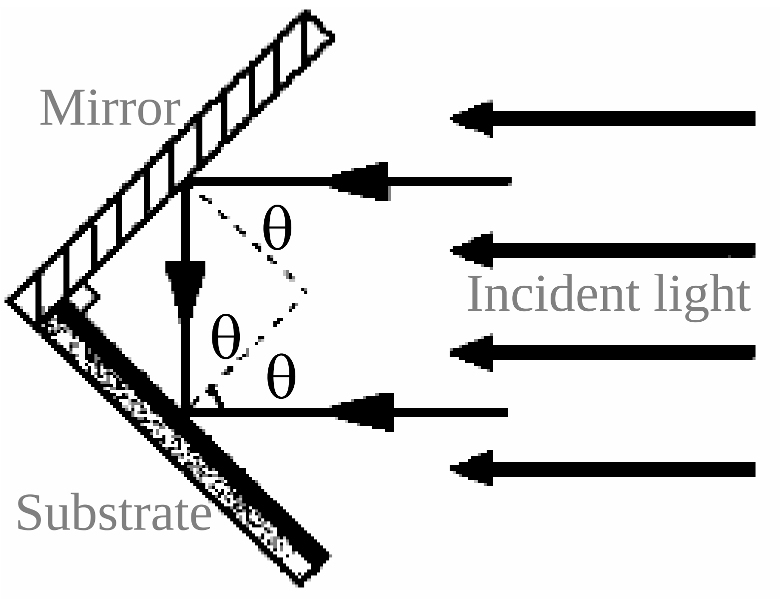
Laser Interference lithography

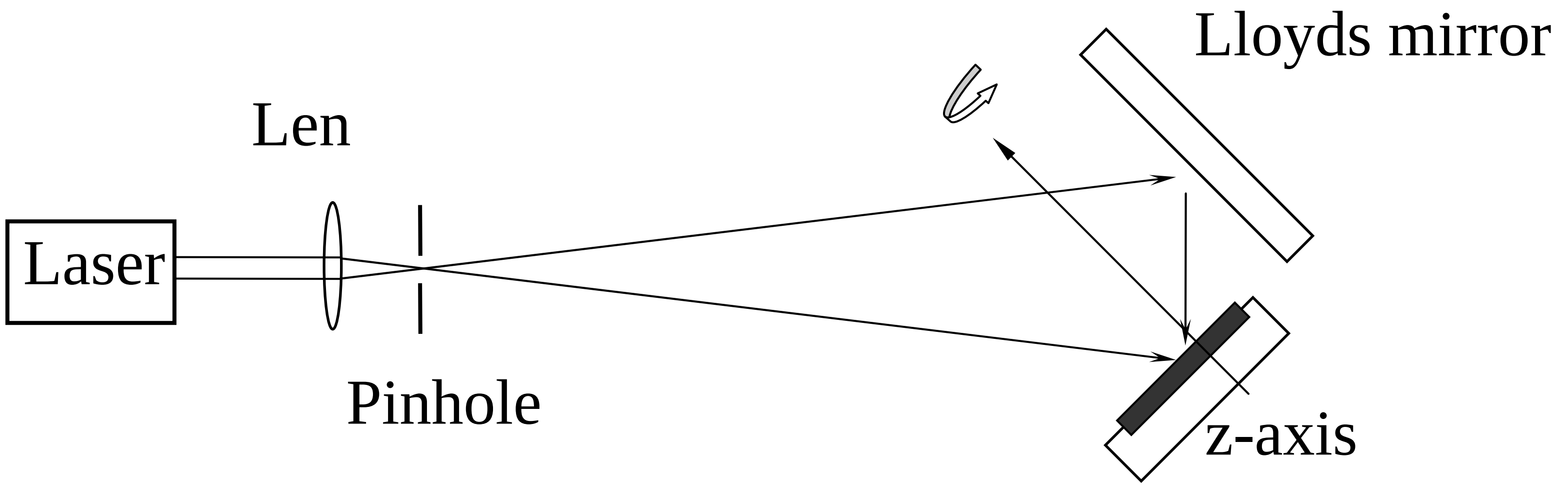
Laser interference lithography: Principle



