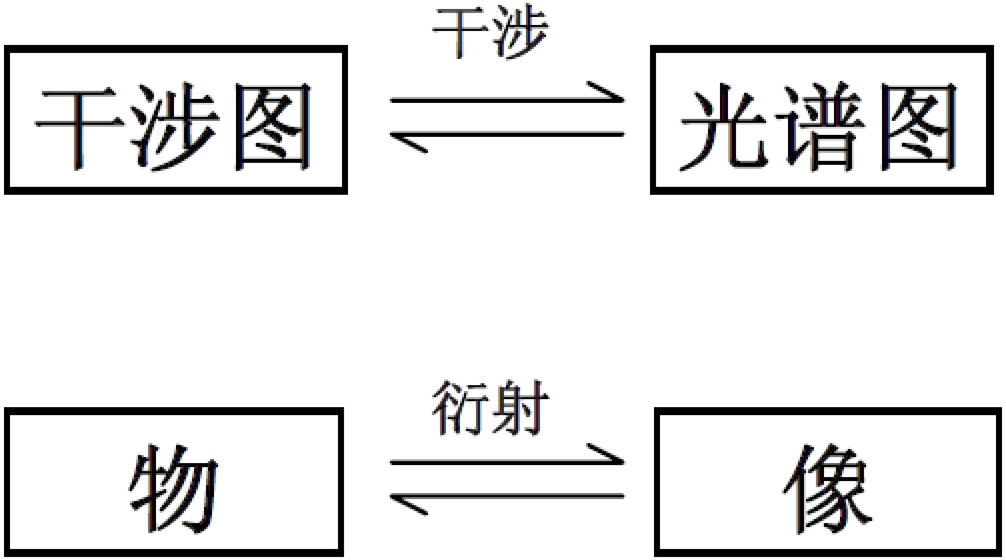
5-03 空间滤波和信息处理

用变换的观点看成像和光谱

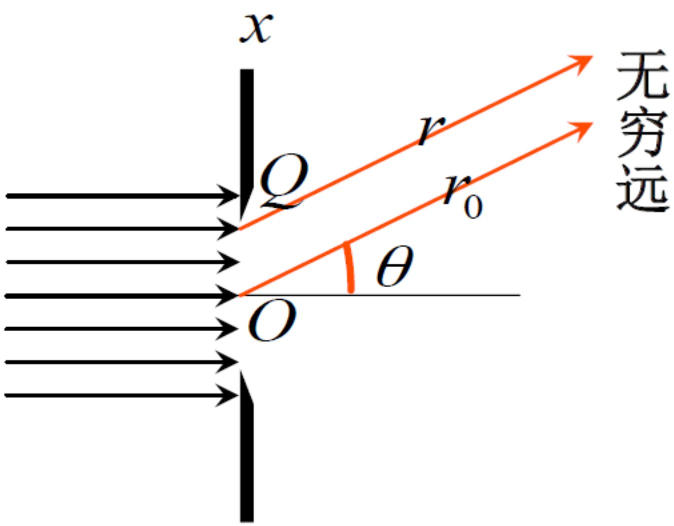


夫琅和费衍射场的标准形式

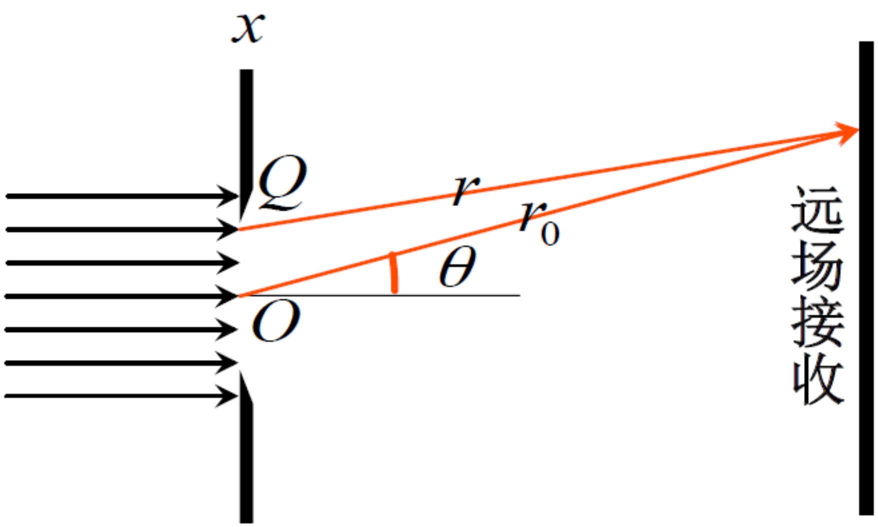
1 接受夫琅和费衍射场的装置
2 夫琅和费衍射积分的标准形式

1. 接受夫琅和费衍射场的装置

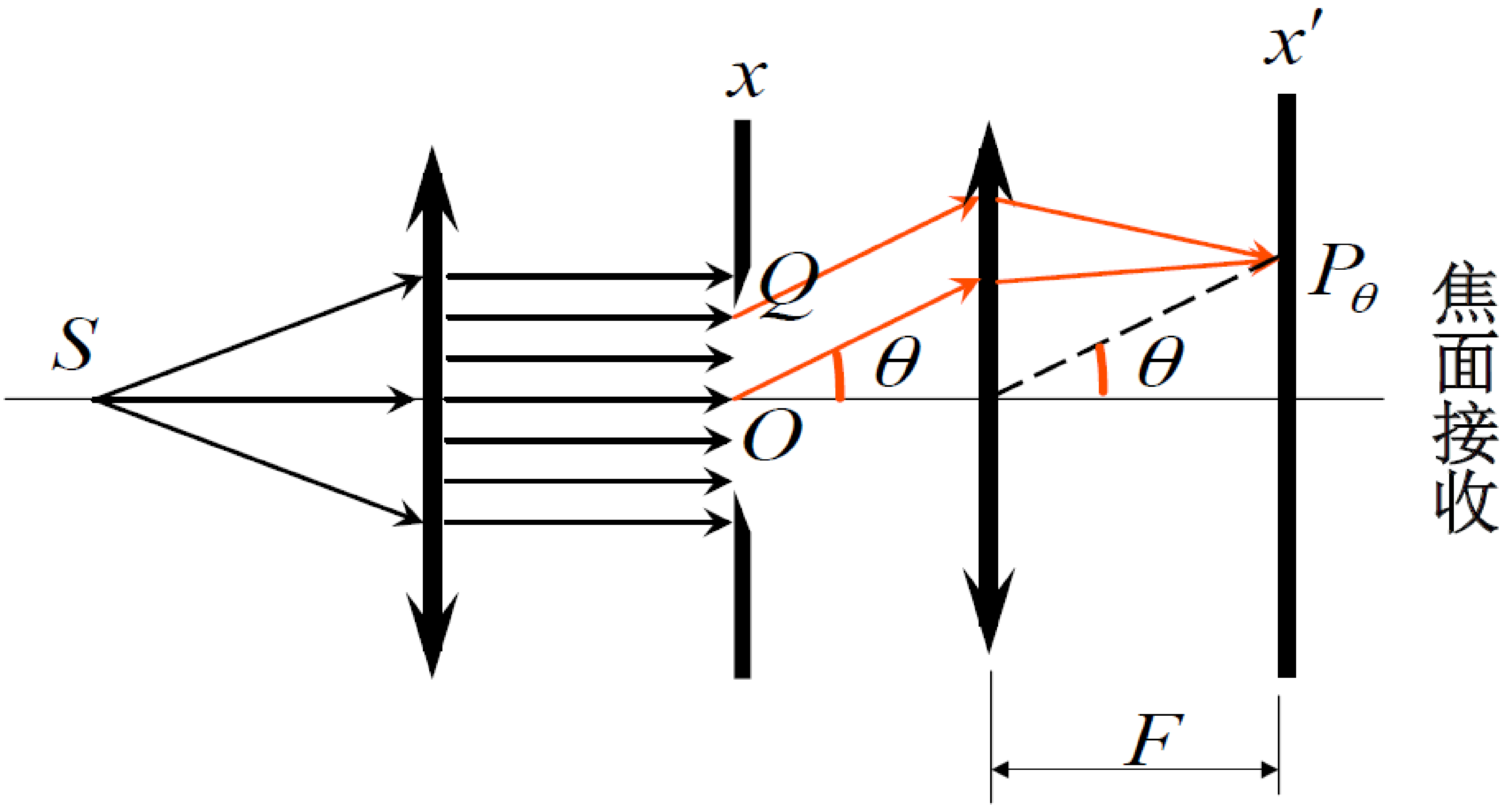
	定义装置	
远场接受	近似装置	激光、演示
焦面接受	焦面装置	
像面接受	等价装置	



