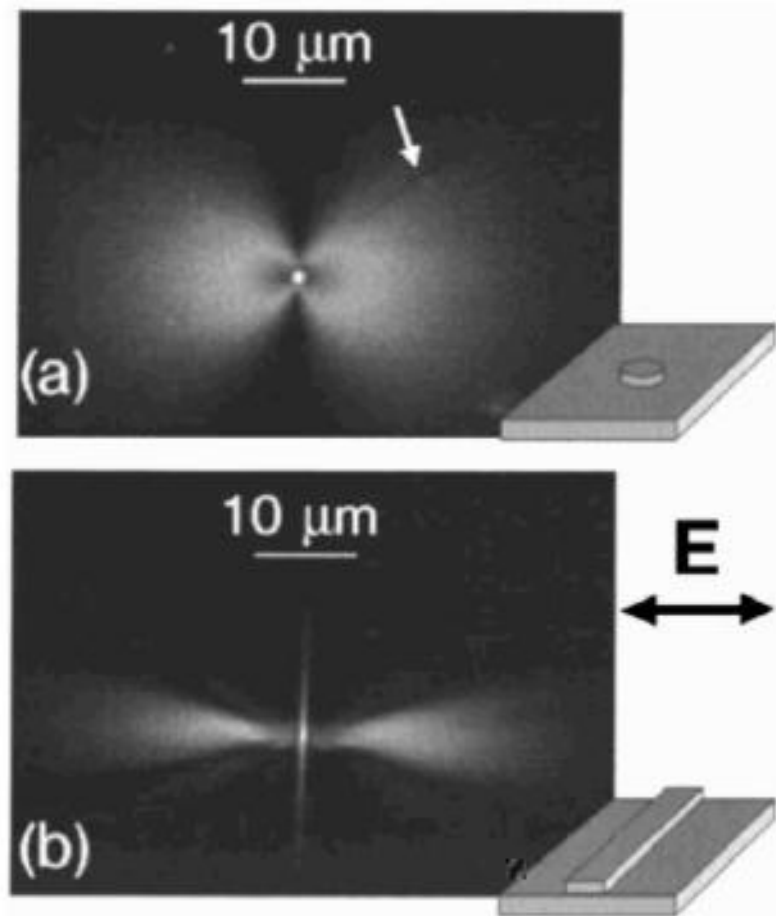
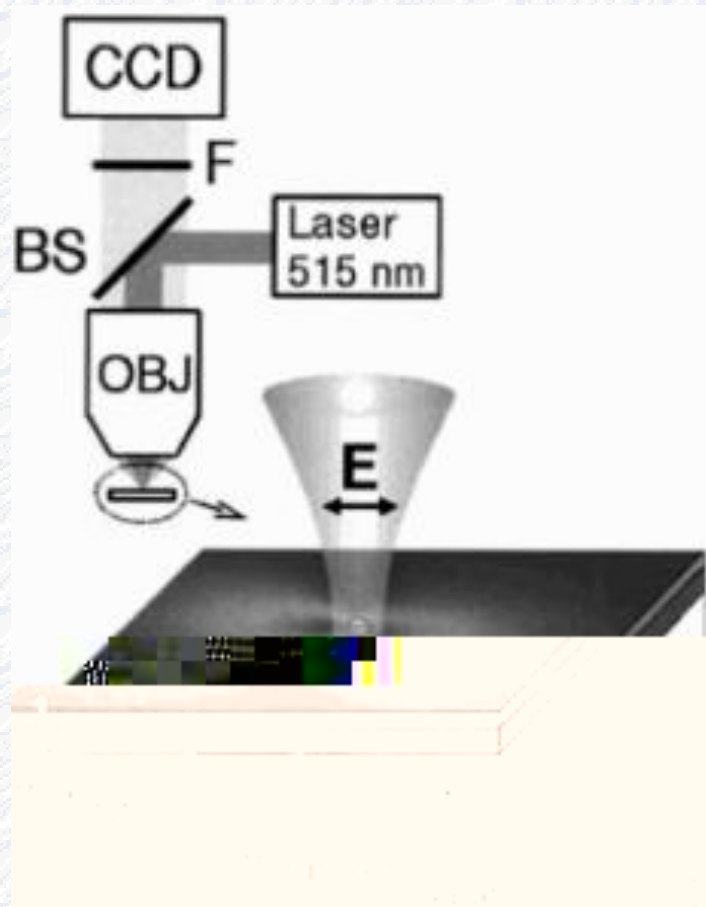


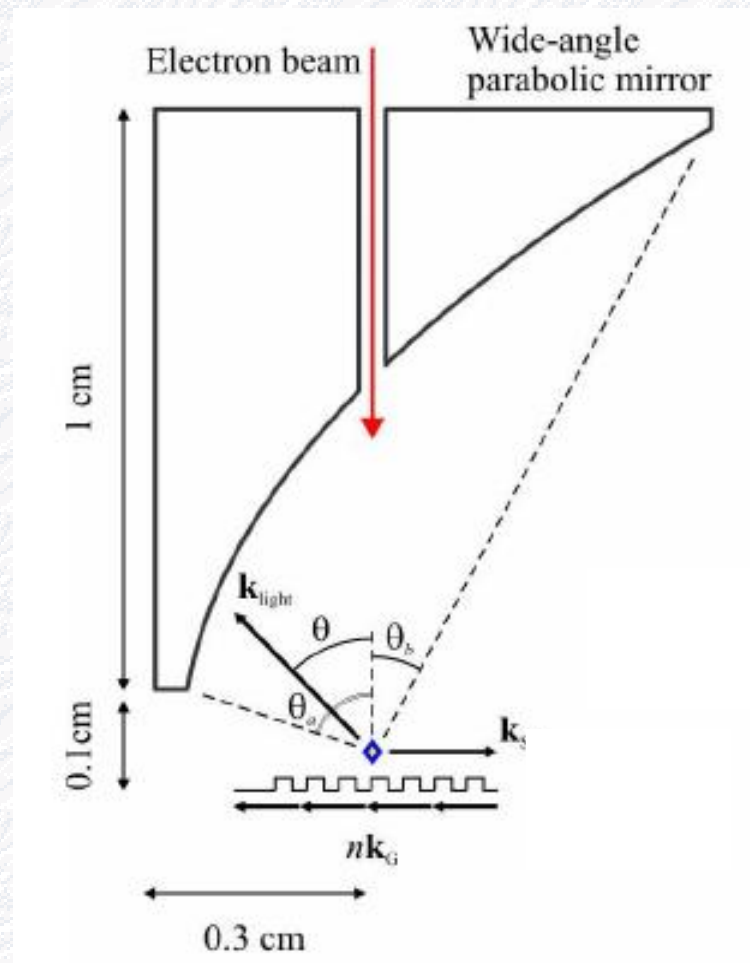
$$|E_{\parallel}|^2$$

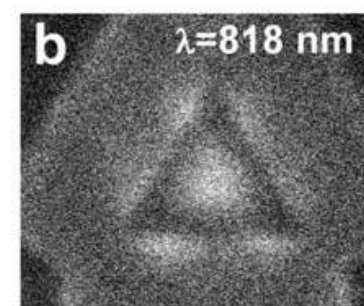
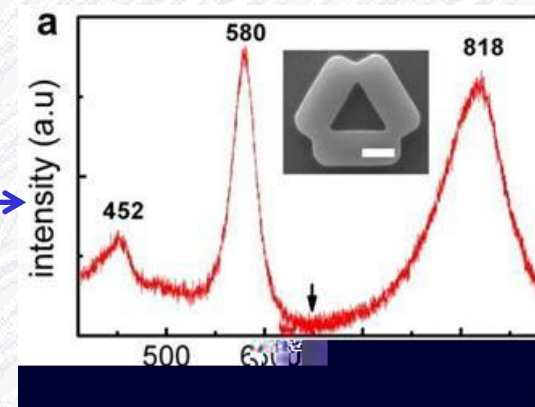
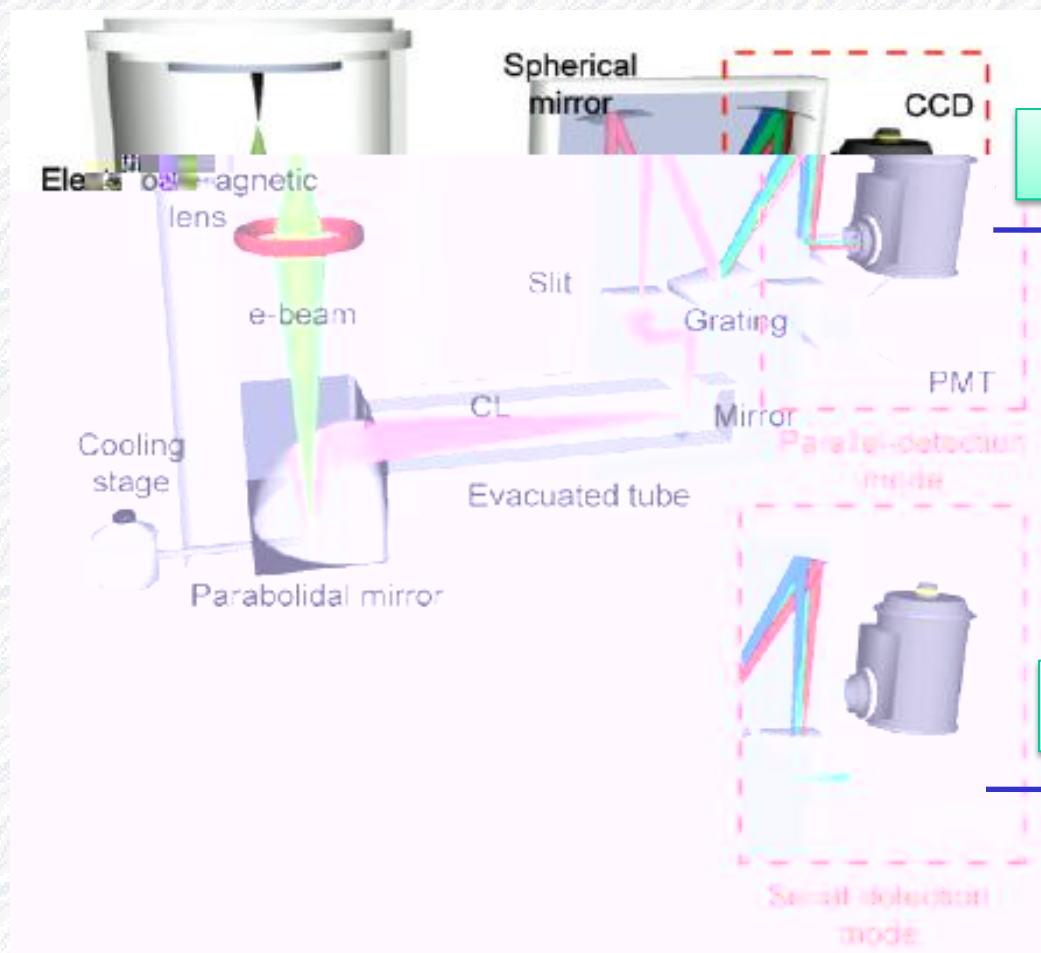


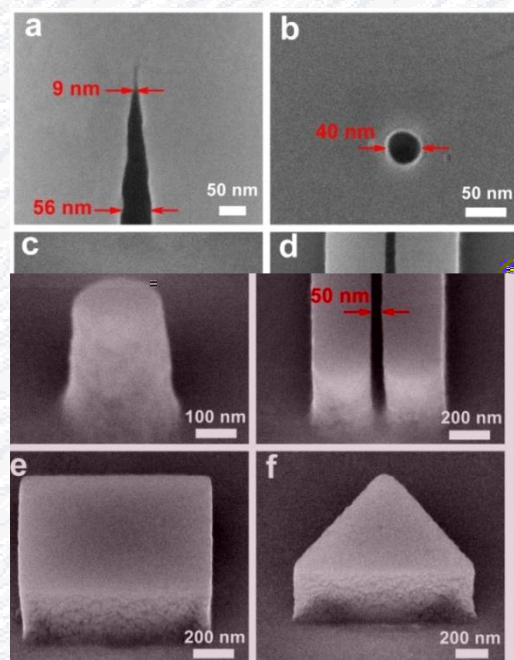
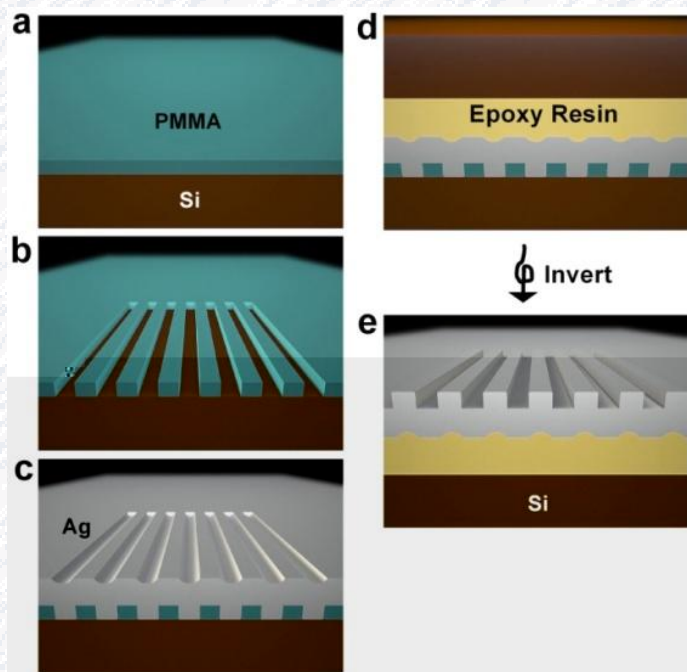