$$d = \lambda / (2 \sin \theta)$$

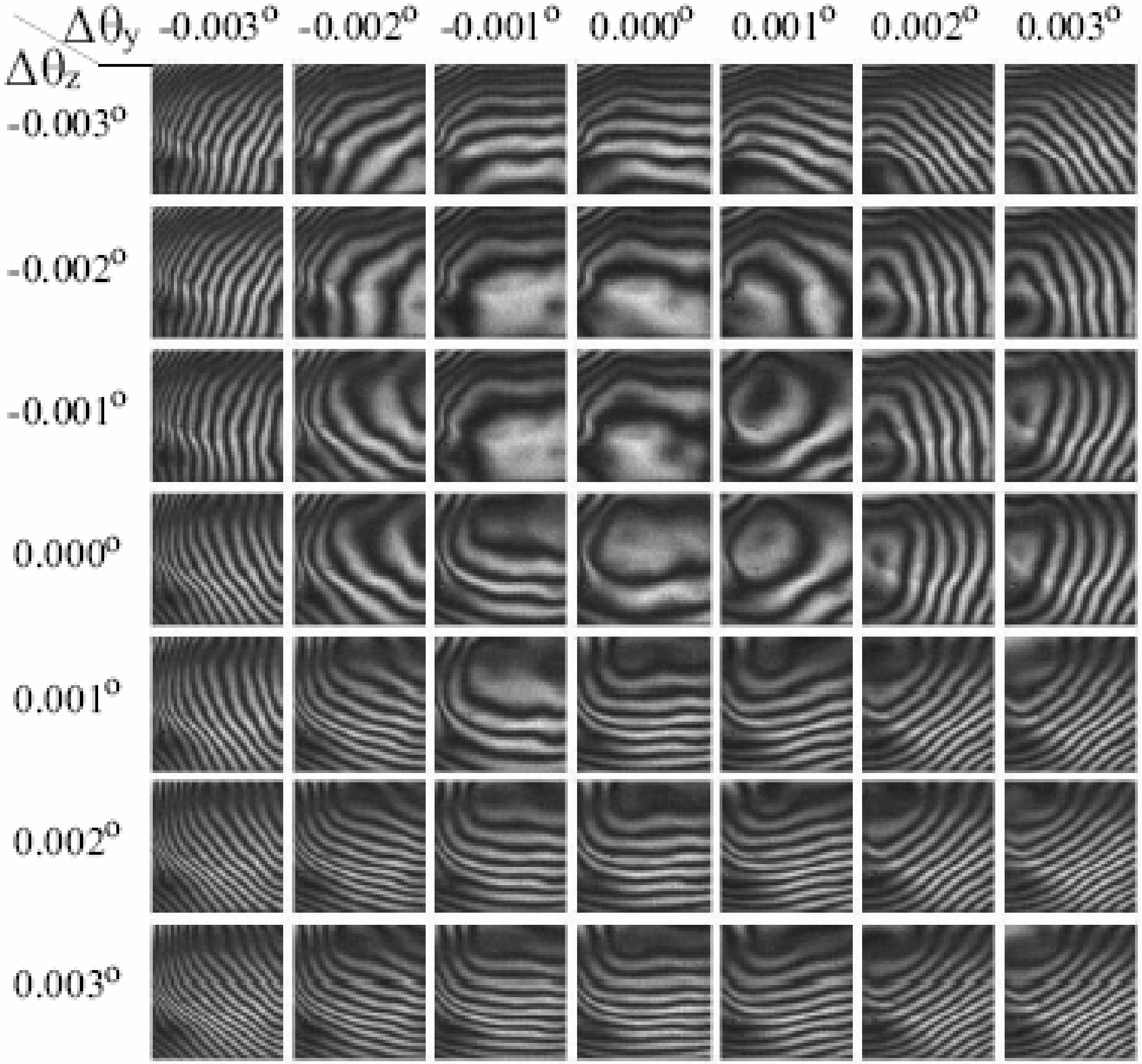
$$I(x) = 2I_0[1 + \cos(2kx \sin \theta)]$$

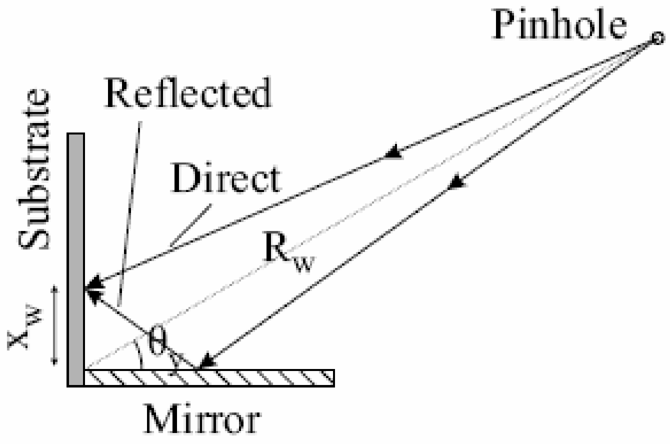
$$I(x, y) = 2I_0[2 + \cos(2kx \sin \theta) + \cos(2ky \sin \theta)]$$