定义装置

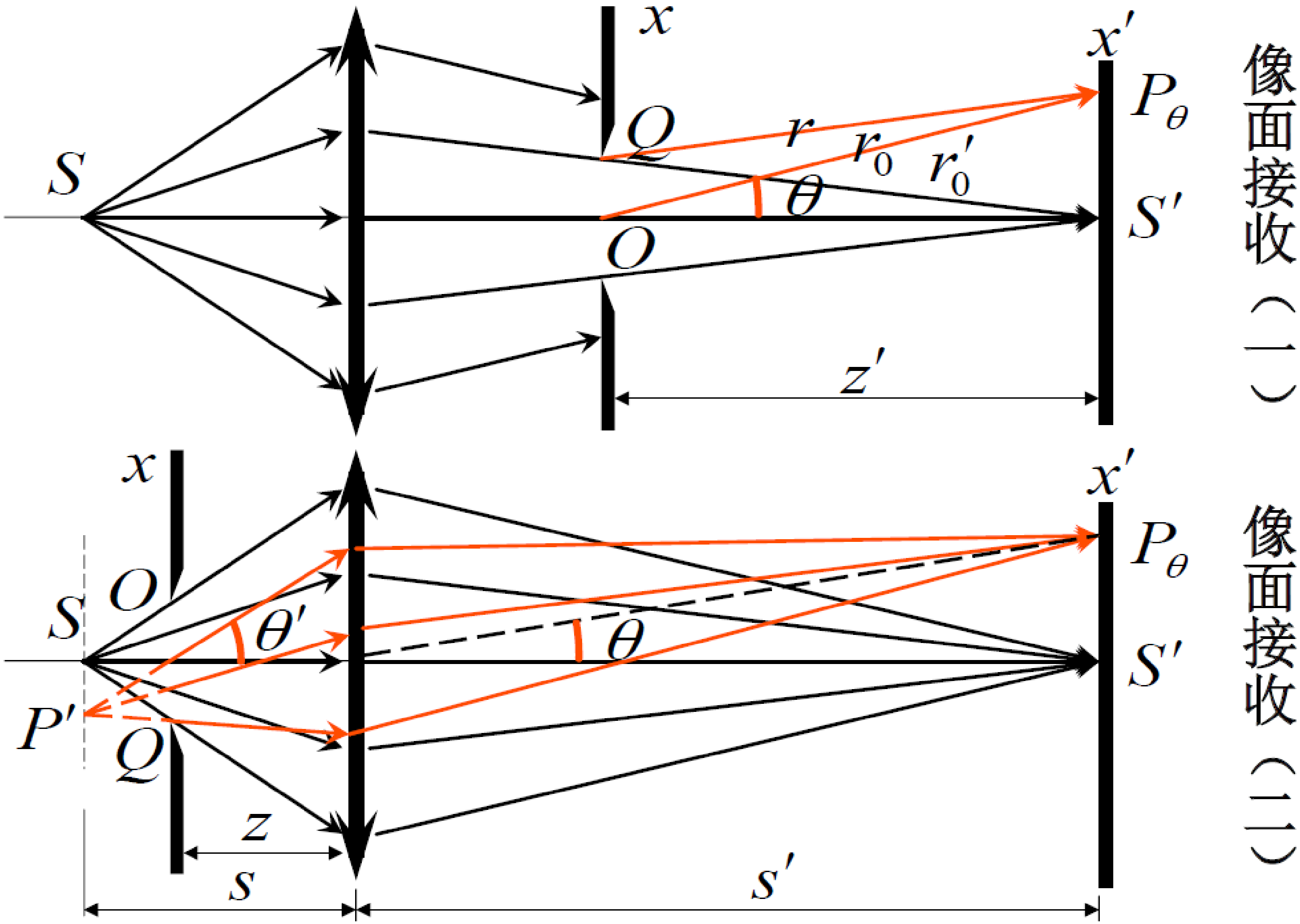


近似装置



焦面装置

等价装置



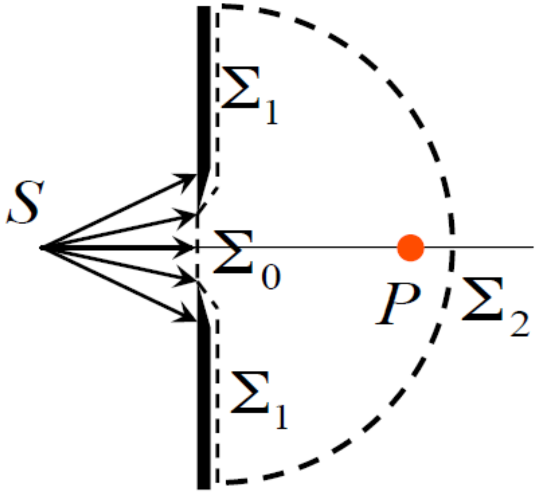
2. 夫琅和费衍射积分的标准形式

基尔霍夫边界条件：

i） Σ_0 全透

ii） Σ_1 全遮蔽

iii） Σ_2 积分为0



$$\widetilde{U}(x', y') = -\frac{i}{2\lambda}\iint_{\Sigma_0}(\cos\theta_0 + \cos\theta)\widetilde{U}_2(x, y)\frac{e^{ikr}}{r}d\Sigma$$

其中：$\widetilde{U}_2(x, y) = \widetilde{U}_1(x, y)\widetilde{t}(x, y)$

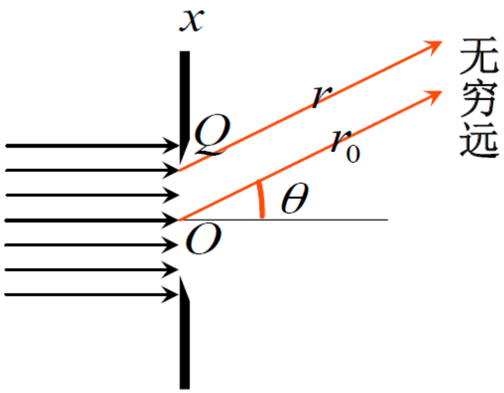
傍轴条件：$\cos\theta_0 \cong 1,\quad \cos\theta_0 \cong 1,\quad \dfrac{1}{r} \cong const.$

$$\tilde{U}(x',y') \approx C\iint \tilde{U}_2(x,y)e^{ikr}dxdy$$

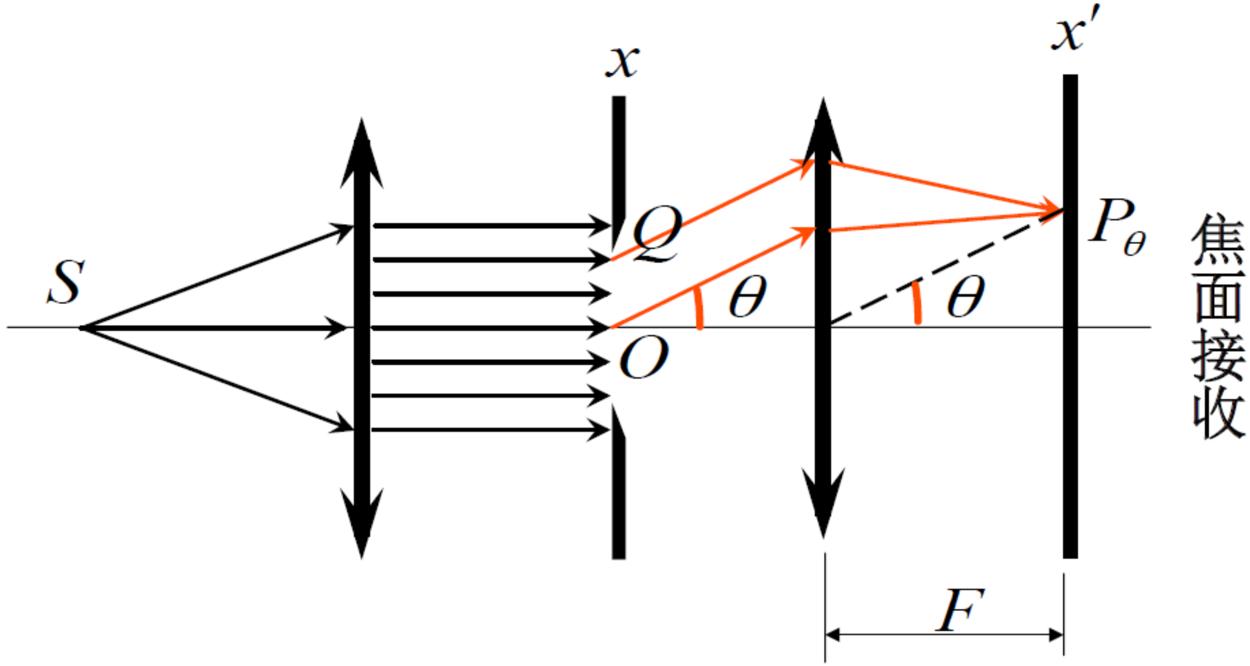
- 对定义装置： $\tilde{U}_1(x,y) = A_1$

$$\tilde{U}(\theta_1,\theta_2) \approx CA_1e^{ikr_0}\iint \tilde{t}(x,y)e^{-i(k\sin\theta_1 x + k\sin\theta_2 y)}dxdy$$