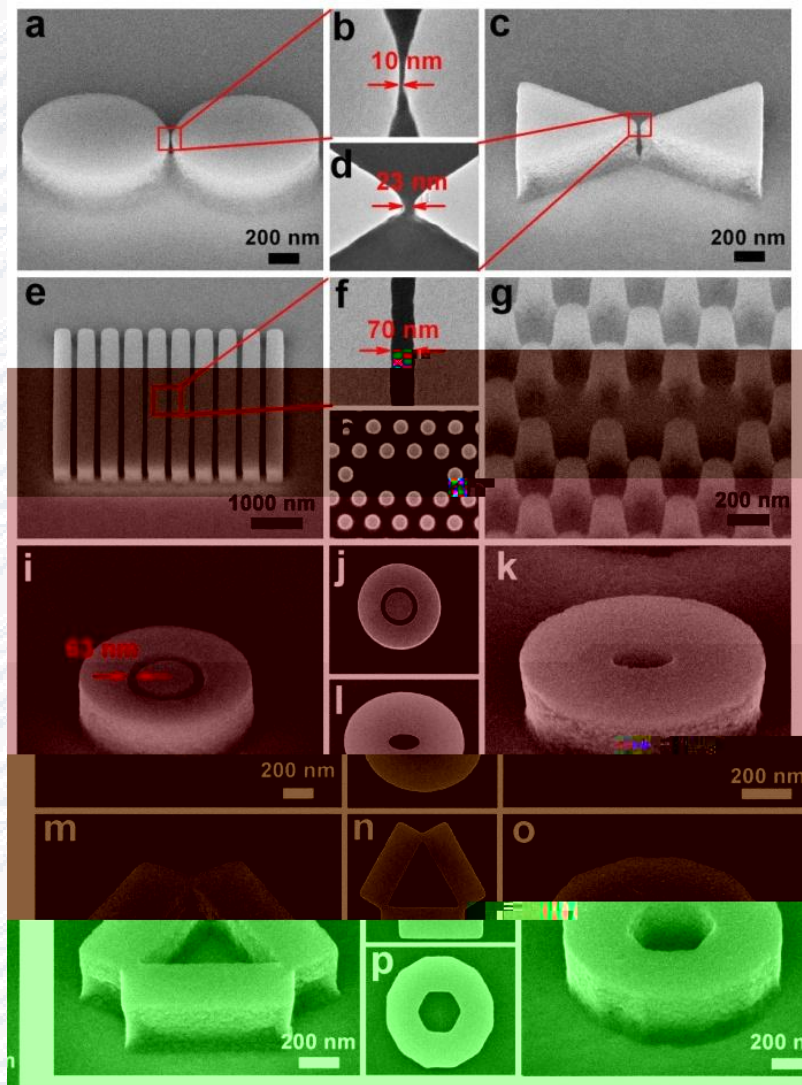
53 nm thick
(scan range



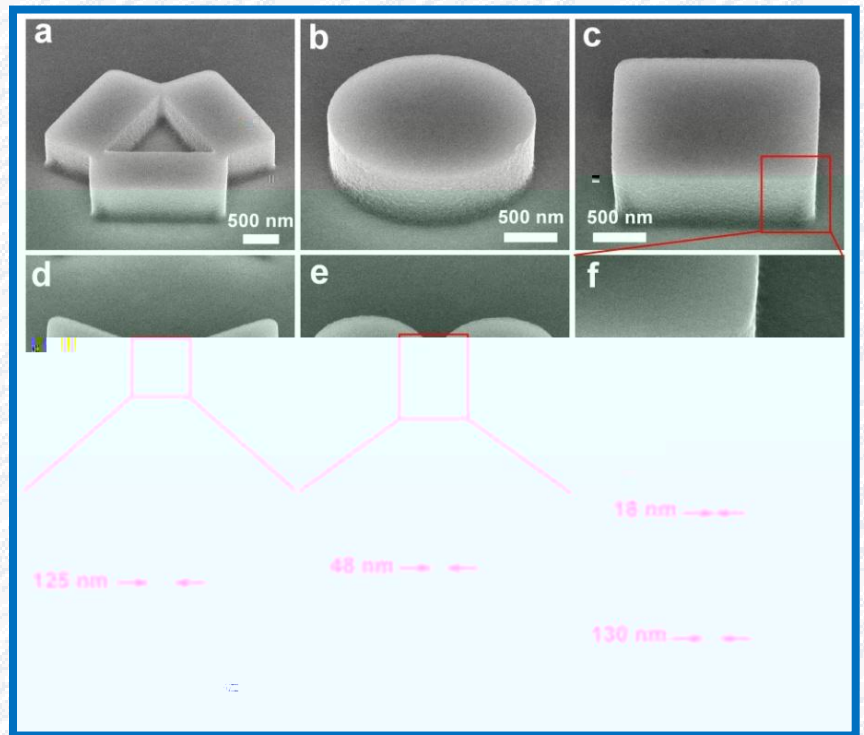








$h = 300 \text{ nm}$



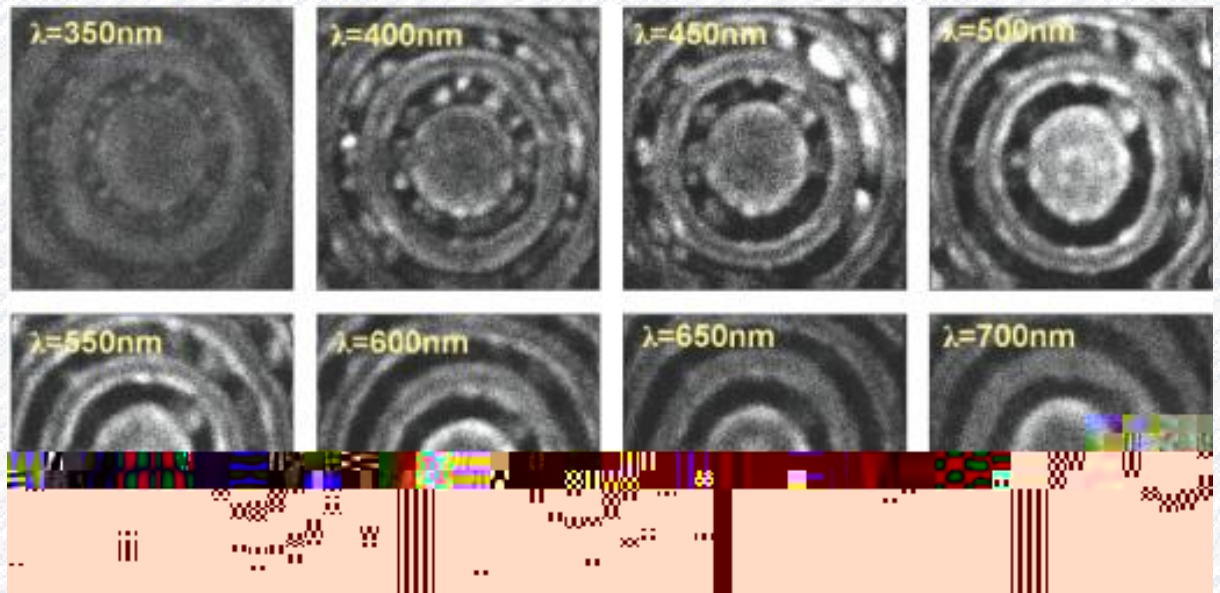
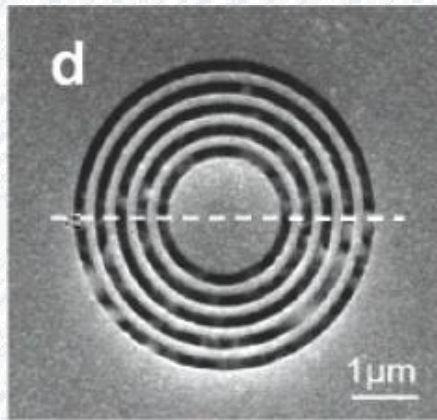
$h = 700 \text{ nm}$

Xinli Zhu et al., **Advanced Materials**,
Published online.



$D = 620\text{nm}$

$M_{0,1}$



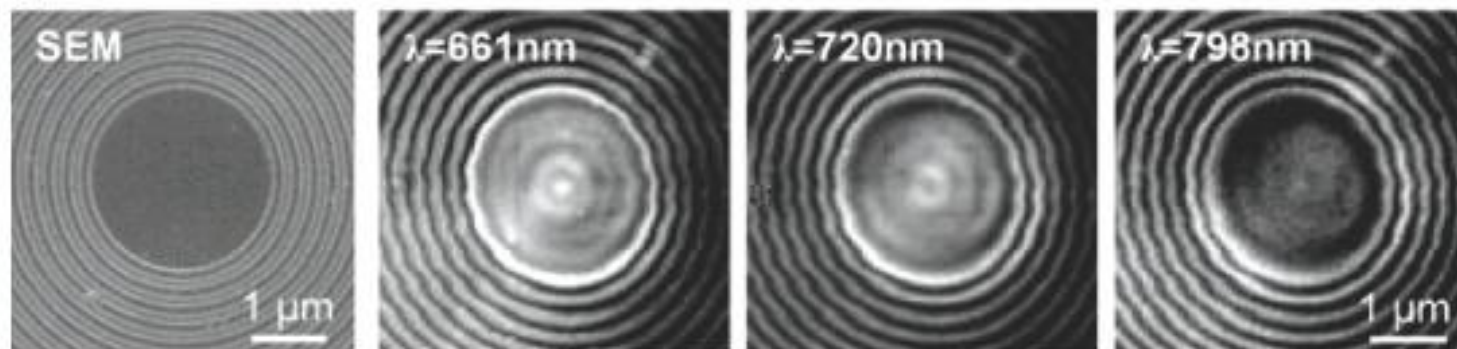
$M_{1,0}$

$M_{0,0}$

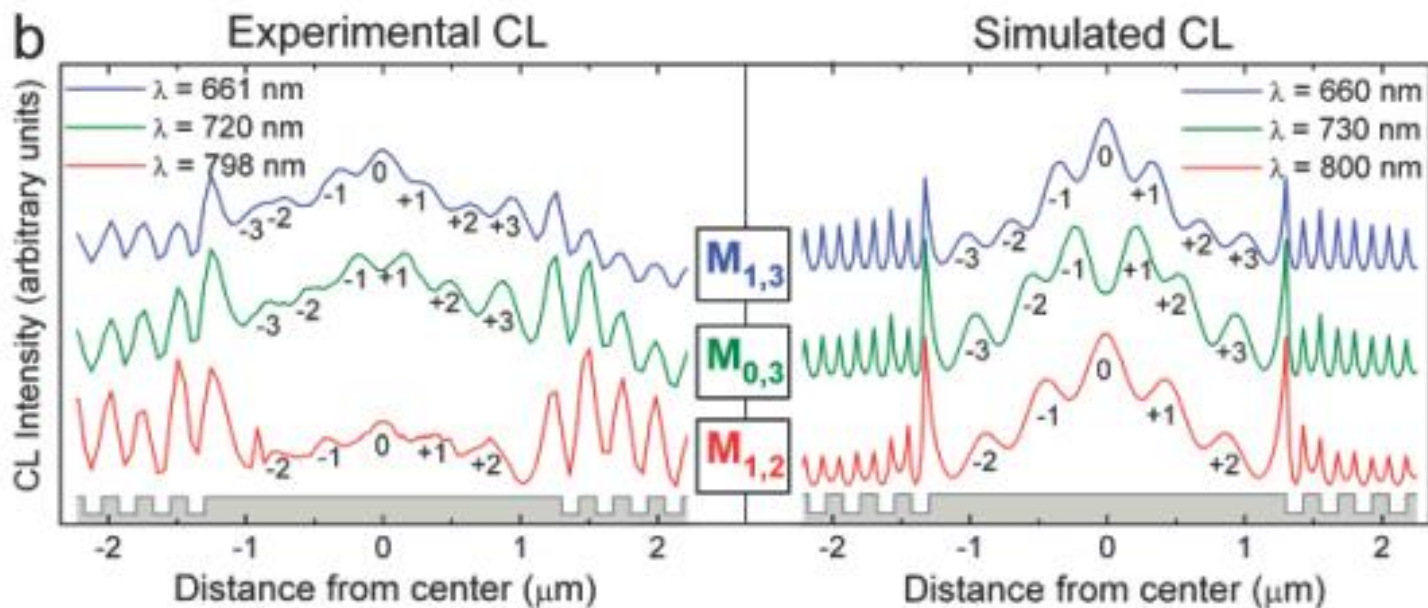
Hofmann et al., Nano Lett. 7, 3612 (2007)

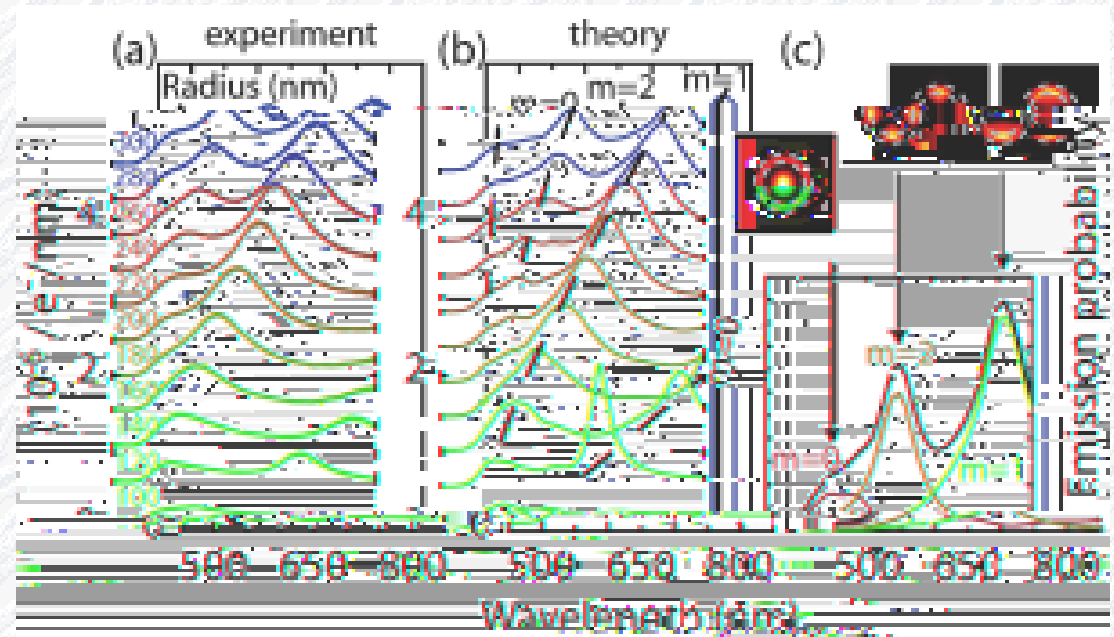
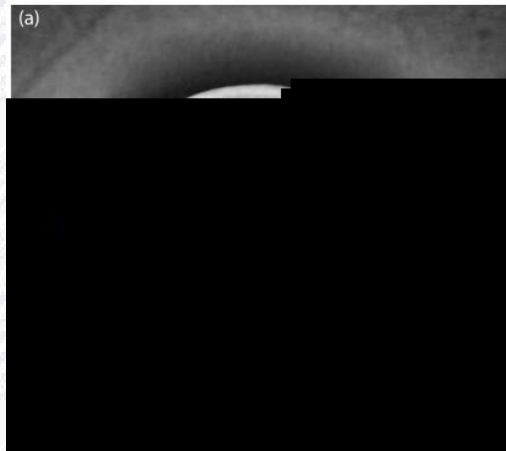
$$D = 2.6 \mu\text{m}$$