Lloyds Mirror dual-beam interference system

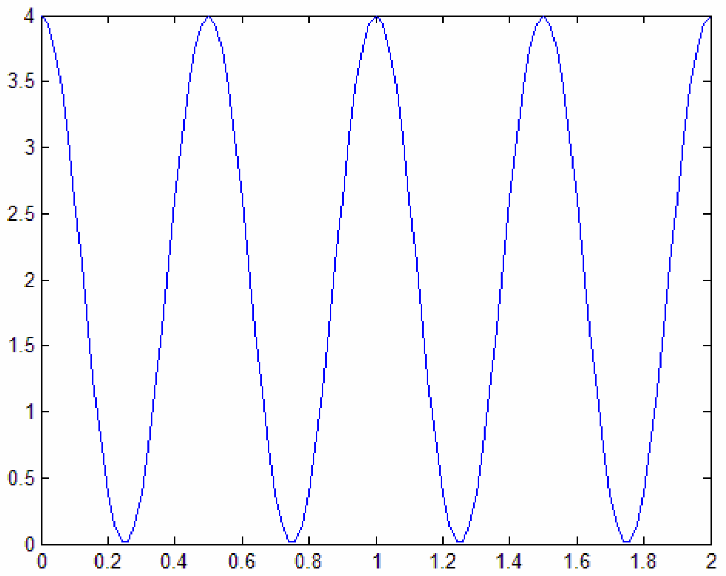
$$W_x = \frac{\lambda}{2\Delta\theta_y \cos\theta_y} \qquad W_y = \frac{\lambda}{2\Delta\theta_z \sin\theta_y}$$