Fraunhofer衍射积分的标准形式



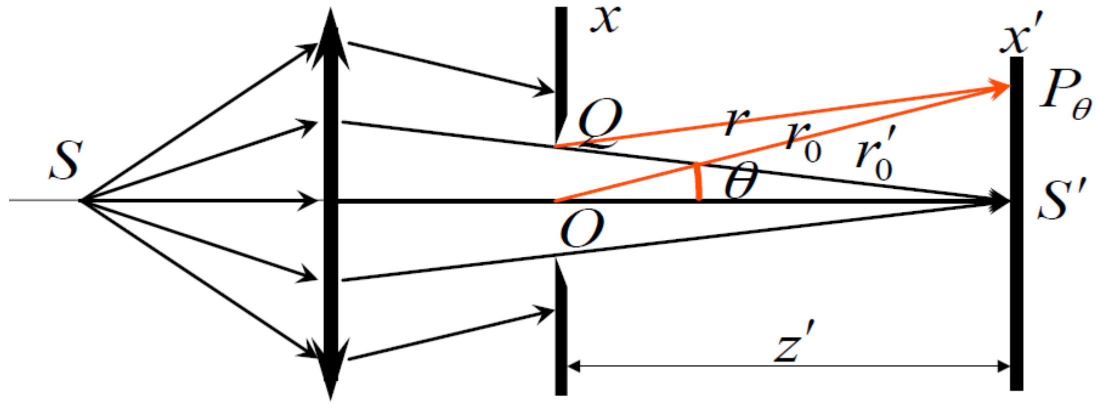
定义装置



焦面装置

- 对焦面装置：

$$\tilde{U}(x',y') \approx CA_1 e^{ikL_0} \iint \tilde{t}(x,y) e^{-ik\frac{xx'+yy'}{F}} dxdy$$



- 对等价装置：

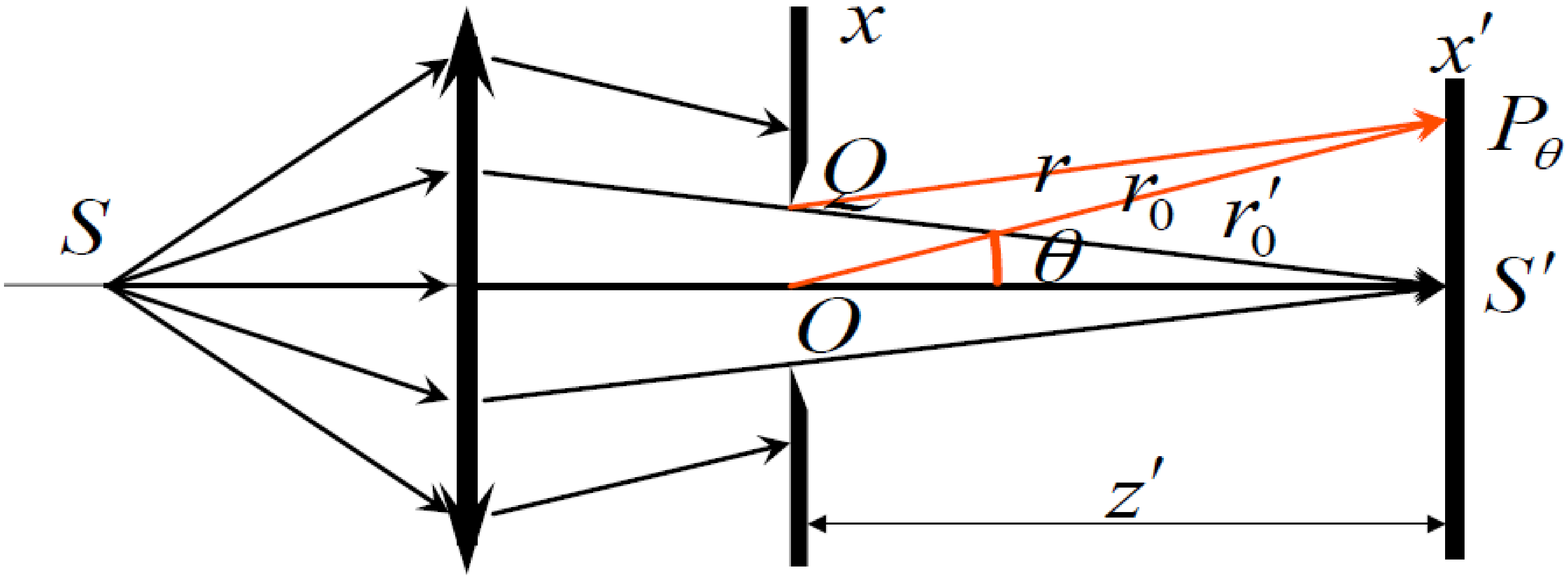
Q 到 P_θ 的光程

球面波照明：$\tilde{U}_1(x,y)=A_1 e^{i\varphi(x,y)}$

$$\tilde{U}(x',y')\approx C\iint \tilde{U}_1(x,y)\tilde{t}(x,y)e^{ik\left(r_0'+\frac{x'^2+y'^2}{2z'}-\frac{xx'+yy'}{z'}\right)}dxdy$$

$$=CA_1e^{ik\frac{x'^2+y'^2}{2z'}}\iint \tilde{t}(x,y)e^{i\varphi(x,y)+ikr_0'-ik\frac{xx'+yy'}{z'}}dxdy$$

其中： $\varphi(x,y)=k(SQ)$， $r_0'=(QS')$



利用物象等光程性：

$$\varphi(x,y)+kr_0'=k\left[(SQ)+(QS')\right]=k(SQS')=kL_0$$

$$\tilde{U}(x',y') \approx CA_1 e^{ikL_0} e^{ik\frac{x'^2+y'^2}{2z'}} \iint \tilde{t}(x,y) e^{-ik\frac{xx'+yy'}{z'}} dxdy$$