a

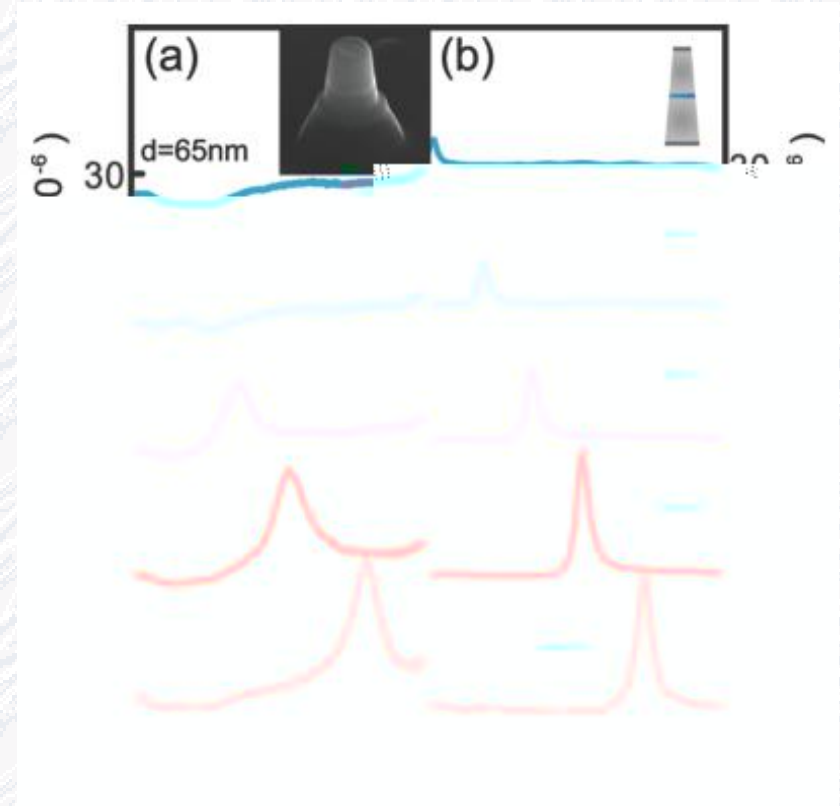
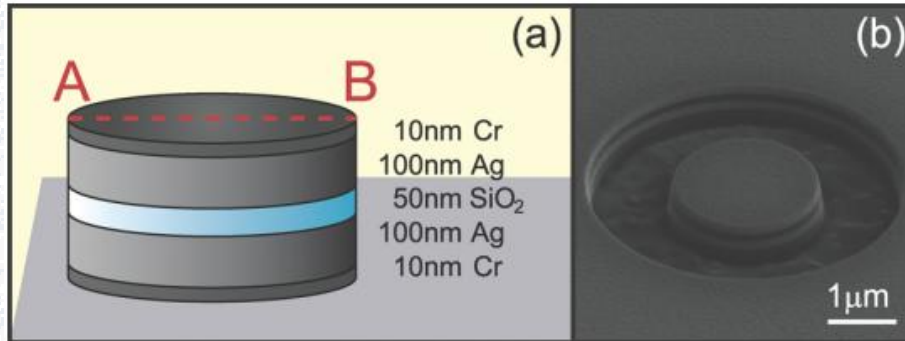


b

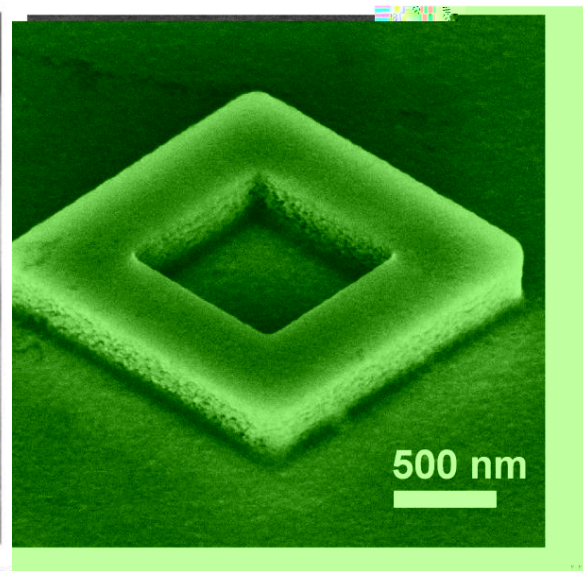
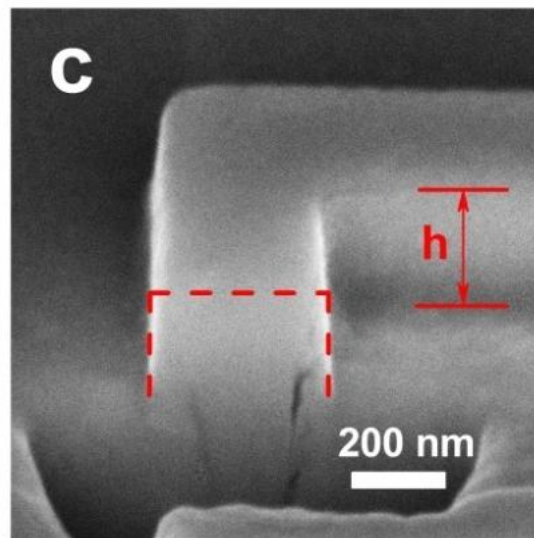
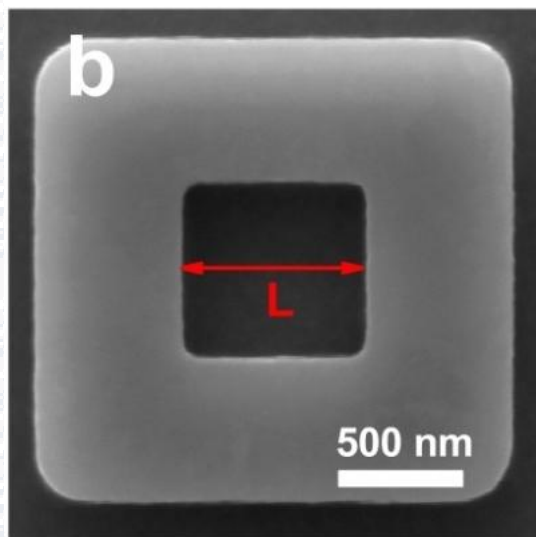


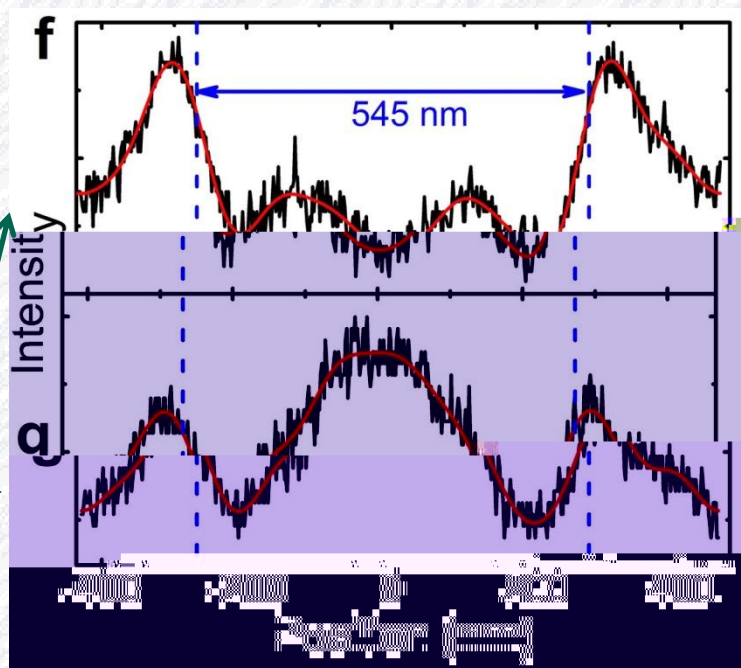
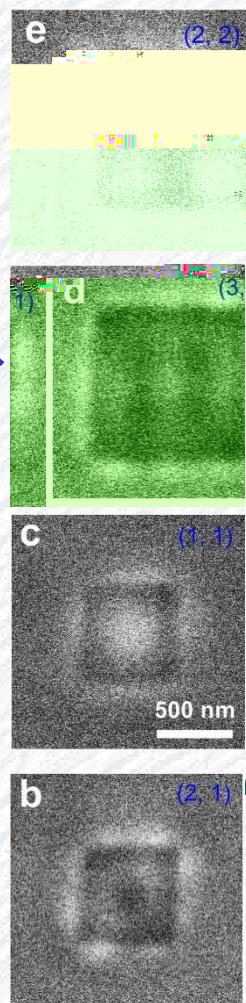
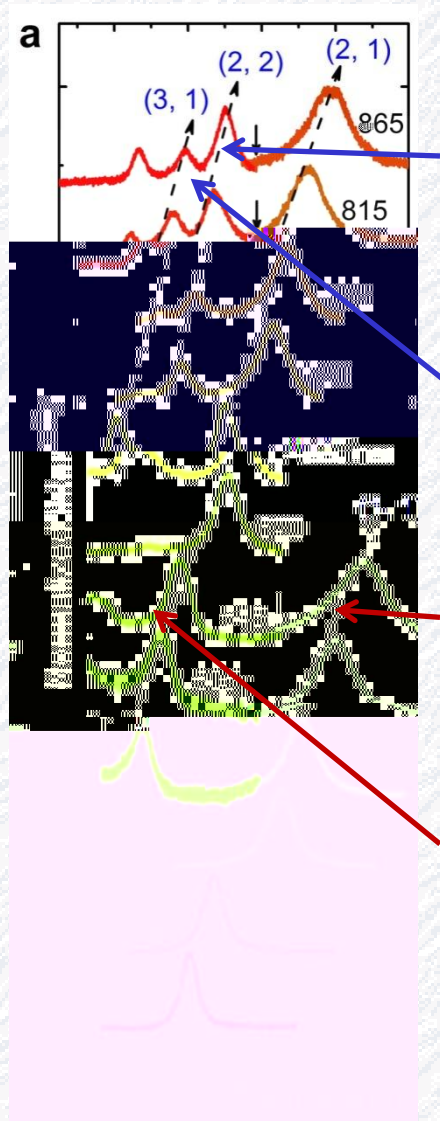


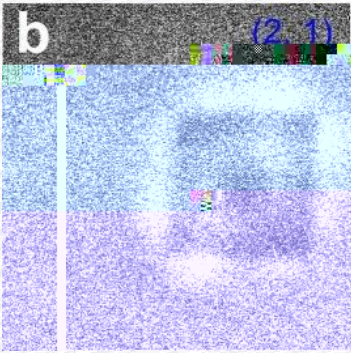
Vesseur et al., Nano Lett. 9, 3147 (2009)



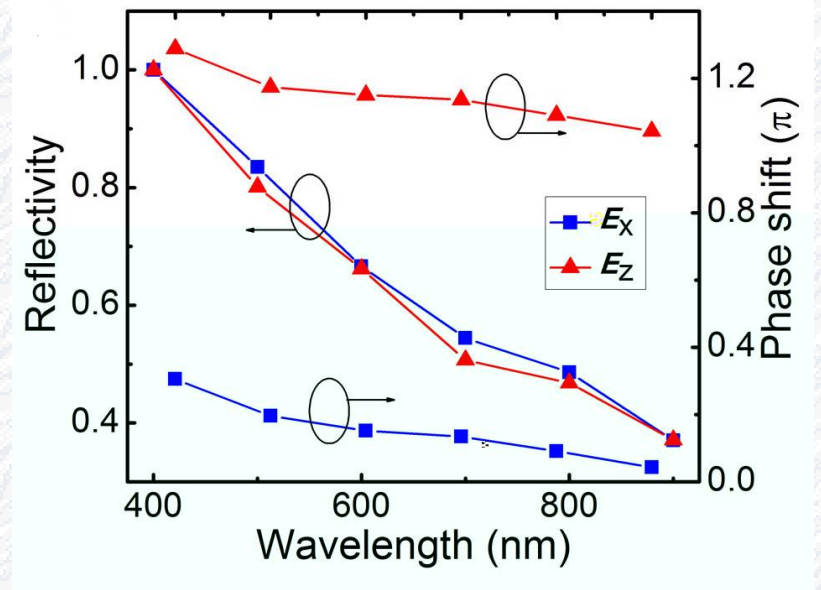
Kuttge et al., Nano Lett. 10, 1537 (2010)



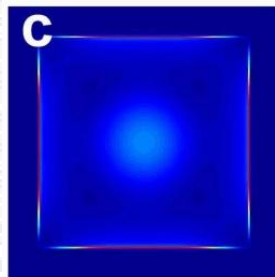
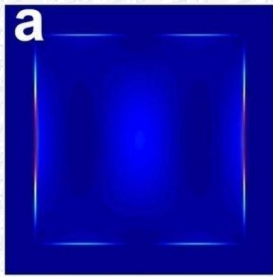




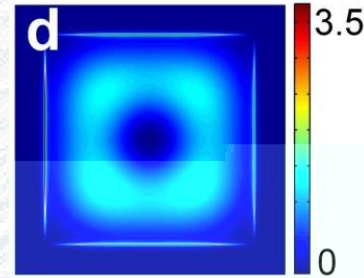
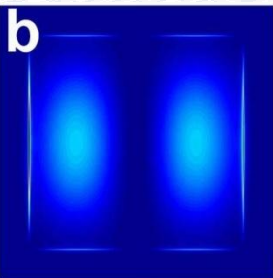
$\lambda=550\text{nm}$
 $l=545\text{nm}$



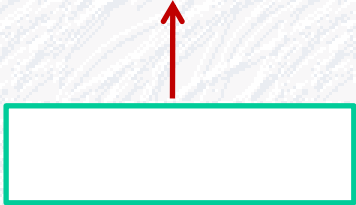
$|\mathbf{E}_{\parallel}|^2$



$|\mathbf{E}_{\perp}|^2$



$$L + 2\delta(\lambda_{\text{SPP}}) = \sqrt{m^2 + n^2} \cdot \frac{\lambda_{\text{SPP}}}{2}$$