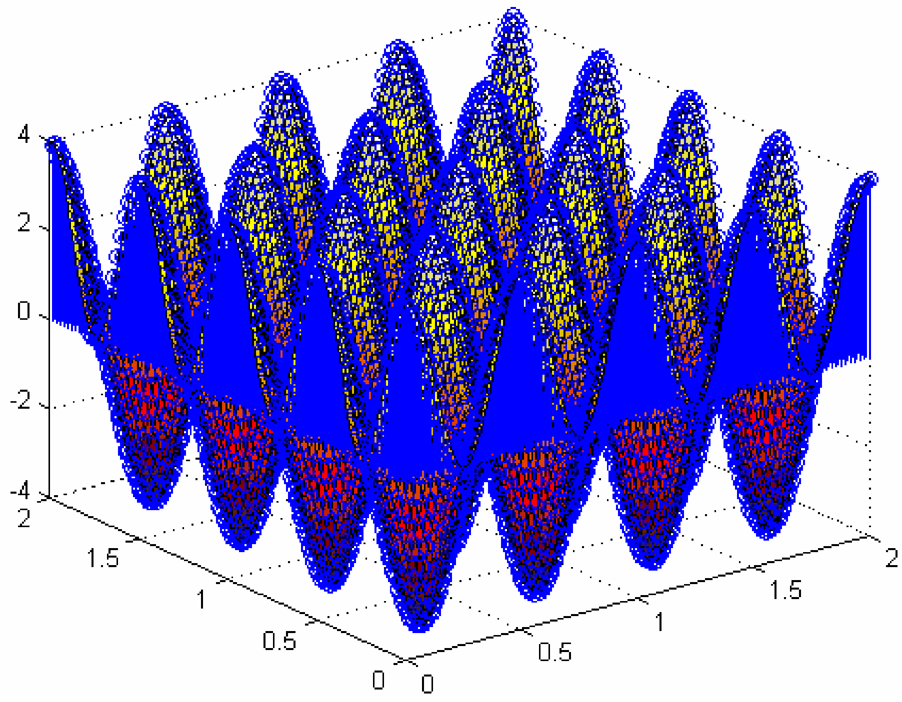


Lloyds interferometer

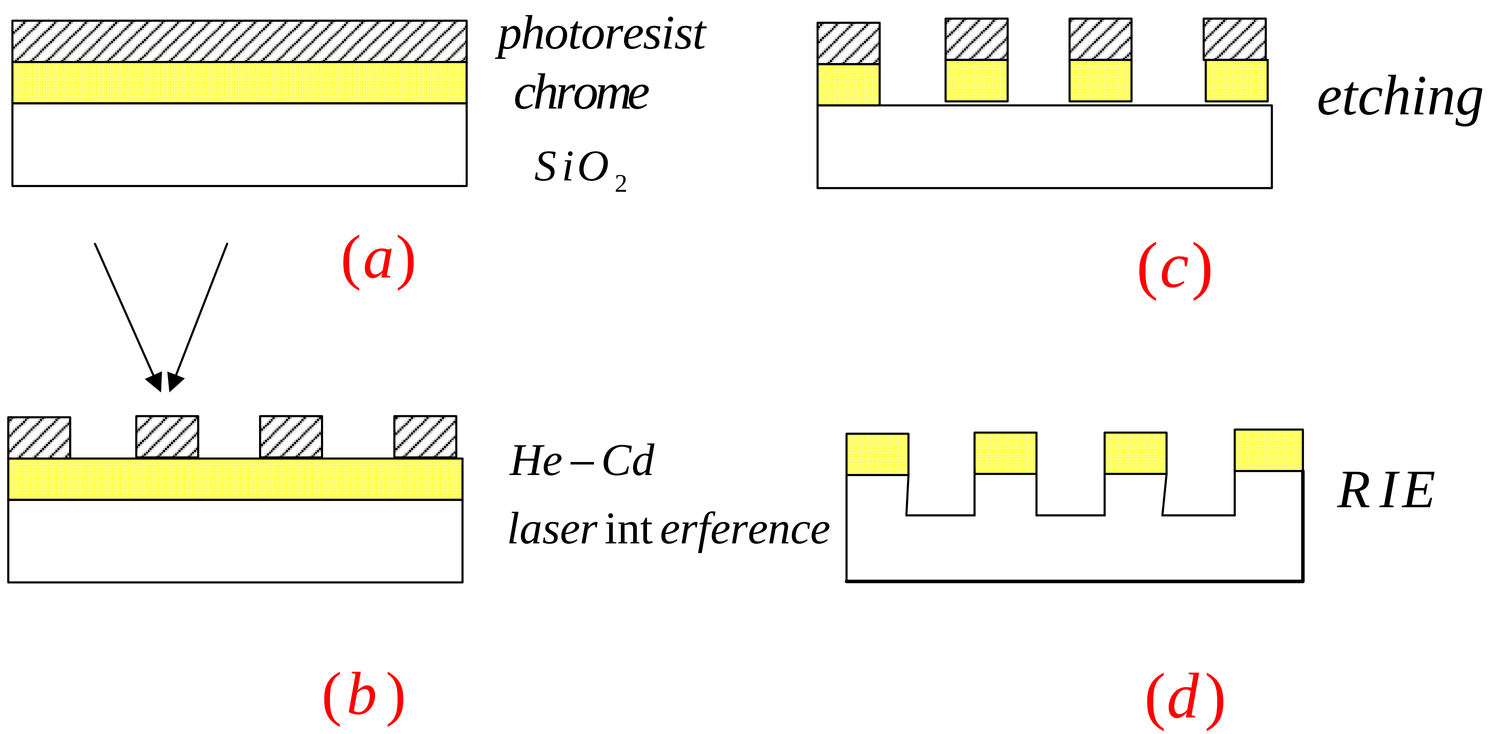
Patterns generated by dual-beam interference system