符合标准形式

结论：在照明光源像平面上接收到的就是屏函数的Fraunhofer衍射场，与屏插在什么位置无关
Fraunhofer衍射就是屏函数的Fourier变换

空间滤波和信息处理

1 用夫琅和费衍射实现屏函数的傅里叶变换
2 相干光学图像处理系统（4F系统）
3 空间滤波实验

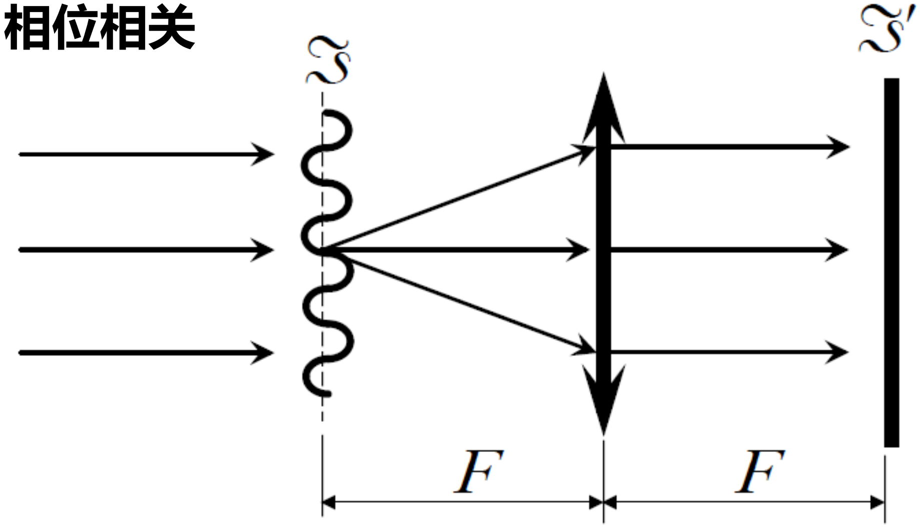
1. 用夫琅和费衍射实现屏函数的傅里叶变换

一次衍射：相位无关

$$\tilde{U}(x',y') = CA_1 e^{i\varphi(x',y')} \Im\{\tilde{t}(x,y)\}$$ → 频谱

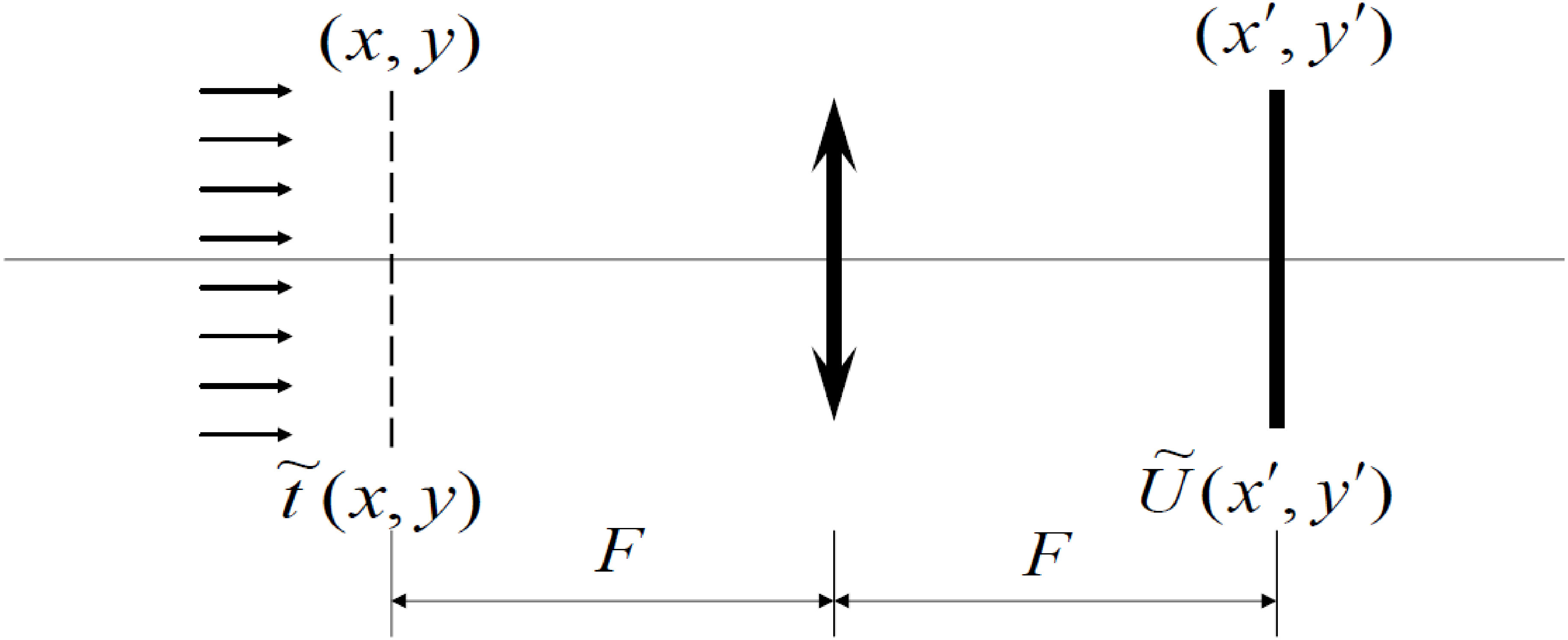
$$I(x',y') = C^2 A_1^2 \Im\{\tilde{t}(x,y)\}\Im^*\{\tilde{t}(x,y)\}$$ → 频谱强度

二次衍射：相位相关



等光程光路：$\phi(x',y') = kL_0(x',y') = const.$

二次衍射(成像)时，不附加场点位置相移



$$\tilde{U}(x', y') = \Im\{\tilde{t}(x, y)\}$$

$$(f_x, f_y) = \frac{k}{2\pi F}(x', y') = \frac{1}{\lambda F}(x', y')$$

1、$\delta(x)\delta(y)$

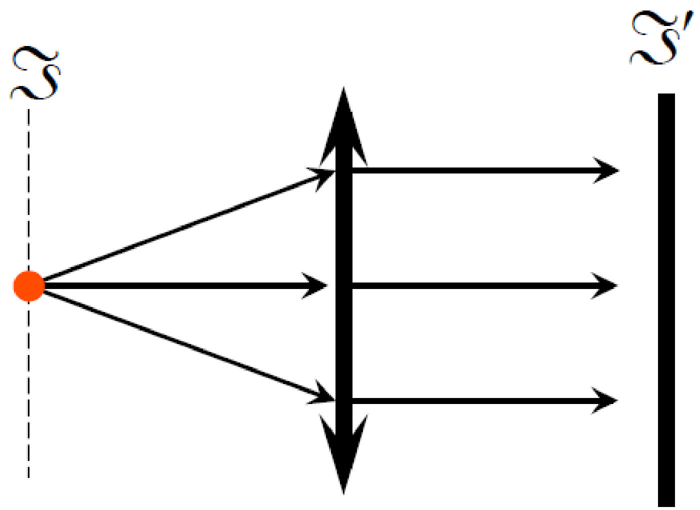
2、$\delta(x+x_0)\delta(y+y_0)$

3、$\delta(x+d/2)\delta y+\delta(x-d/2)\delta y$

的频谱和频谱强度

1、$\tilde{U}(x', y') = \Im\{\delta(x)\delta(y)\} \propto 1$

$I(x', y') \propto 1$



1、 $\delta(x)\delta(y)$

2、 $\delta(x+x_0)\delta(y+y_0)$

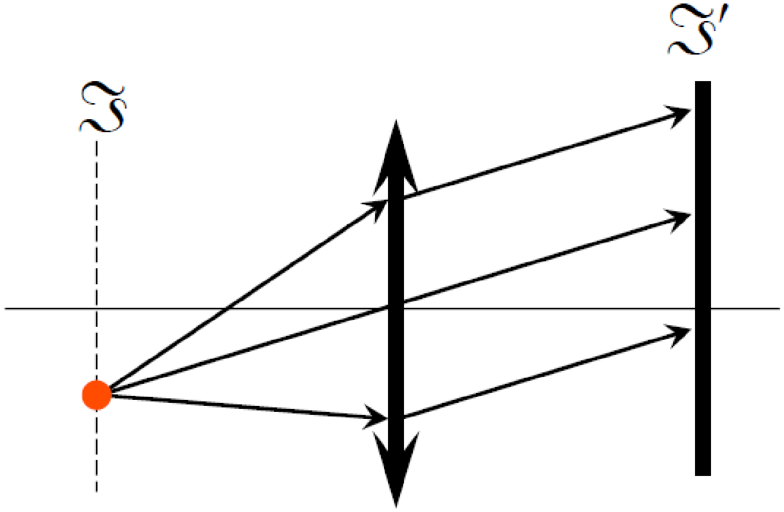
3、 $\delta(x+d/2)\delta y+\delta(x-d/2)\delta y$

的频谱和频谱强度

2、 $\tilde{U}(x',y') = \Im\{\delta(x+x_0)\delta(y+x_0)\}$

$$\propto e^{i2\pi(f_x x_0 + f_y y_0)}$$

$$I(x',y') \propto 1$$



1、$\delta(x)\delta(y)$

2、$\delta(x+x_0)\delta(y+y_0)$

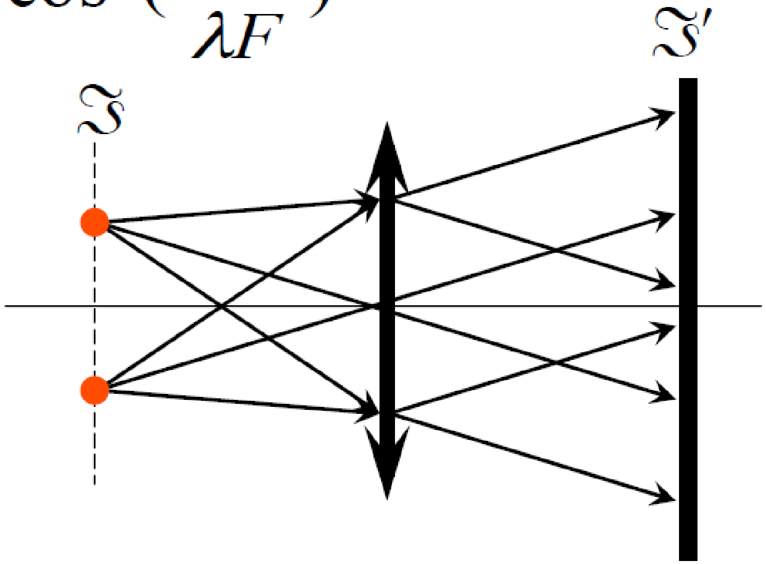
3、$\delta(x+d/2)\delta y+\delta(x-d/2)\delta y$

的频谱和频谱强度

3、$\widetilde{U}(x',y') = \Im\left\{\delta(x+\frac{d}{2})\delta y + \delta(x-\frac{d}{2})\delta y\right\}$