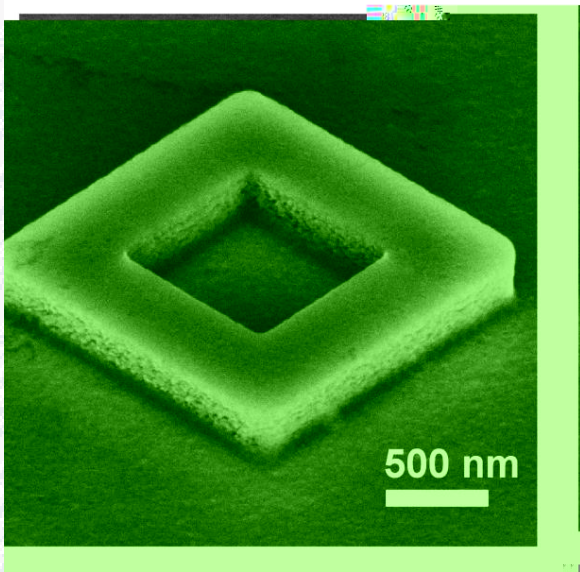


$$\delta \lambda$$

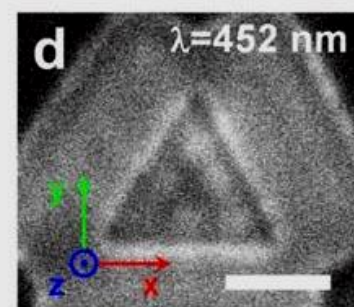
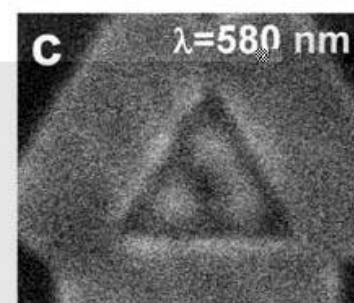
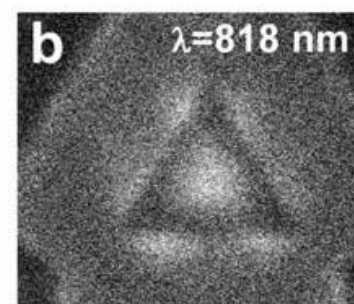
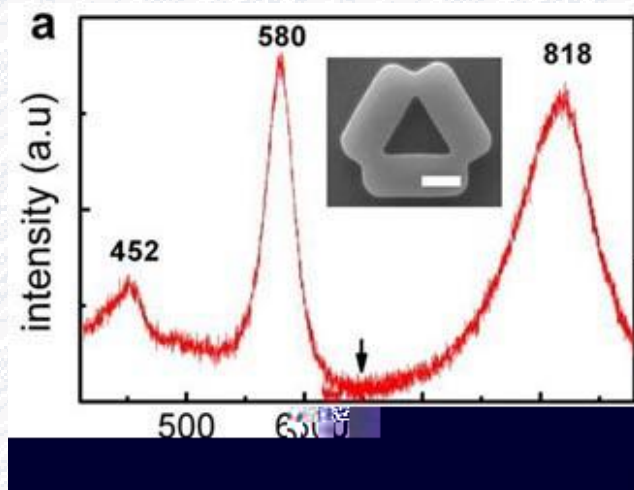
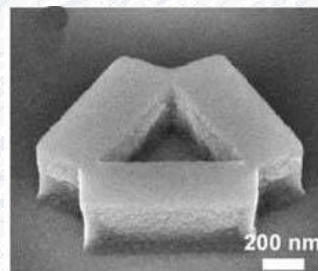
$$V = \lambda_{\text{SPP}}^3 \left(1 + \left|\varepsilon_{\text{m}}'\right|\right) \left(32\pi \sqrt{\left|\varepsilon_{\text{m}}'\right|}\right)^{-1}$$

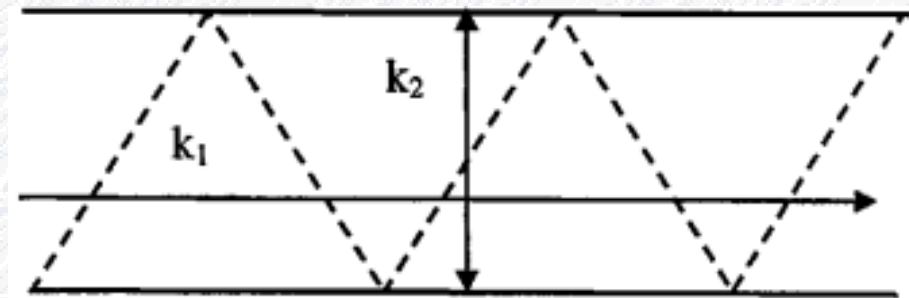
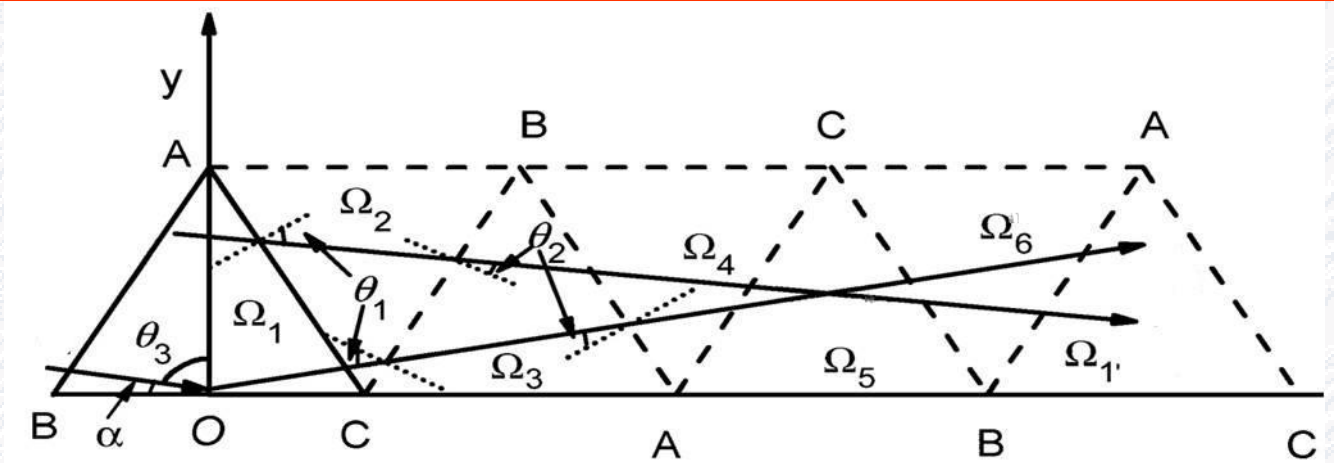
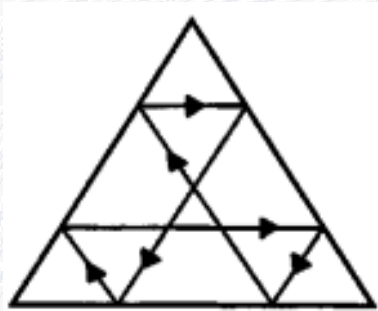
$$\lambda_{\text{SPP}}^3$$

$$\mu$$



X. L. Zhu et al., **Phys. Rev. Lett.** 105, 127402 (2010).



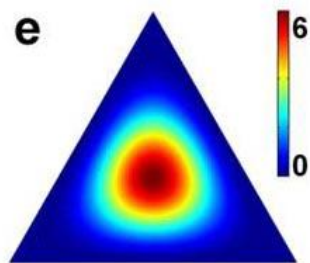
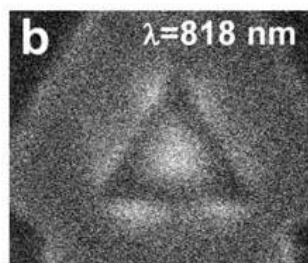
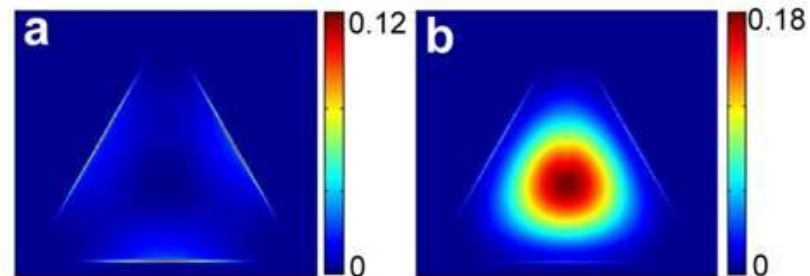


(n, m)

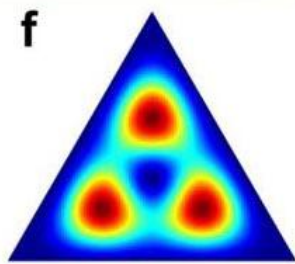
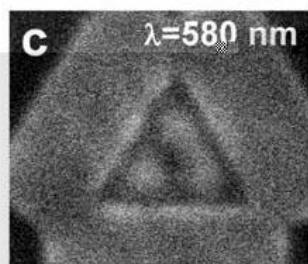
$$k_2 = \frac{2n\pi}{\sqrt{3}a}, \quad n = 1, 2, 3, \dots \quad k_1 = \pm \frac{2m\pi}{3a}, \quad m = 1, 2, 3, \dots$$

$$|\mathbf{E}_{\parallel}|^2$$

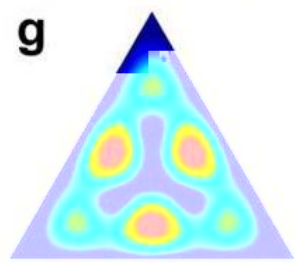
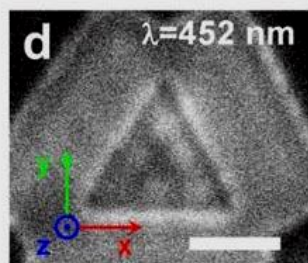
$$|\mathbf{E}_{\perp}|^2$$



(1, 3)



(1, 5)/(2, 4)

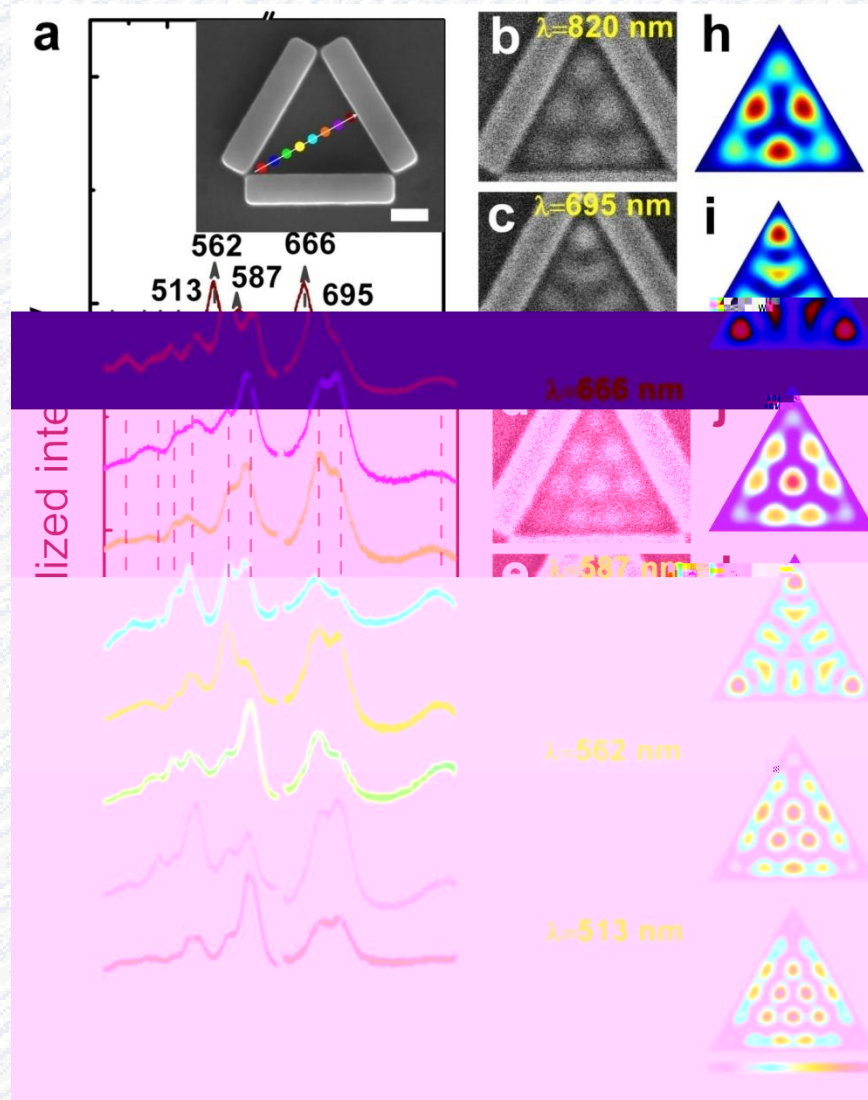


(1, 7)/(3, 5)



$$\mathbf{E} = 0$$

$$a = 2\mu\text{m}$$



(1, 7)/(3, 5)

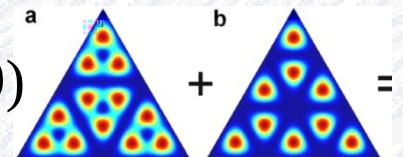
(2, 8)/(3, 7)

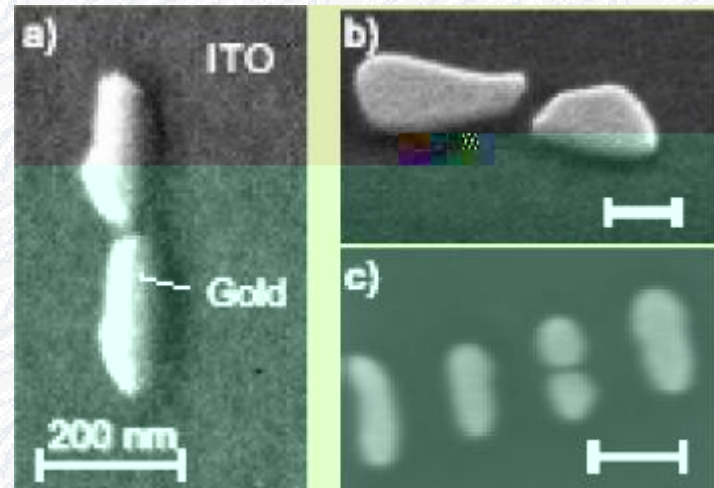
(1, 9)

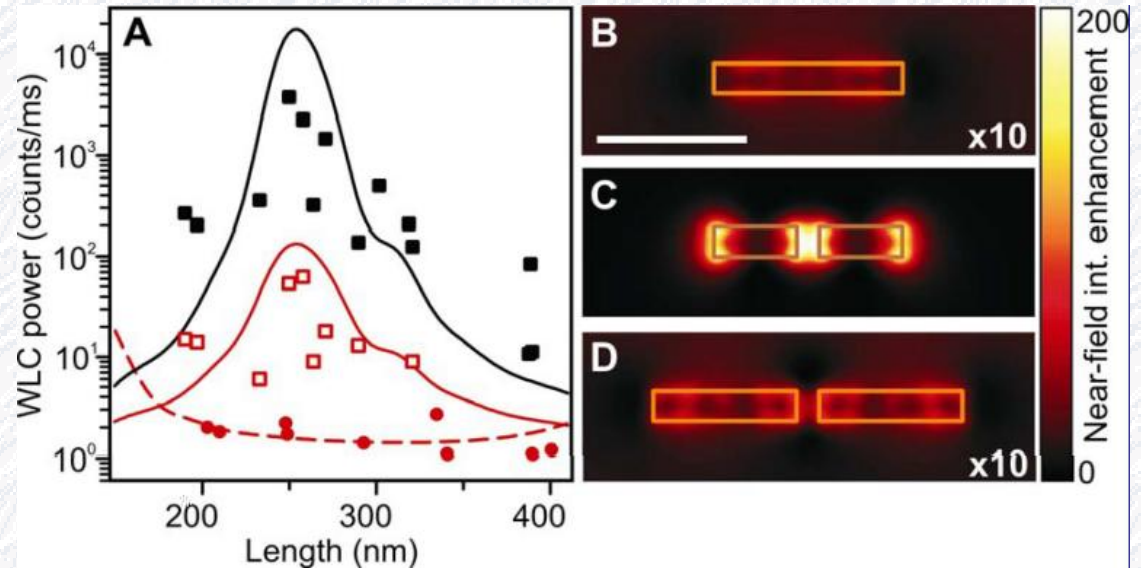
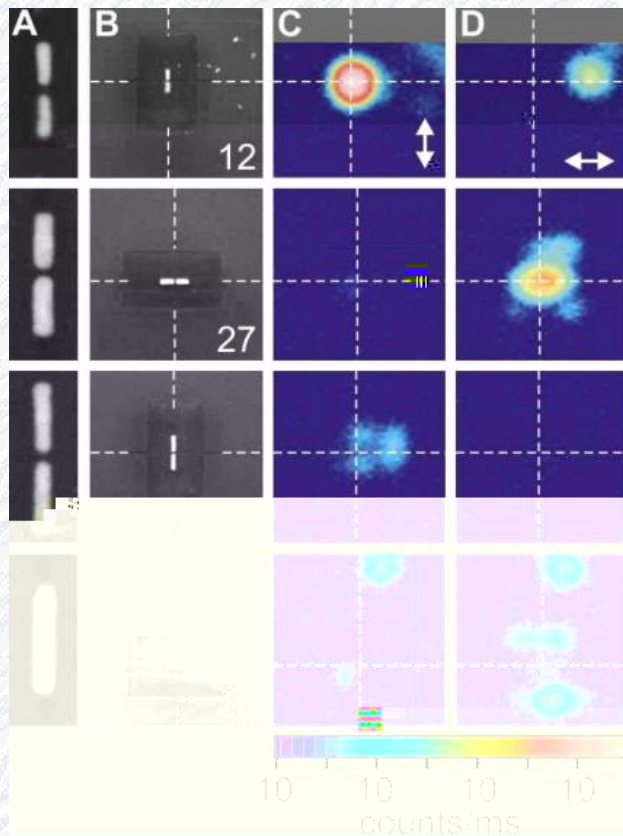
(2, 10) + (3, 9)