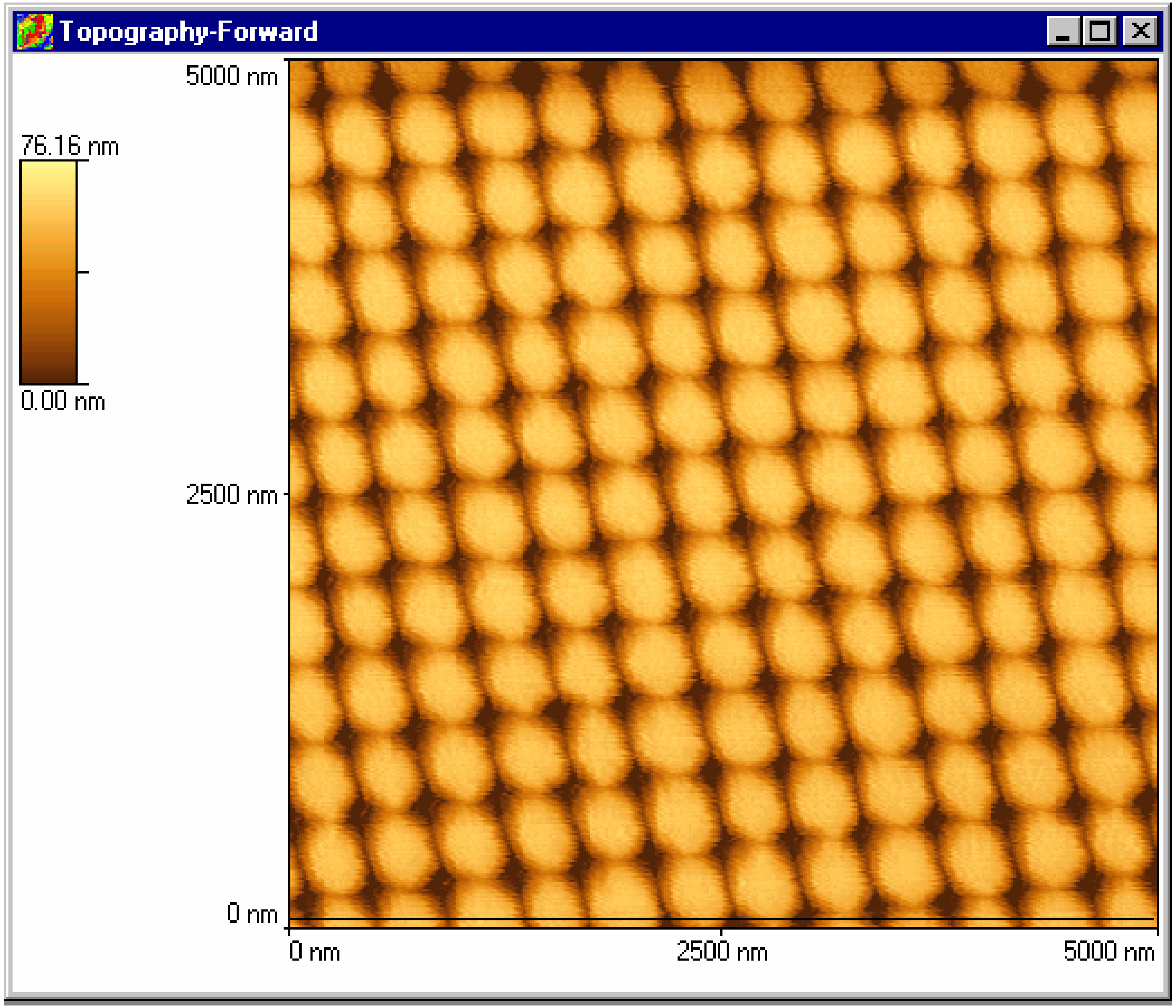
Simulated 2D profile



Simulated dots pattern



Experimental flow chart



主要实验参数：

Ar-P3170为100nm

He-Cd laser

λ=441.6nm

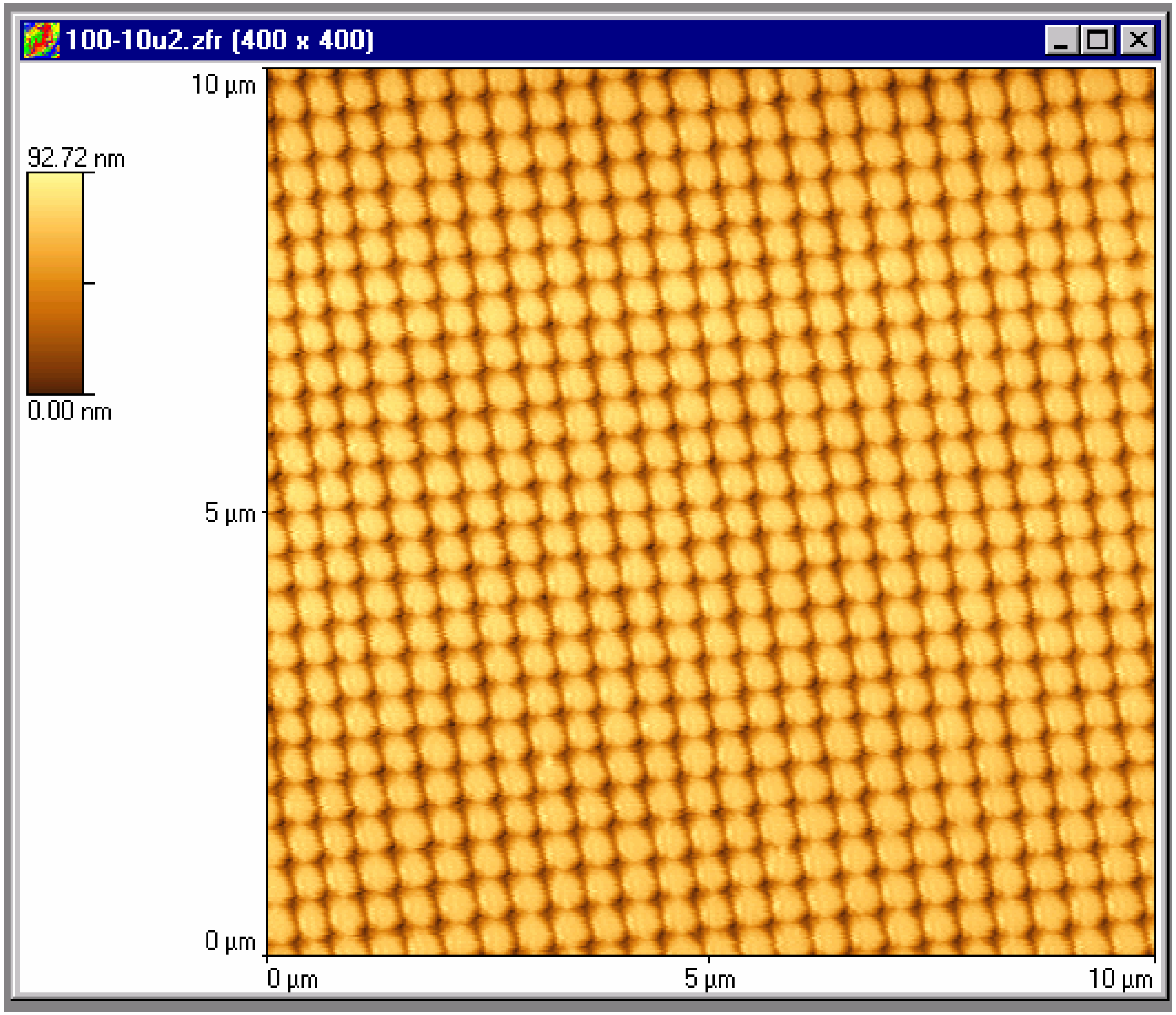