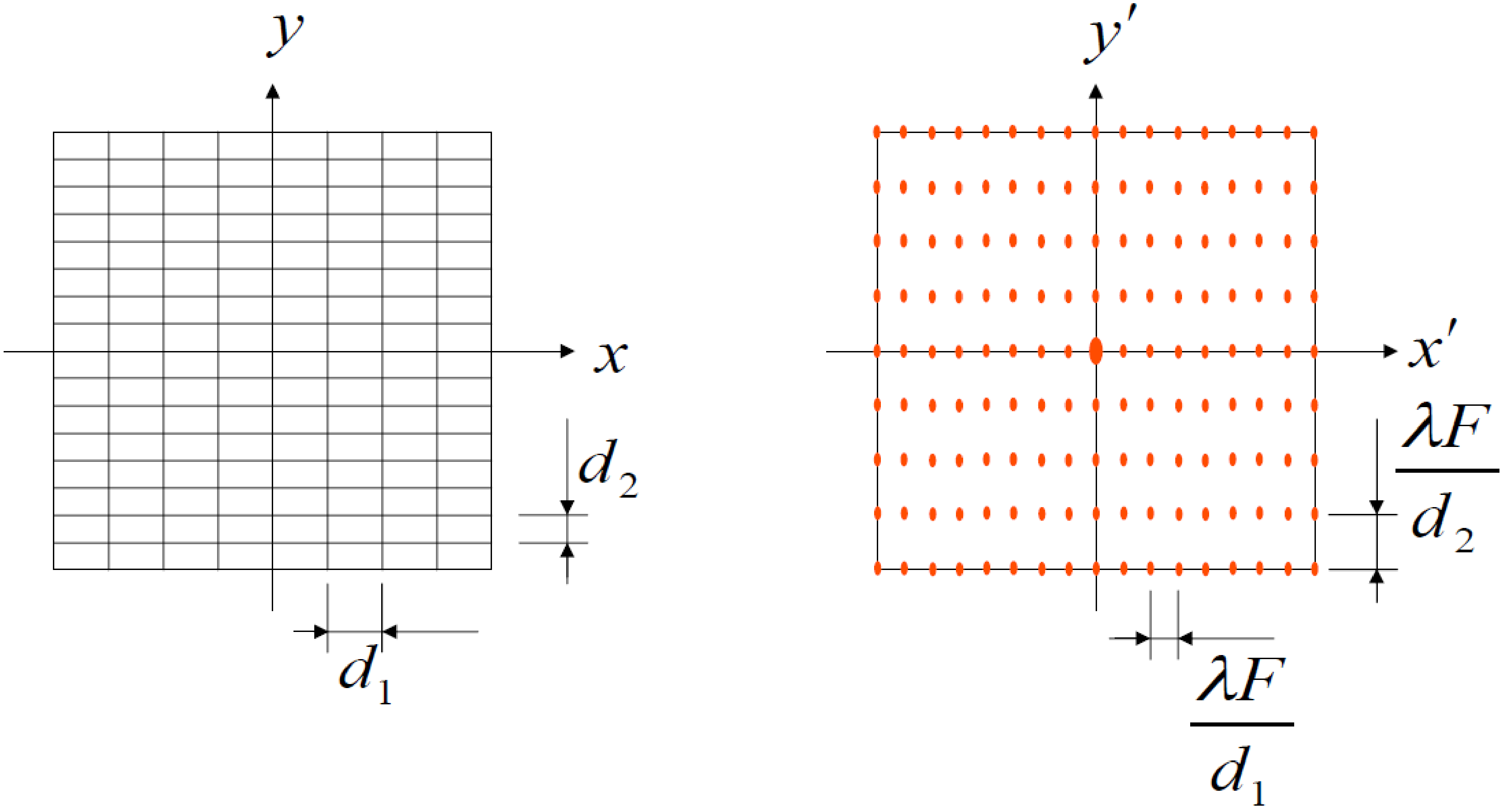
$$\propto e^{i\pi f_x d} + e^{-i\pi f_x d} = \cos(\pi f_x d) = \cos(\frac{\pi d x'}{\lambda F})$$