(1, 11)

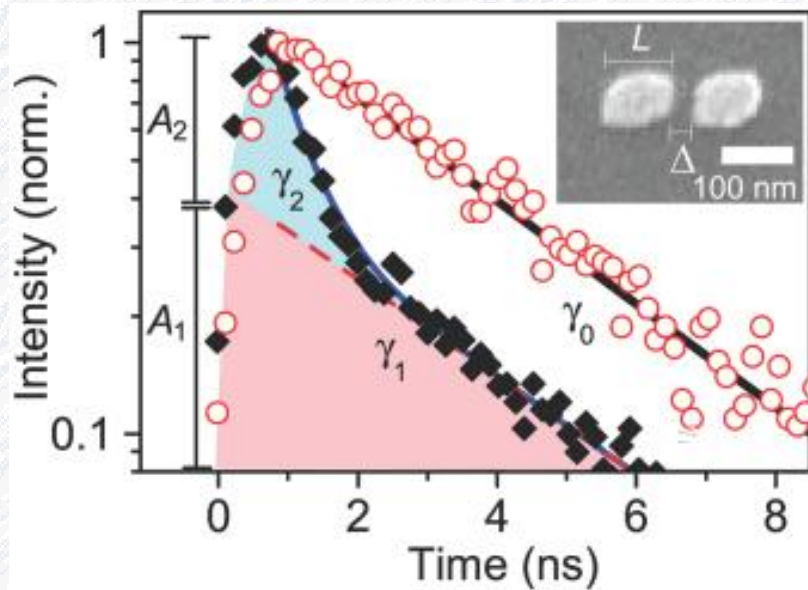
(1, 13)



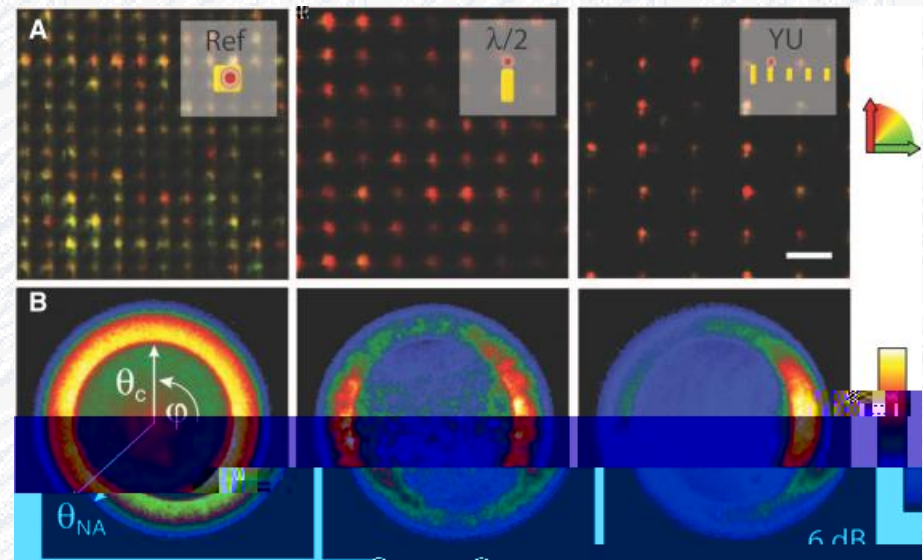
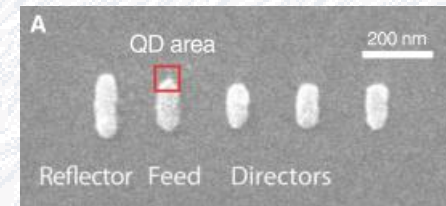




Muhlschlegel et al., Science 308, 1607 (2005).

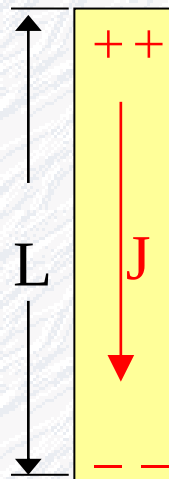


Muskens et al., Nano Lett.
7, 2871 (2007).

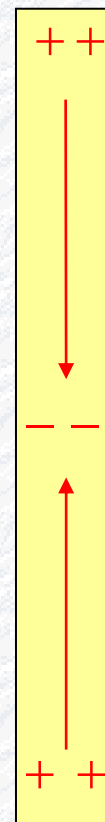


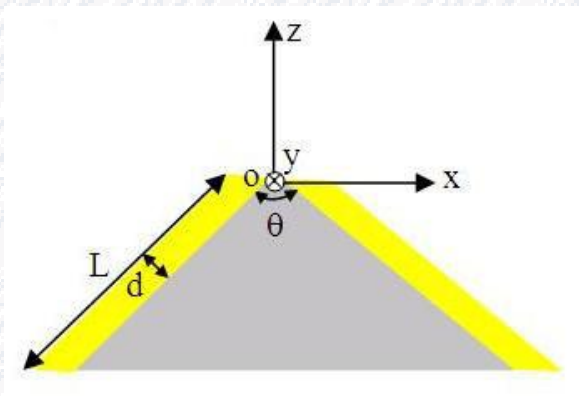
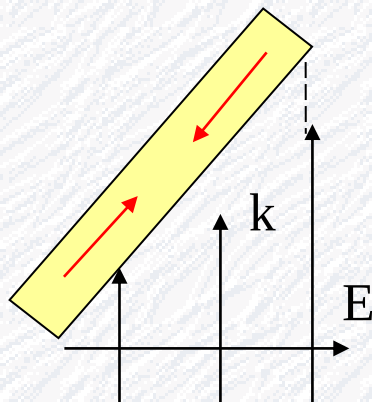
Curto et al., Science 329, 930 (2010).

E

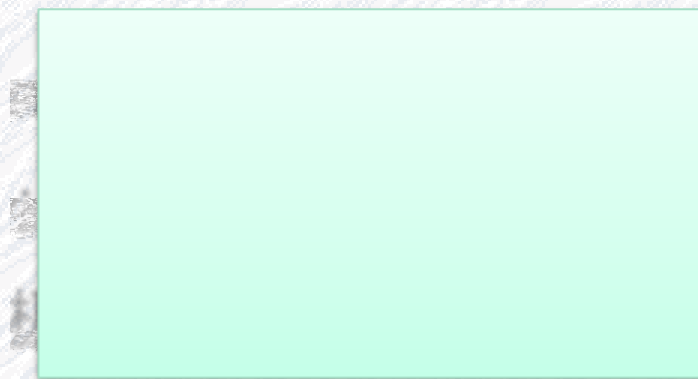


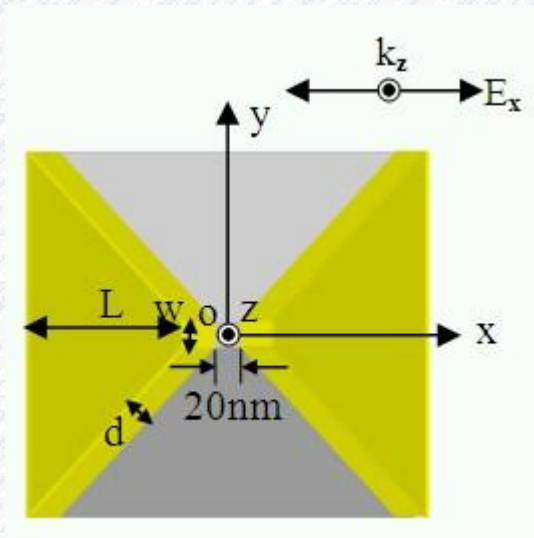
E



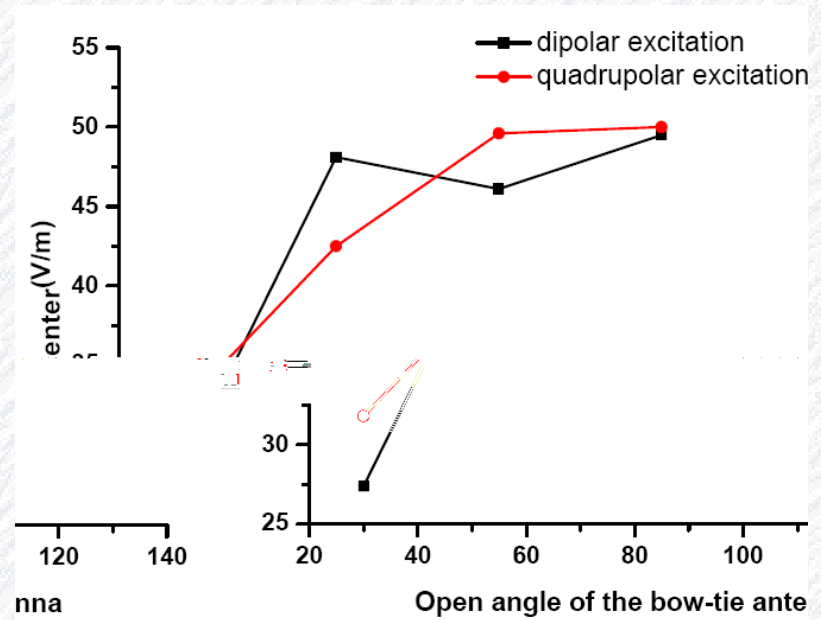


V



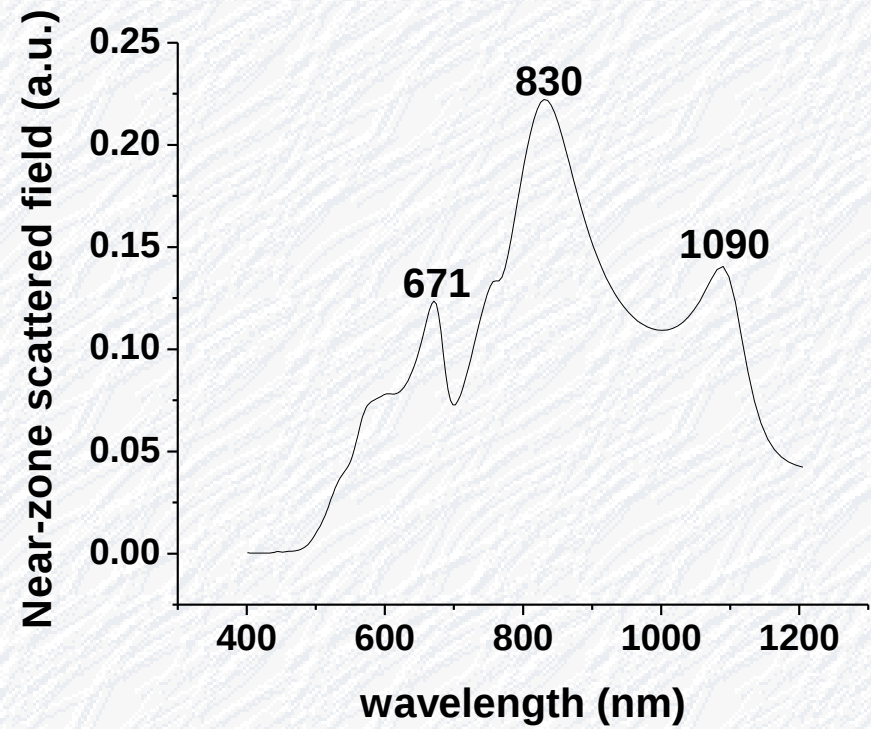
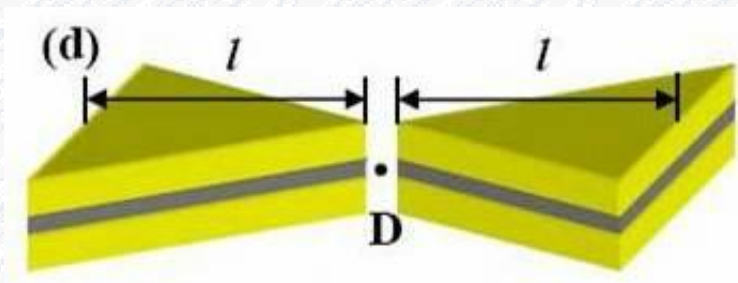