Exposure flux：

1.5mw/cm^2

Exposure time：

10s

Measured dots pattern generated by the dual-beam system



主要实验参数：

Ar-P3170为100nm

He-Cd laser

波长441.6nm

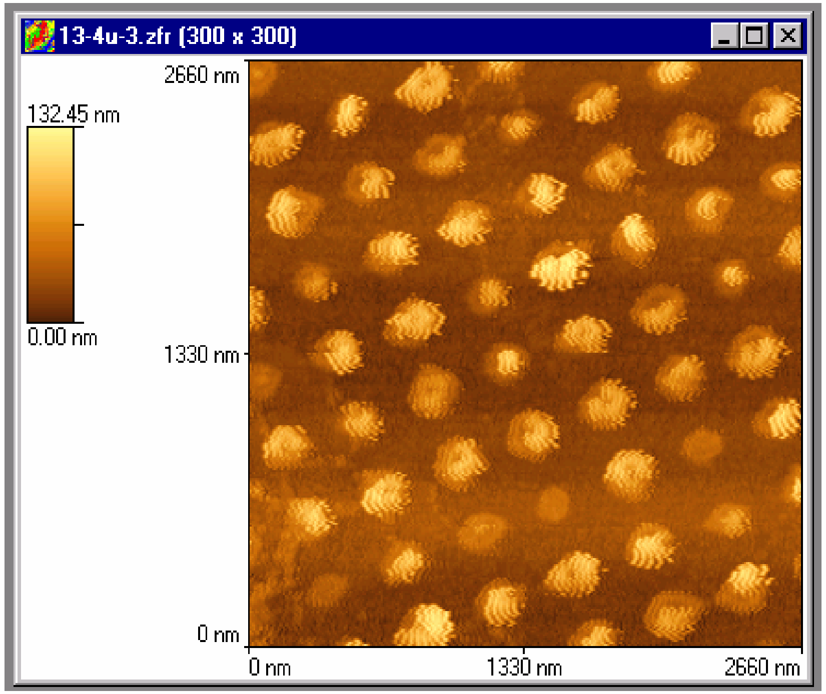