$$I(x',y') \propto \cos^2(\frac{\pi d x'}{\lambda F})$$

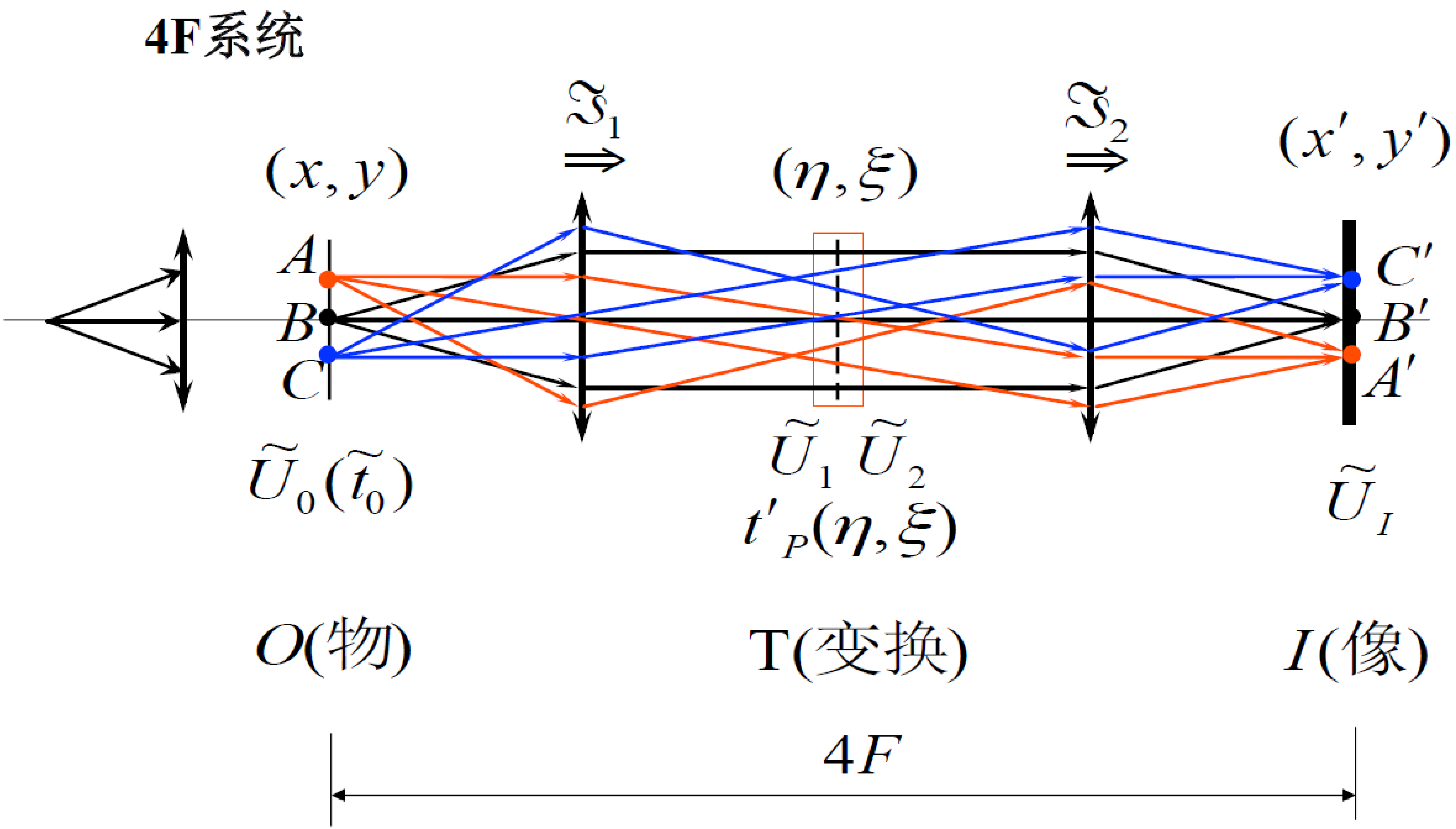


正弦光栅

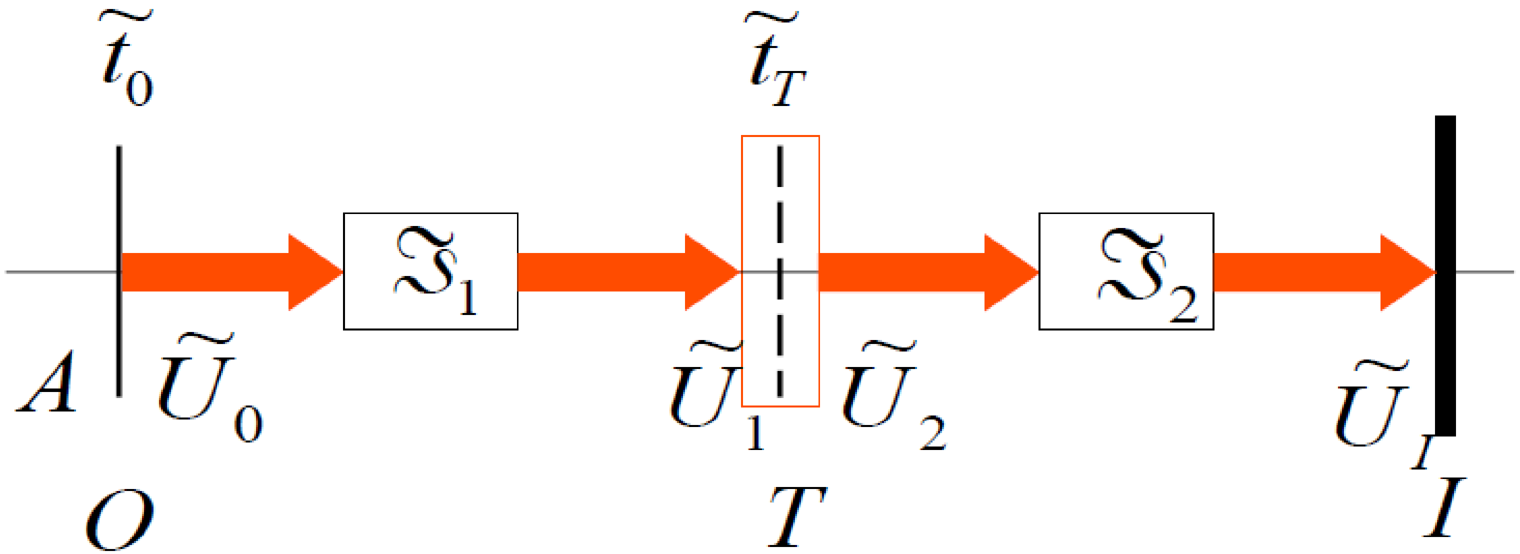
正交网格的频谱



2. 相干光学图像处理系统（4F系统）



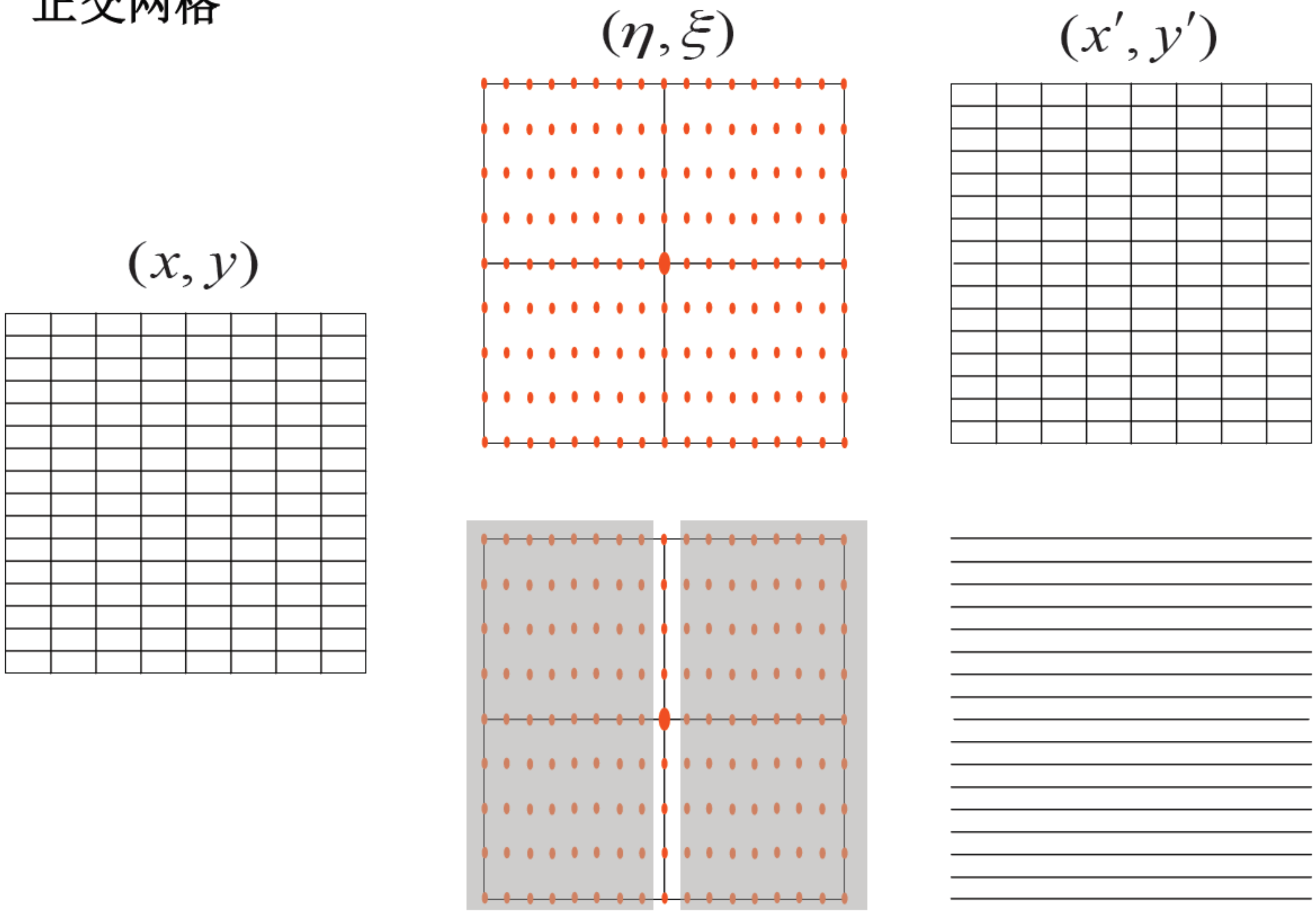
4F系统



$\tilde{t}_0$
$\tilde{t}_T$
$\Im_1$
$\Im_2$
A
$\tilde{U}_0$
$\tilde{U}_1$
$\tilde{U}_2$
$\tilde{U}_I$
O
T
I

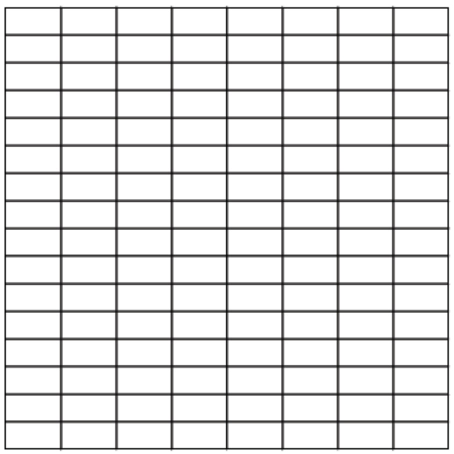
3. 空间滤波实验

正交网格

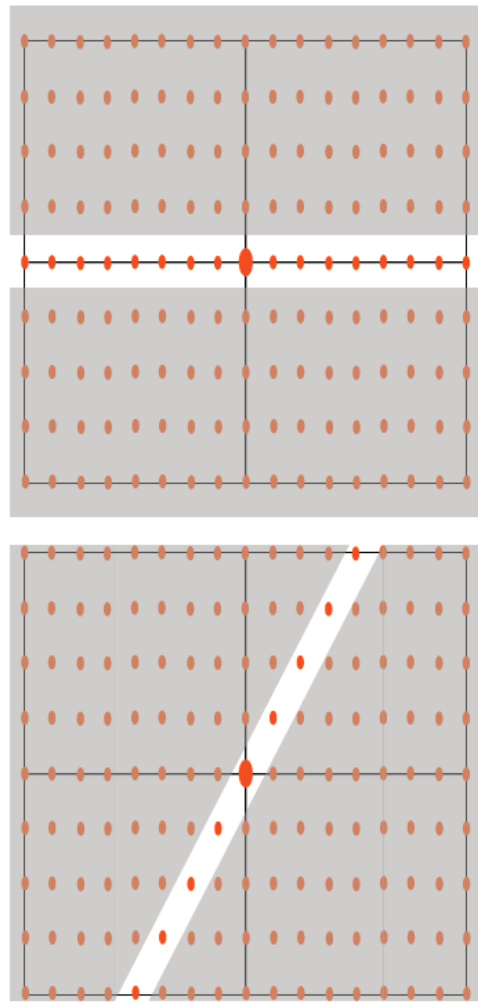


正交网格

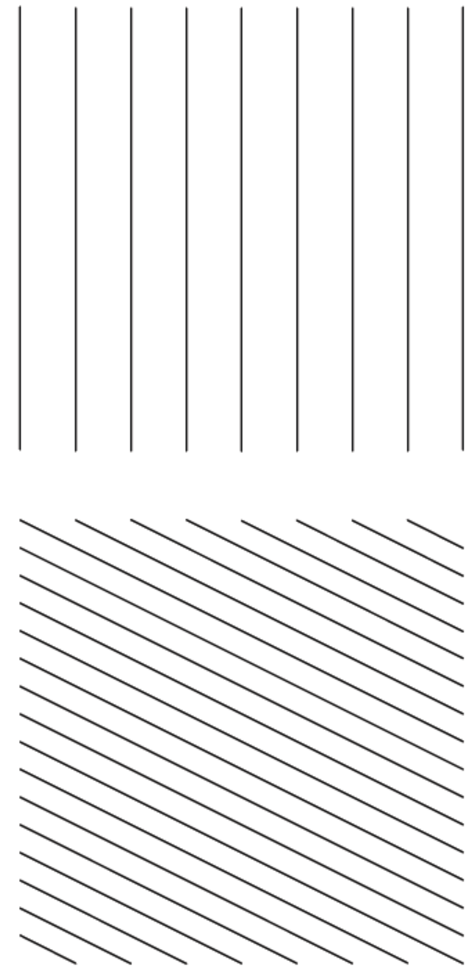
(x, y)