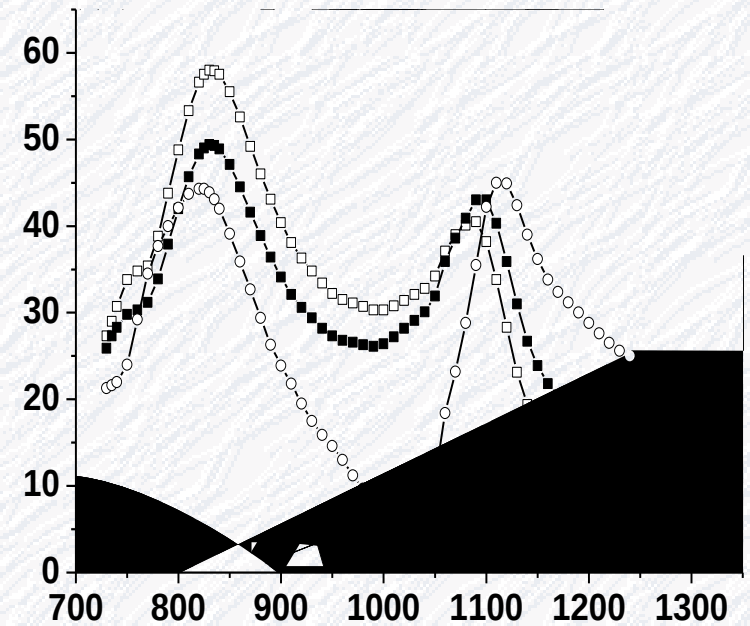
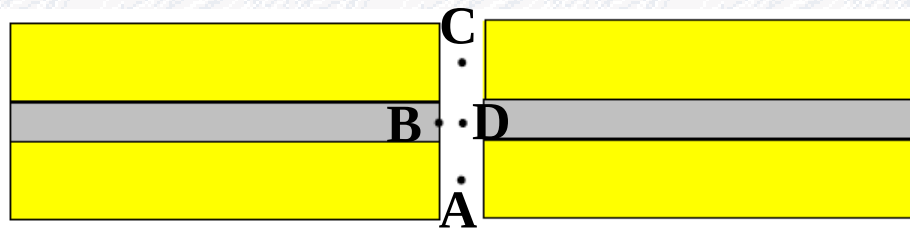
V



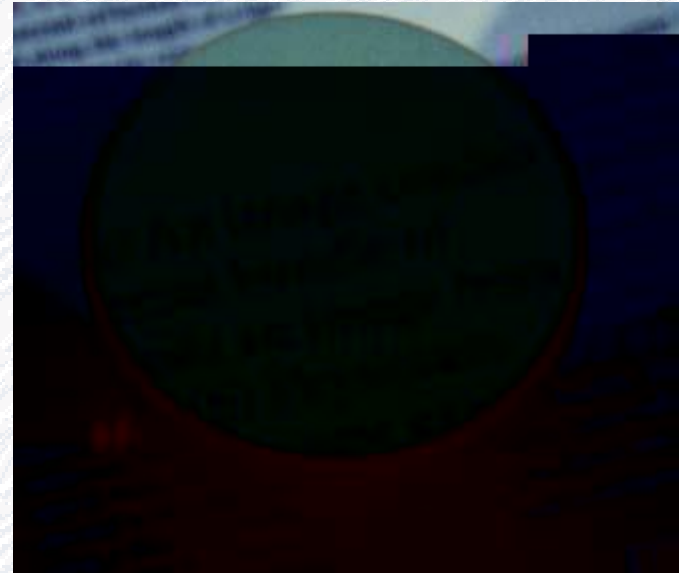
V

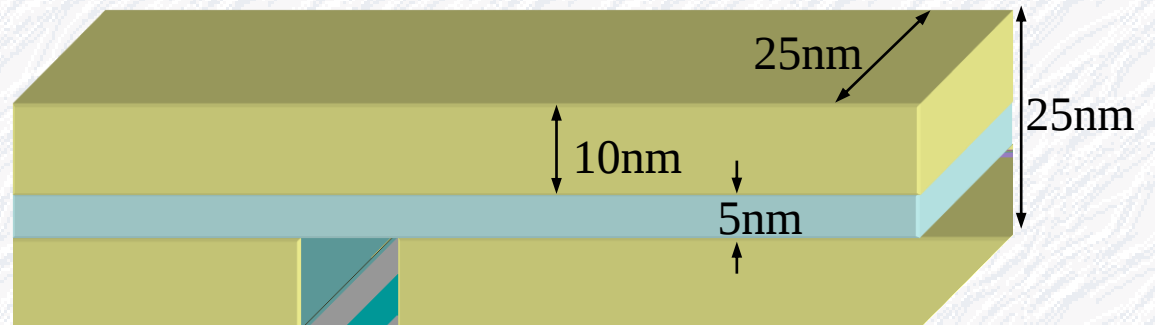
Jing Yang et al., Opt. Express 15, 16852 (2007).

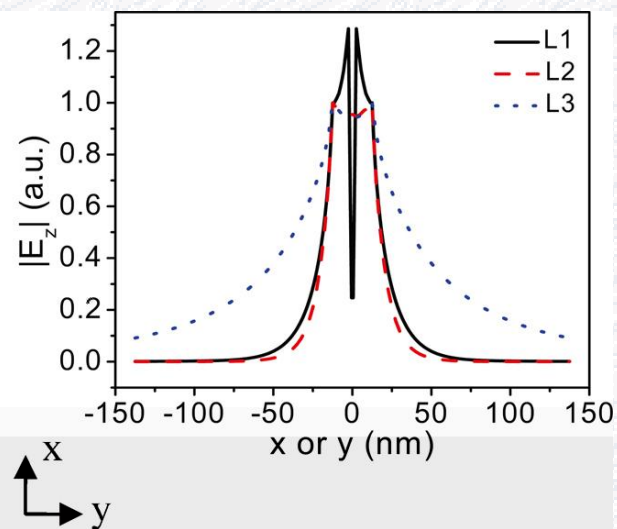
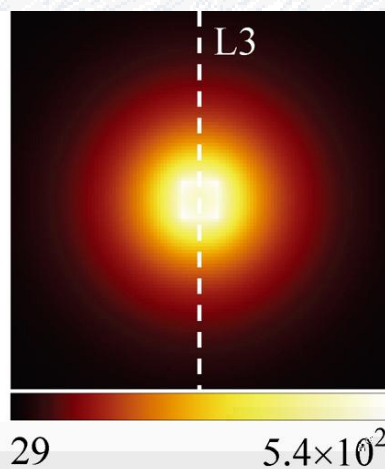
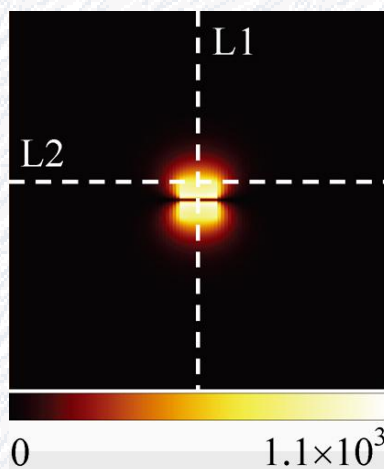
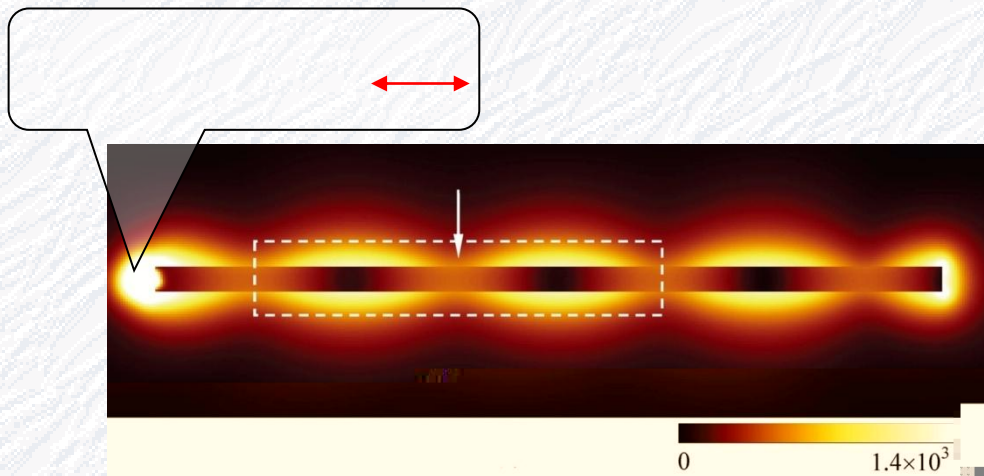
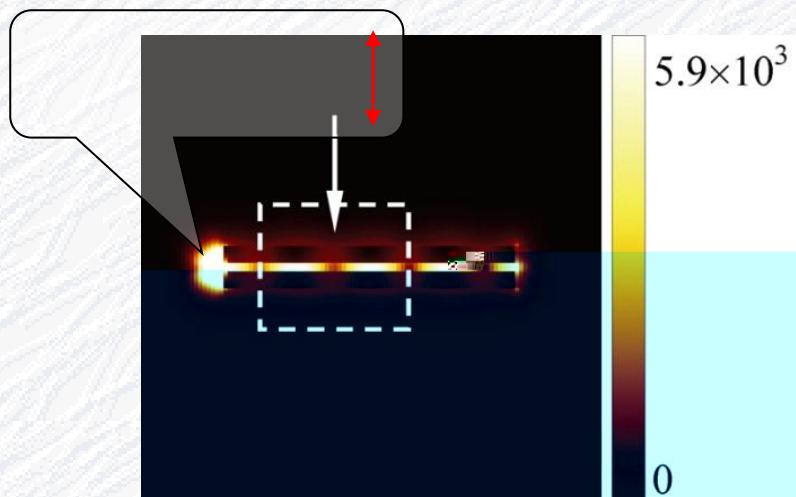


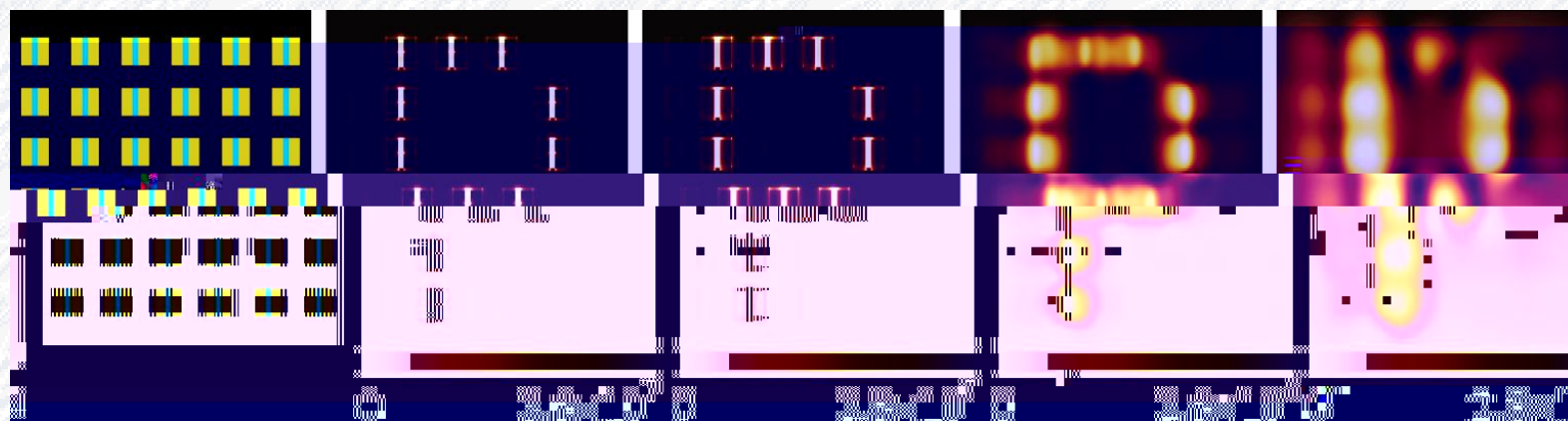


Lisheng Wang et al., Opt. Commun. 281, 5444 (2008).