Exposure flux：

0.13mw/cm^2

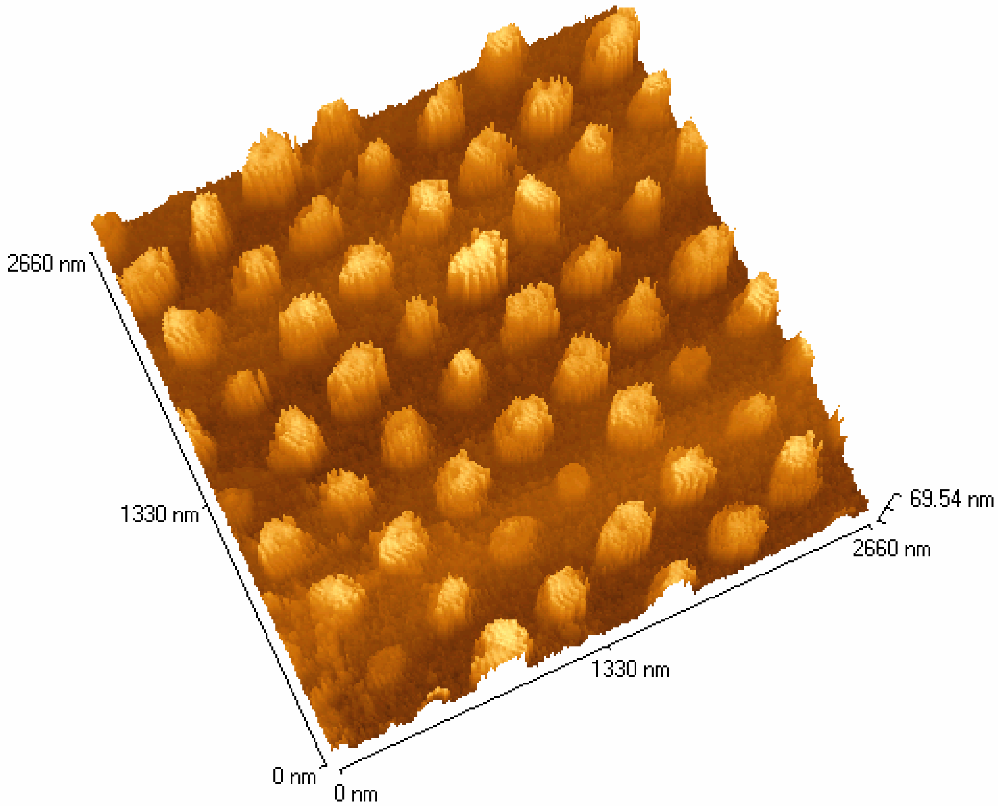
Exposure time：

100s

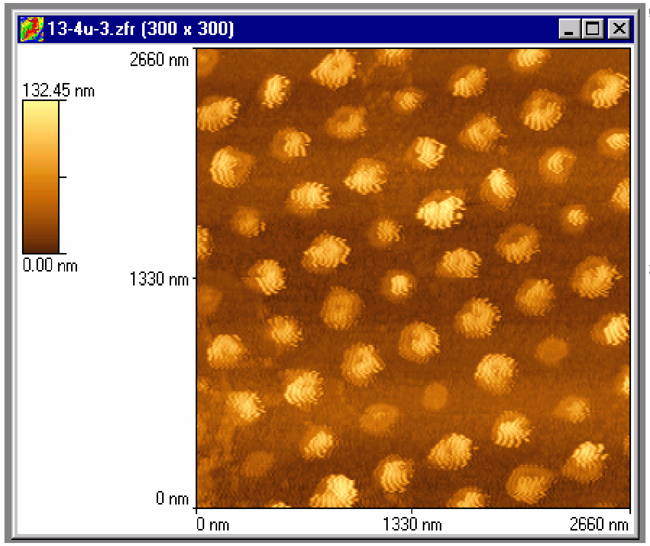
AFM measurement results: topography

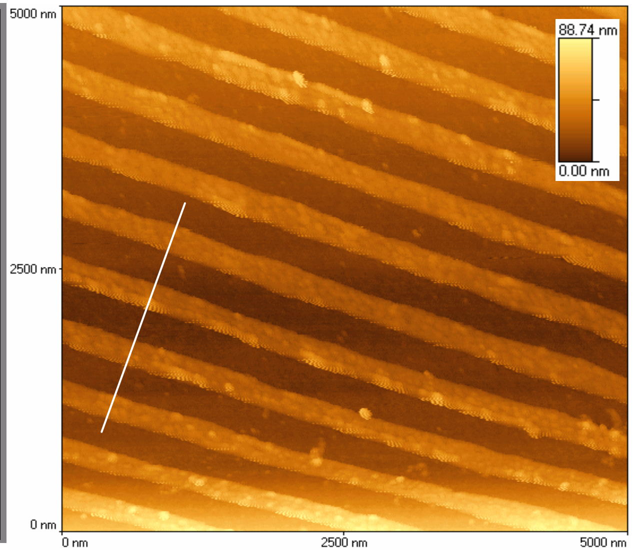