(η, ξ)

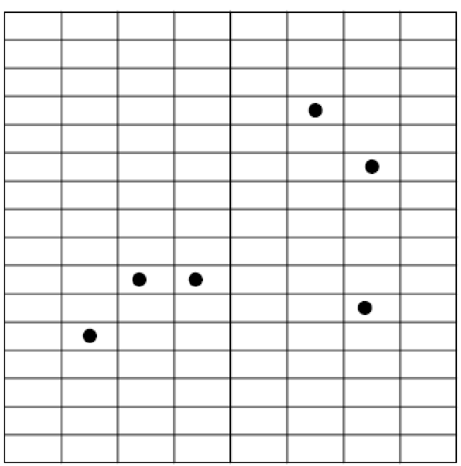


(x', y')

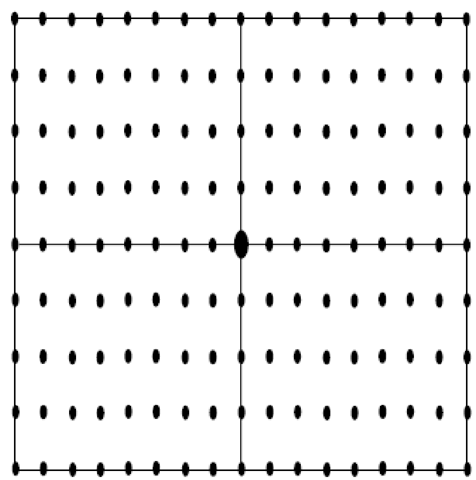


正交网格

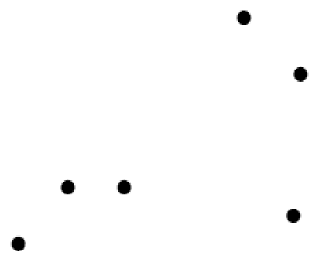
(x, y)



(η, ξ)

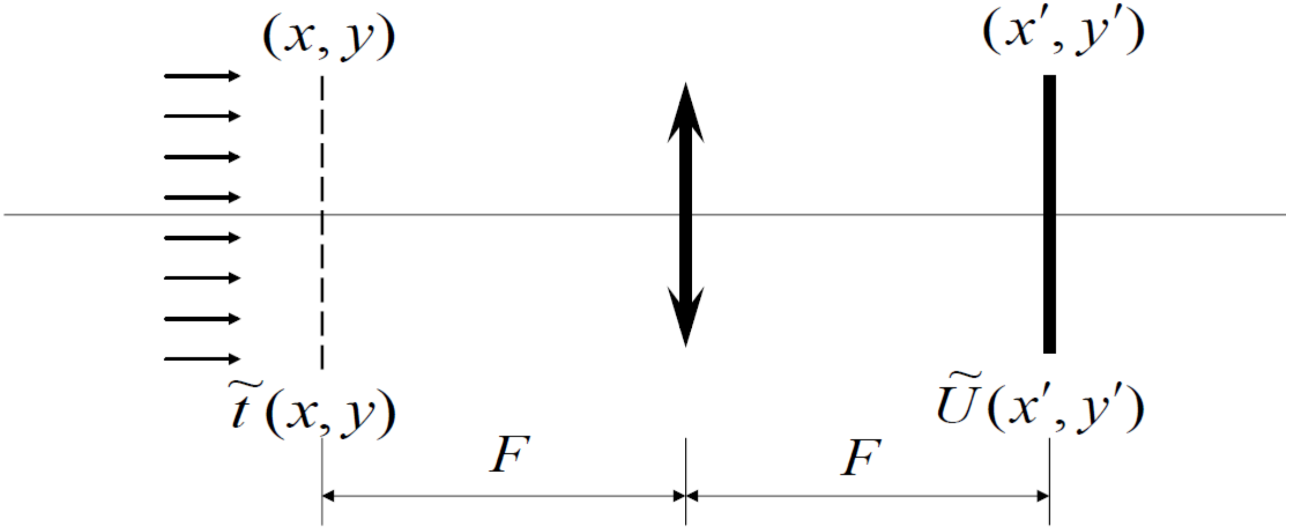


(x', y')