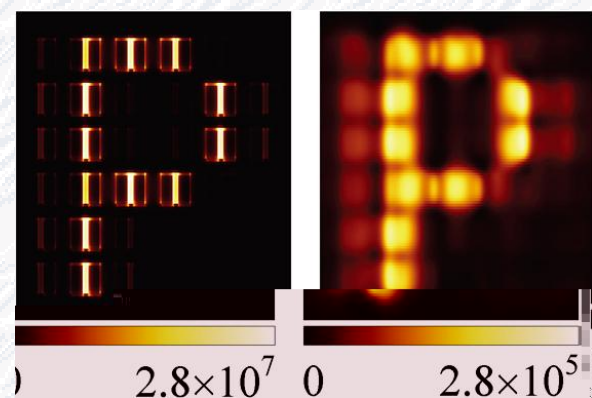




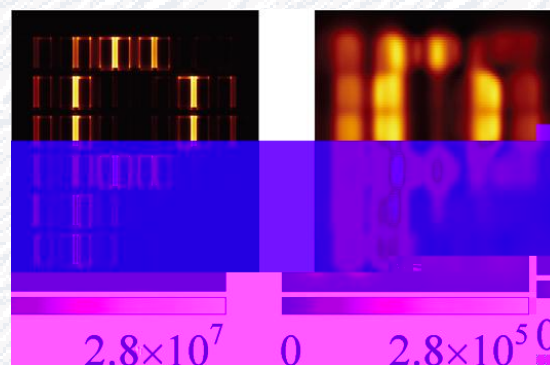




MIM 20nm

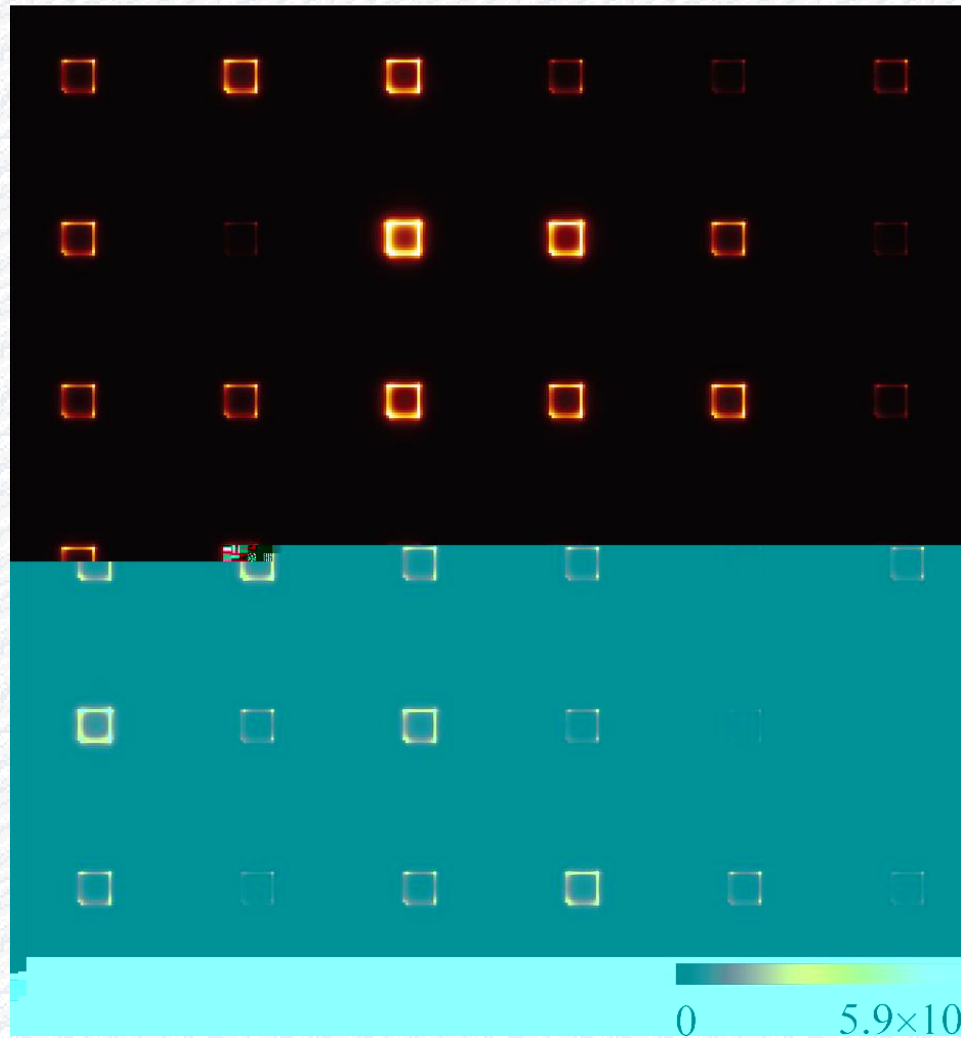


MIM 15nm



MIM 10nm

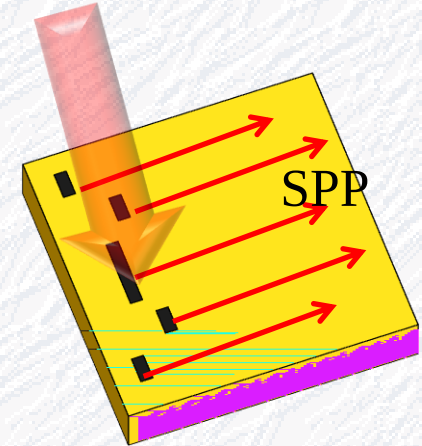
40nm $\sim \lambda/20$



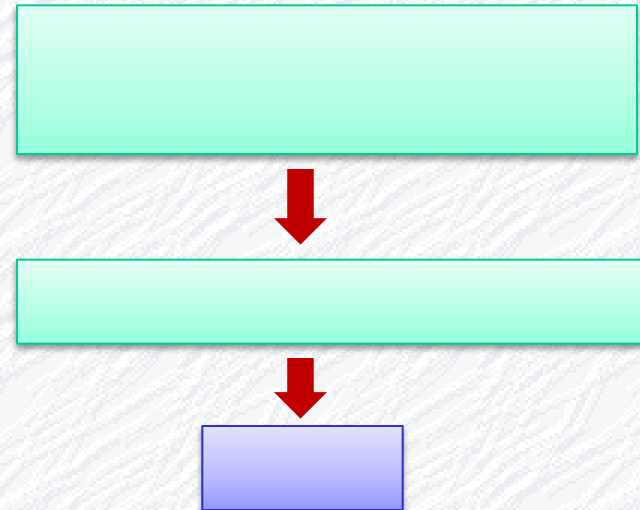
Au 120nm

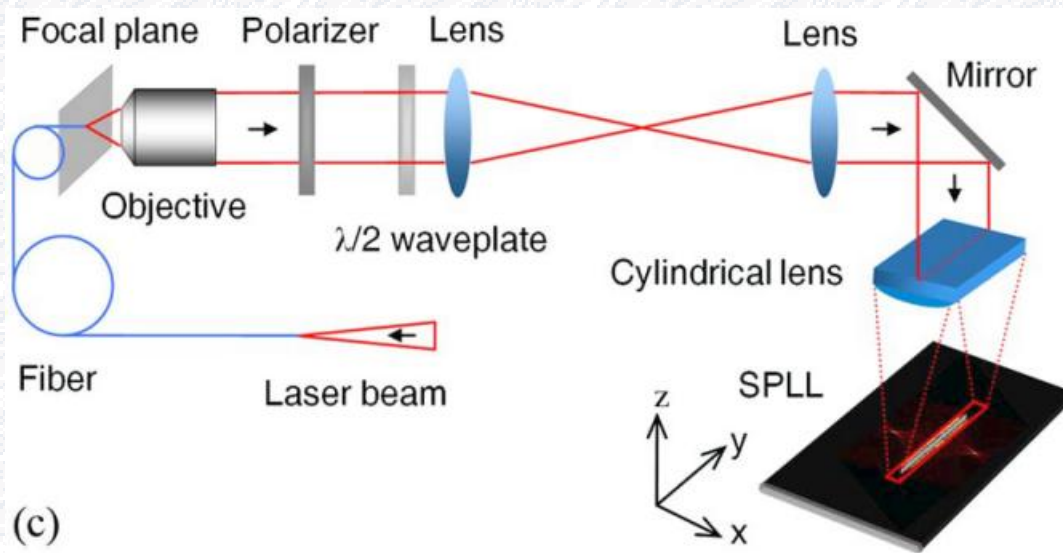
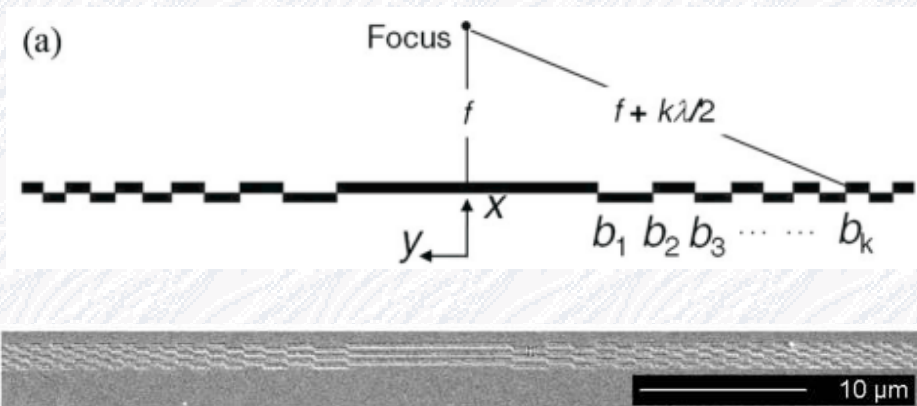
Xiaofei Wu et al., Opt. Express **17**, 2818 (2009).

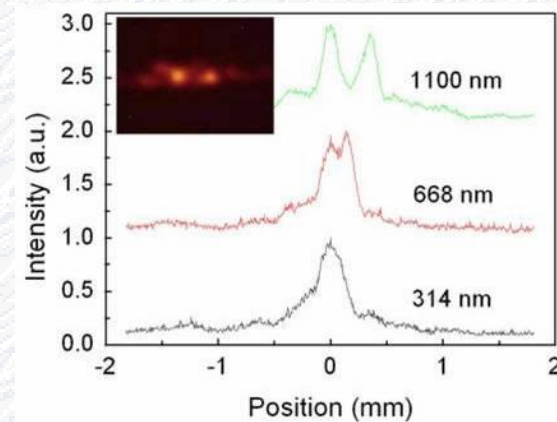
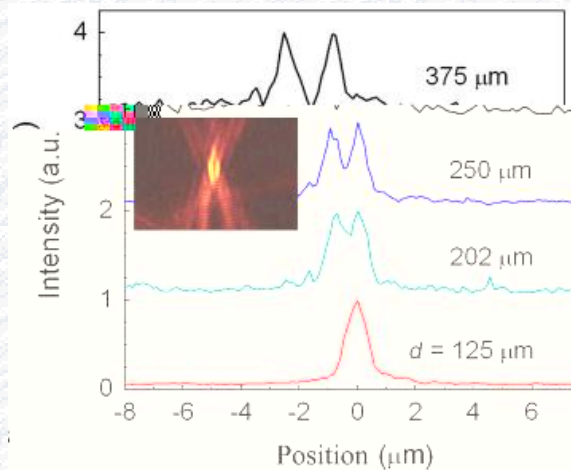
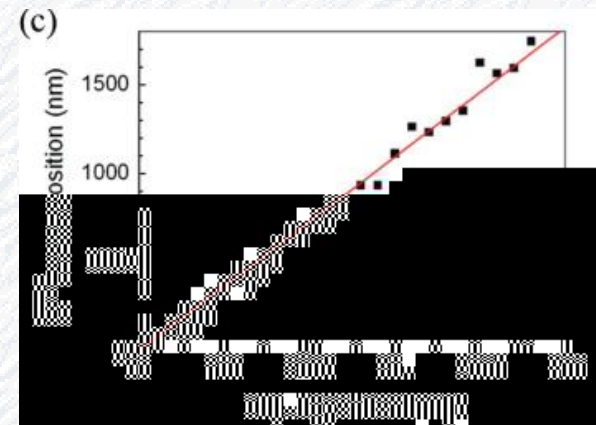
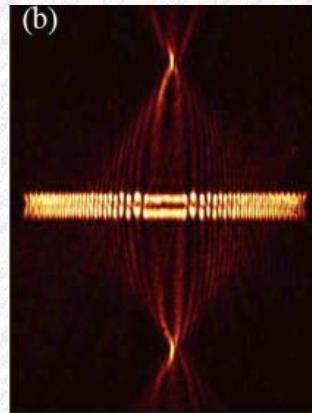
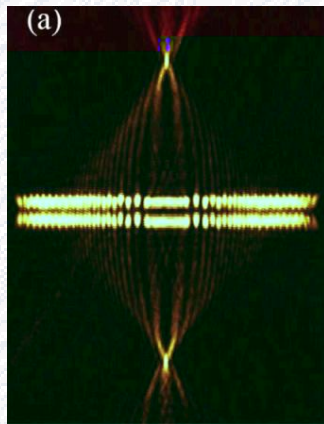
SPP



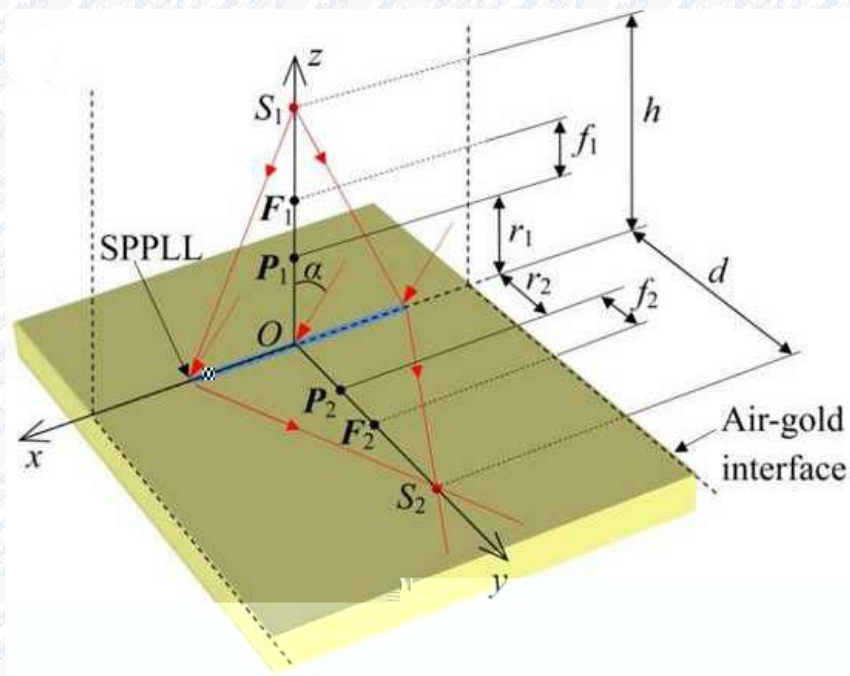
✓
✓
✓
✓



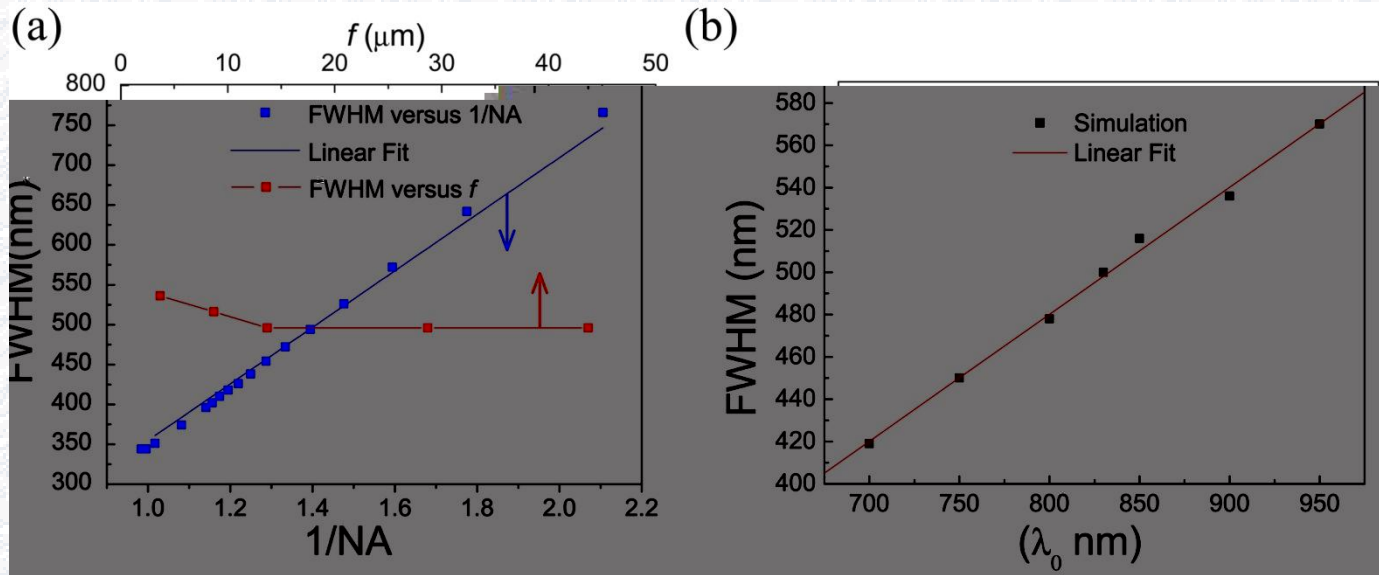




Jiayuan Wang et al., **Appl. Phys. Lett.** 94, 081116 (2009).