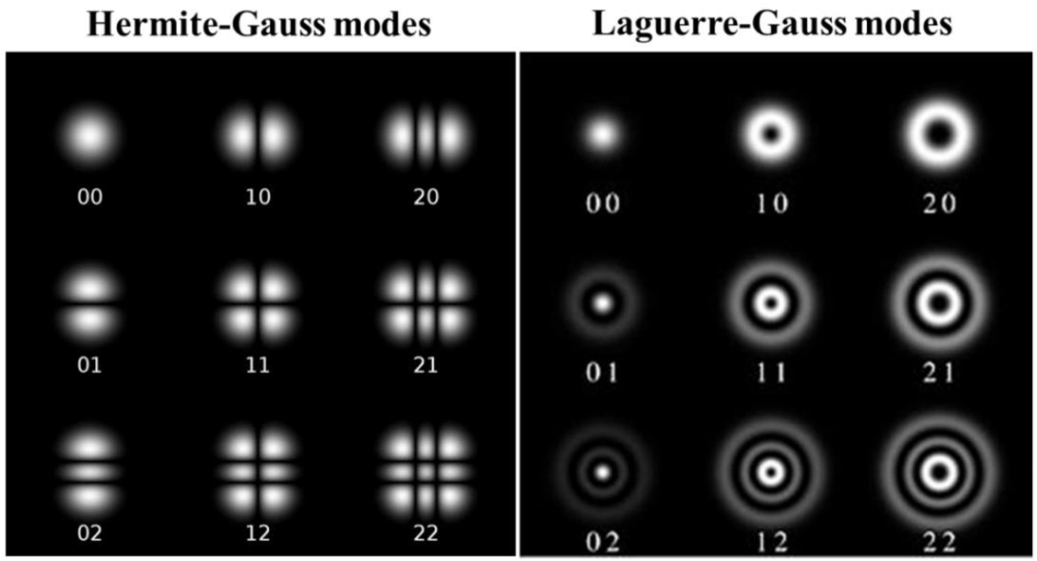
作业：P127， 1, 2

光学变换

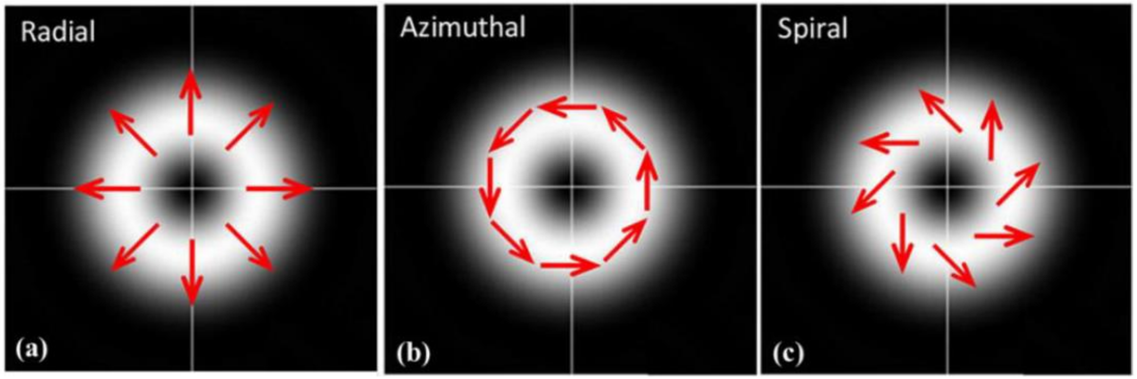


$$\tilde{U}(x', y') = \Im\left\{\tilde{t}(x, y)\right\}$$

$$(f_x, f_y) = \frac{k}{2\pi F}(x', y') = \frac{1}{\lambda F}(x', y')$$

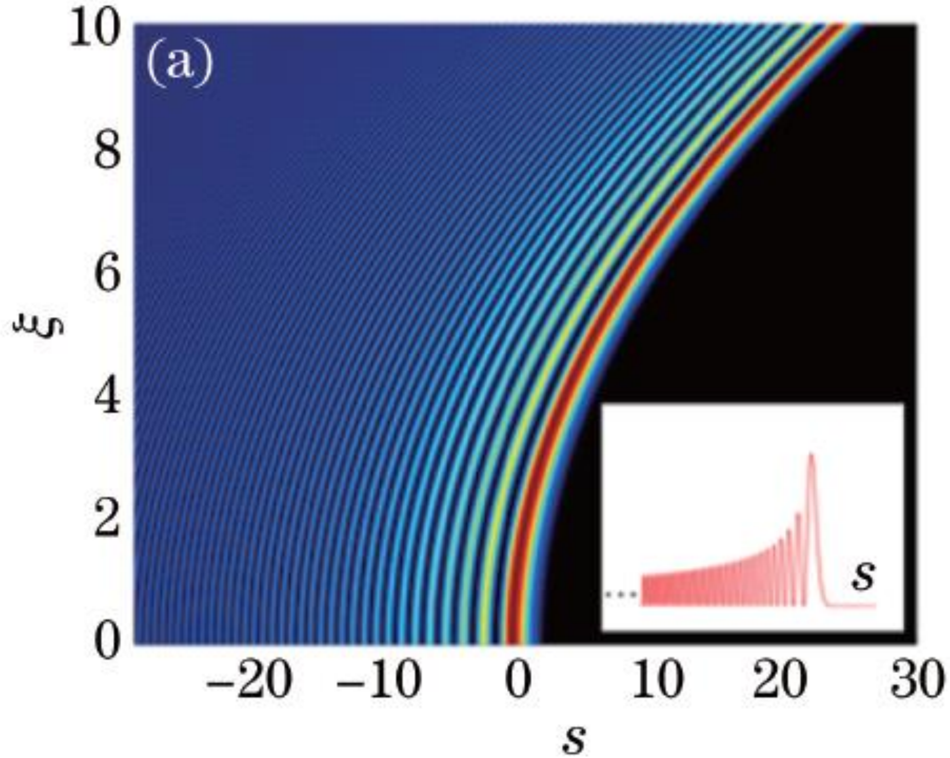


Cylindrical vector beam



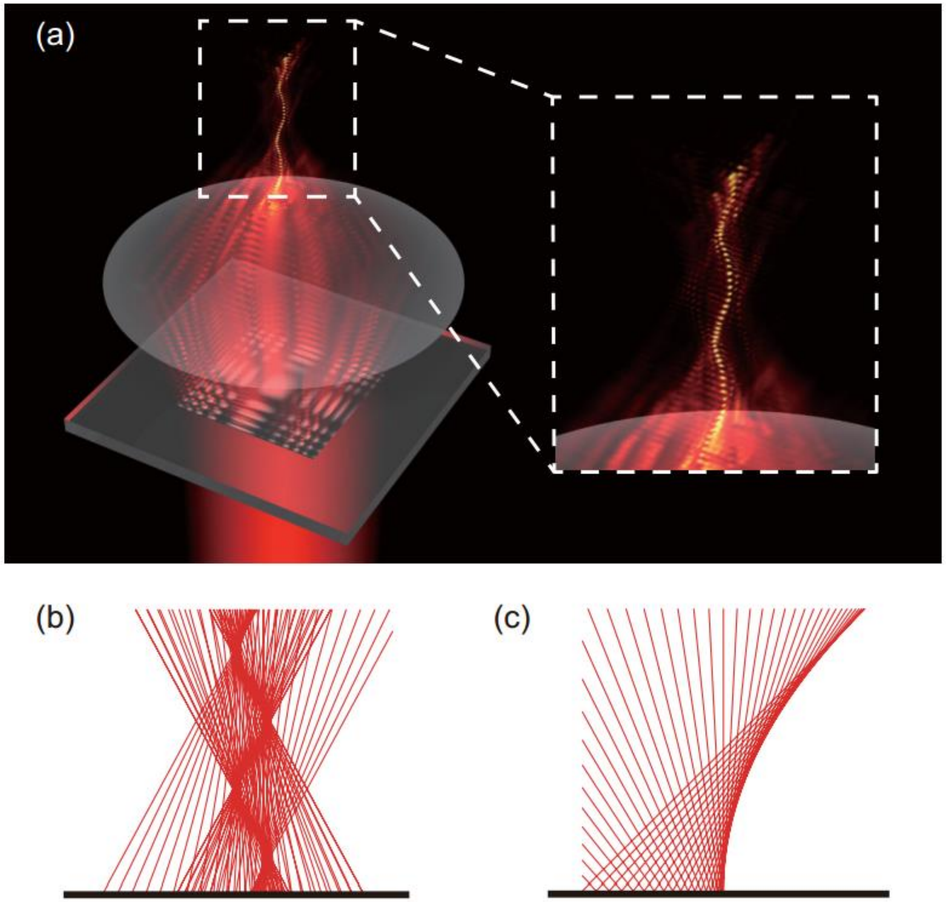
摘自于 龚雷，中国科学技术大学博士论文 （2016）。

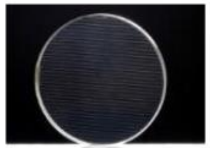
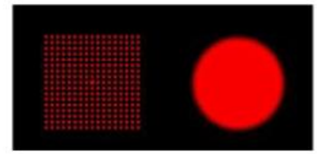
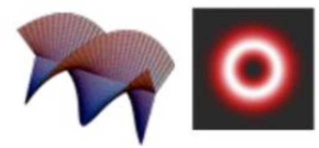
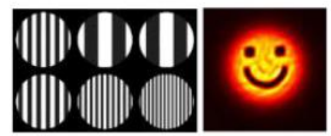
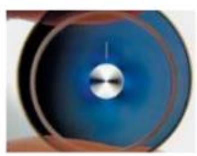
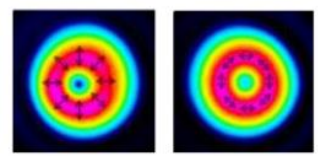
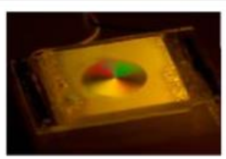
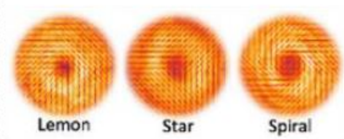
Airy beam



PHYSICAL REVIEW A **94**, 013829 (2016)

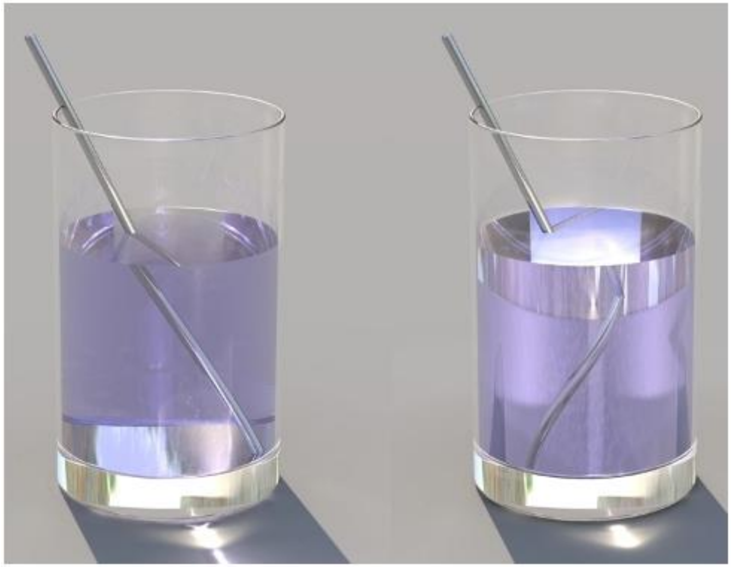
Winding light beams along elliptical helical trajectories



类型	实物	功能	案例	说明
衍射光学元件(DOE)		强度调控		二元光学器件，用于激光束整形，如均匀化、准直、聚焦、形成图案
液晶空间光调制器(LCSLM)		相位调控		可编程和动态的相位调控，在Fourier平面生成特定强度分布的光场
数字微镜器件(DMD)		振幅调控		二值化器件，直接进行光强调控，产生任意分布的图案
S-waveplate		偏振调控		调节入射光的偏振态可改变出射的偏振分布，也能产生光学涡旋
Q-plate		偏振调控		可编程的偏振调制器，能产生各种空间分布的偏振光场。

摘自于 龚雷，中国科学技术大学博士论文 （2016）。

傅里叶变换：调节n（实部对应相位变化，虚部对应振幅增减）
如果能调节ε 和 μ，？？？？
→ meta-material, …



PRL 102, 253902 (2009) PHYSICAL REVIEW LETTERS week ending 26 JUNE 2009

Illusion Optics: The Optical Transformation of an Object into Another Object

Yun Lai, Jack Ng, HuanYang Chen, DeZhuan Han, JunJun Xiao, Zhao-Qing Zhang,* and C. T. Chan†

眼见为实？