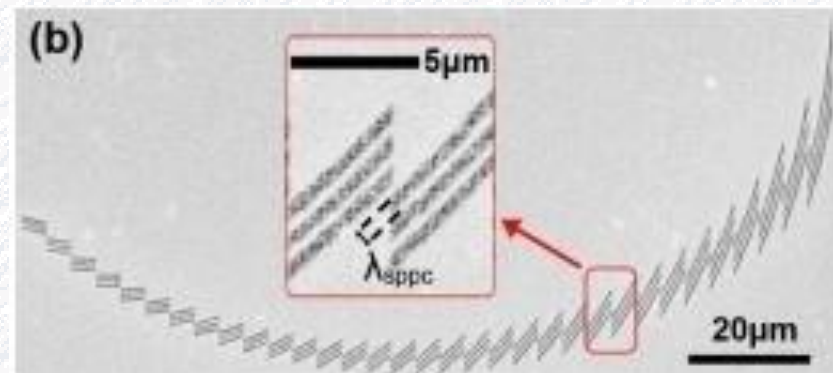
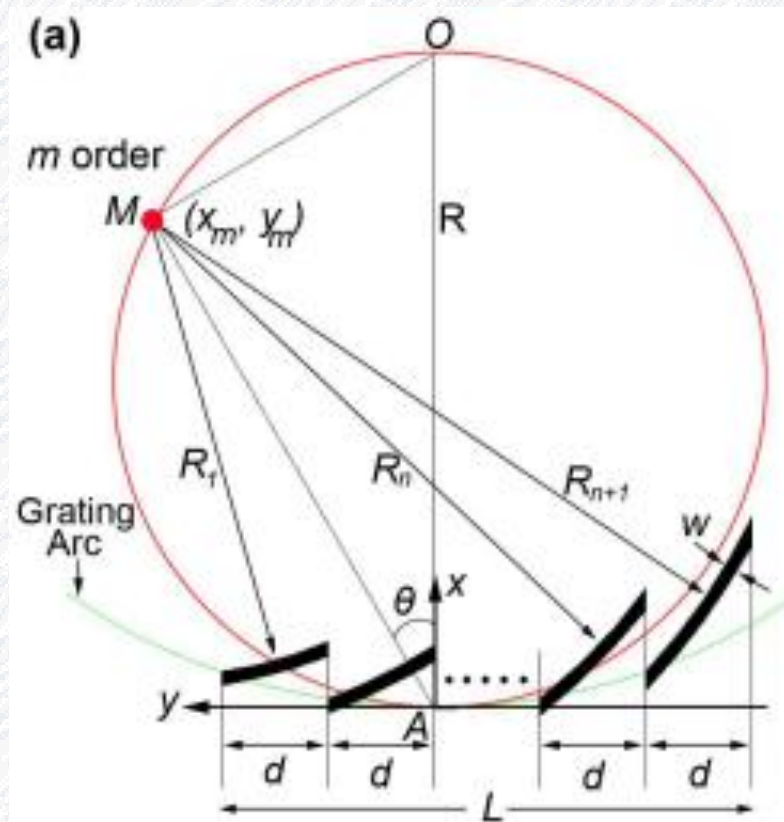
$$\frac{f_1}{h - r_1} + \frac{f_2}{d - r_2} = 1$$

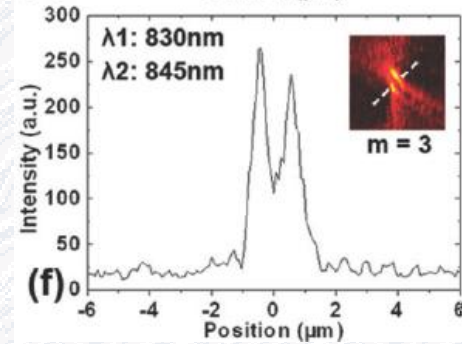
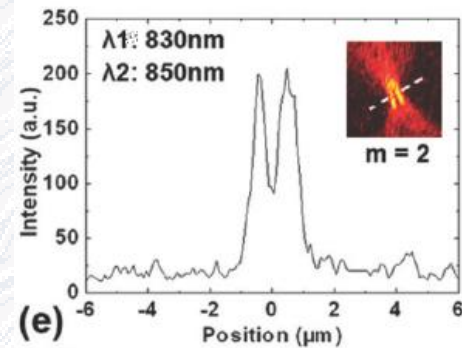
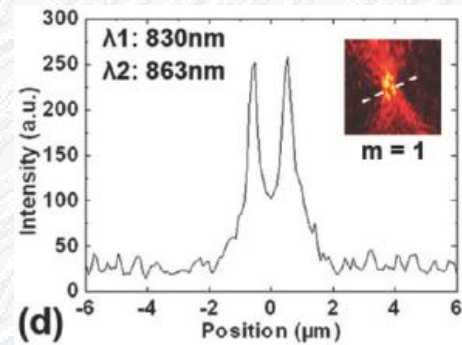
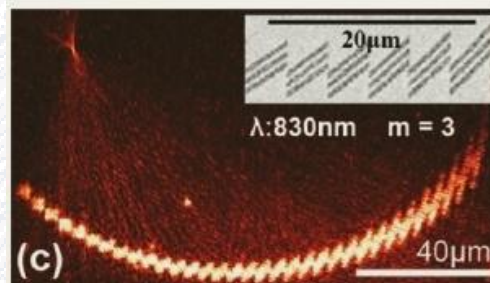
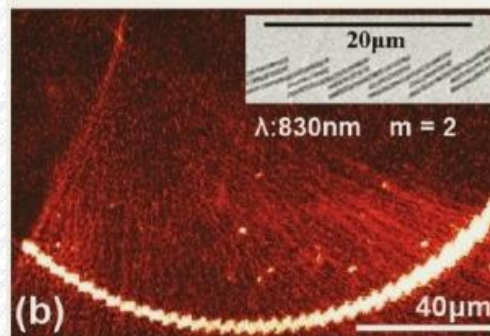
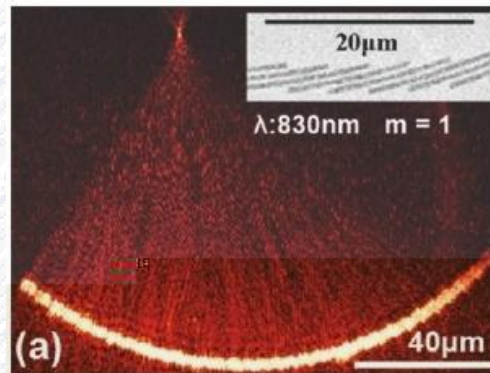


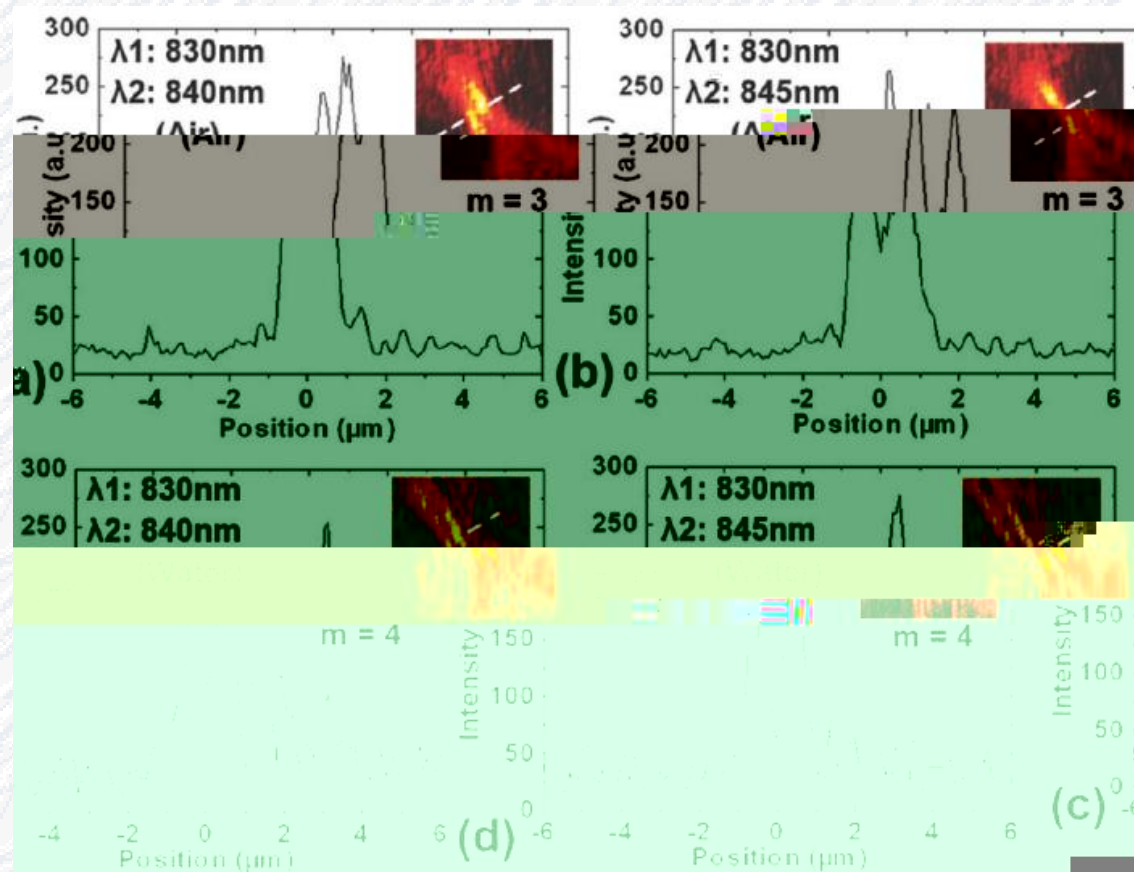
λ

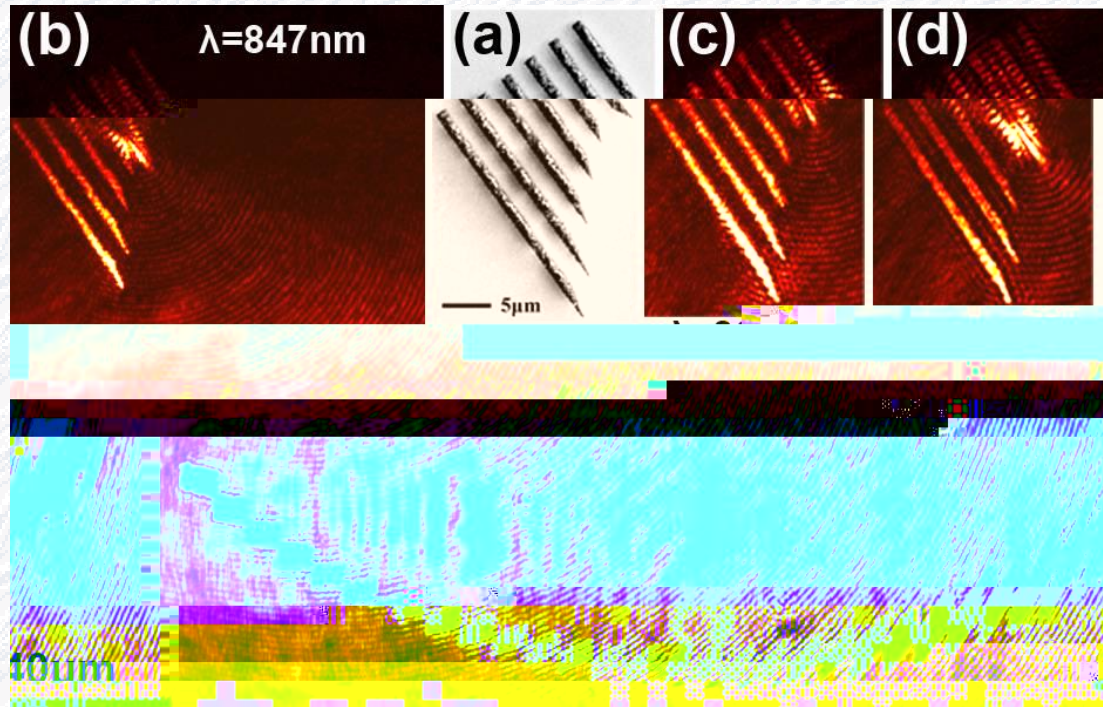
λ

Jiayuan Wang et al., **Opt. Express** 18, 6686-6692 (2010)

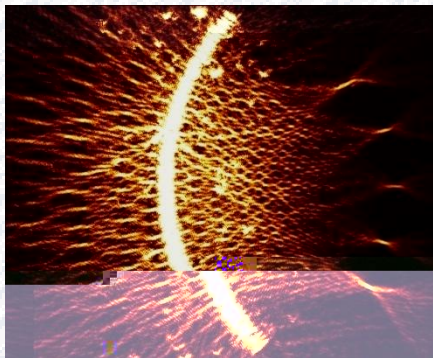




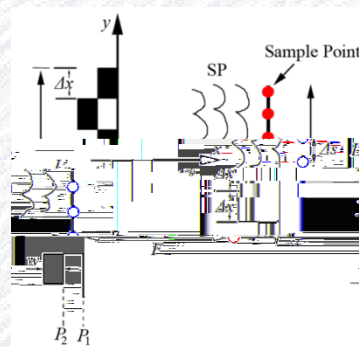




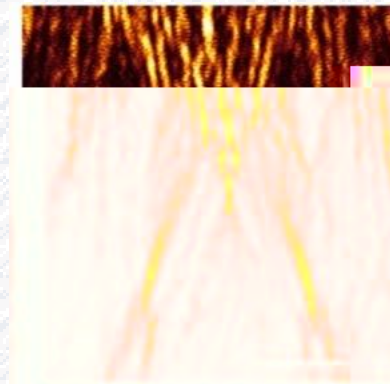
Chenglong Zhao & Jiasen Zhang, **ACS Nano**, published online.



Appl. Phys. Lett. 94, 111105(2009)

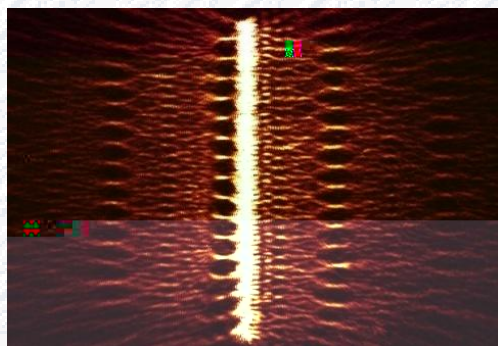


Δx
P1,P2



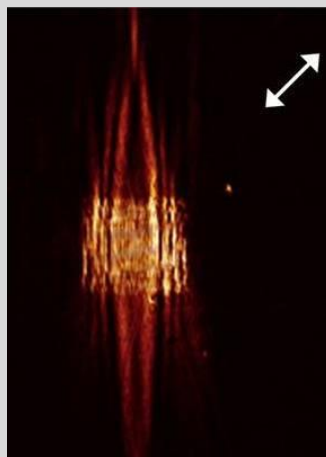
SPP

Opt. Lett. 34, 2417 (2009)

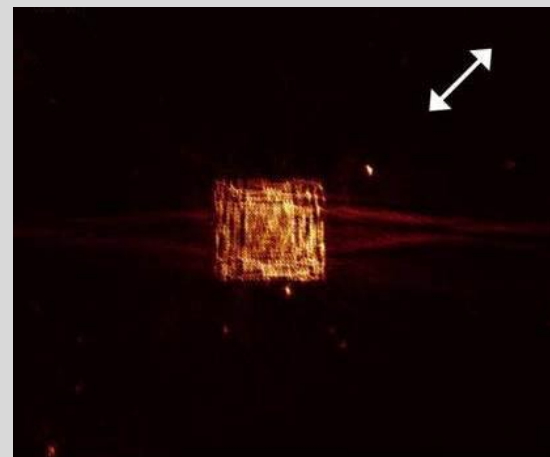


SPP

Opt. Express 17, 19757 (2009)



$\lambda_1 = 809 \text{ nm}$



$\lambda_2 = 873 \text{ nm}$







谢谢!

張家
森印