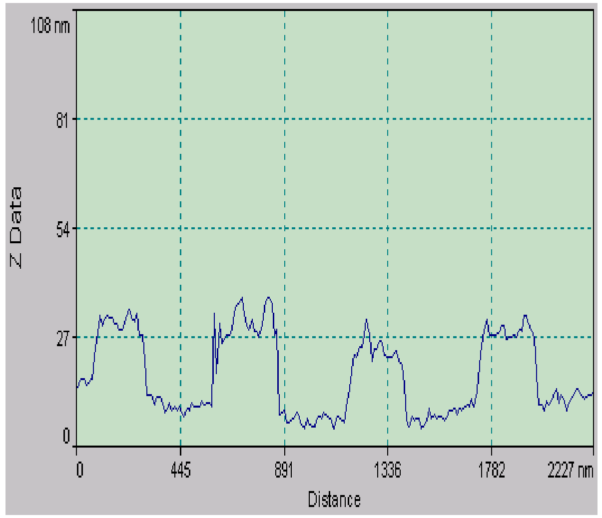
2D pattern on Cr film

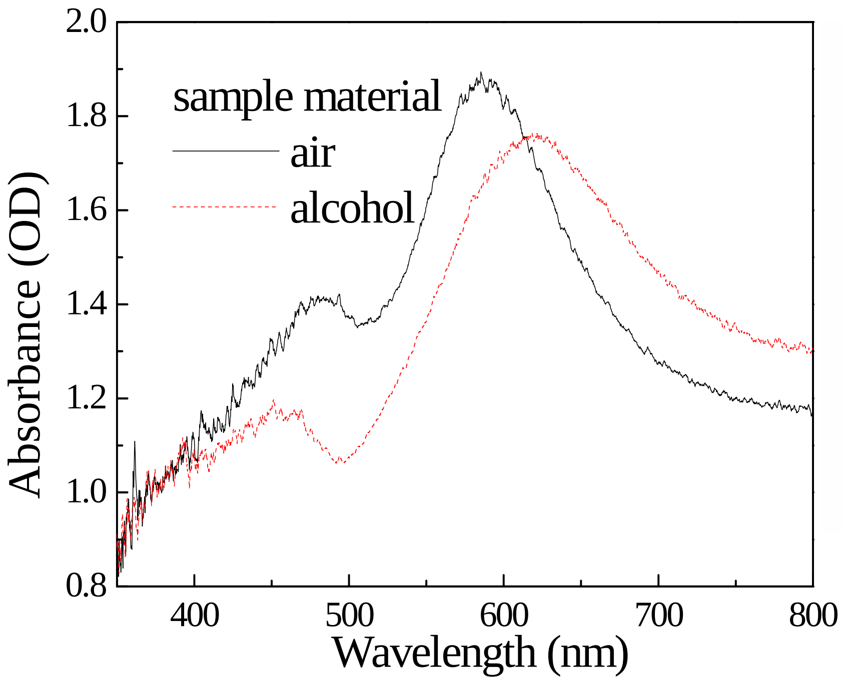


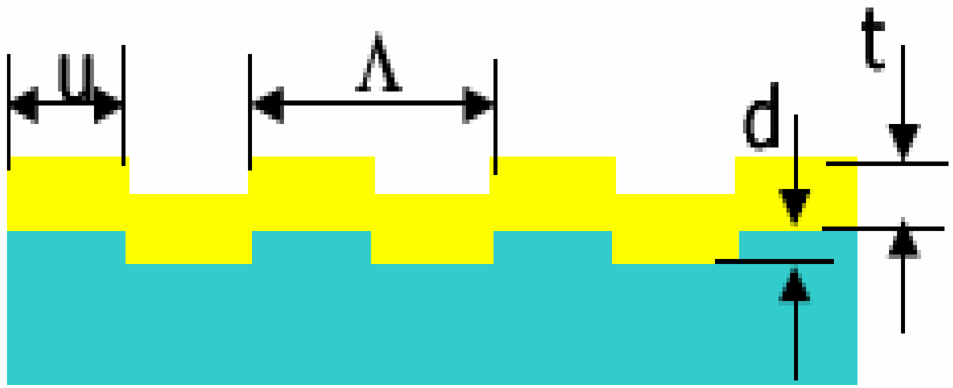
Measured 3D pattern on Cr film

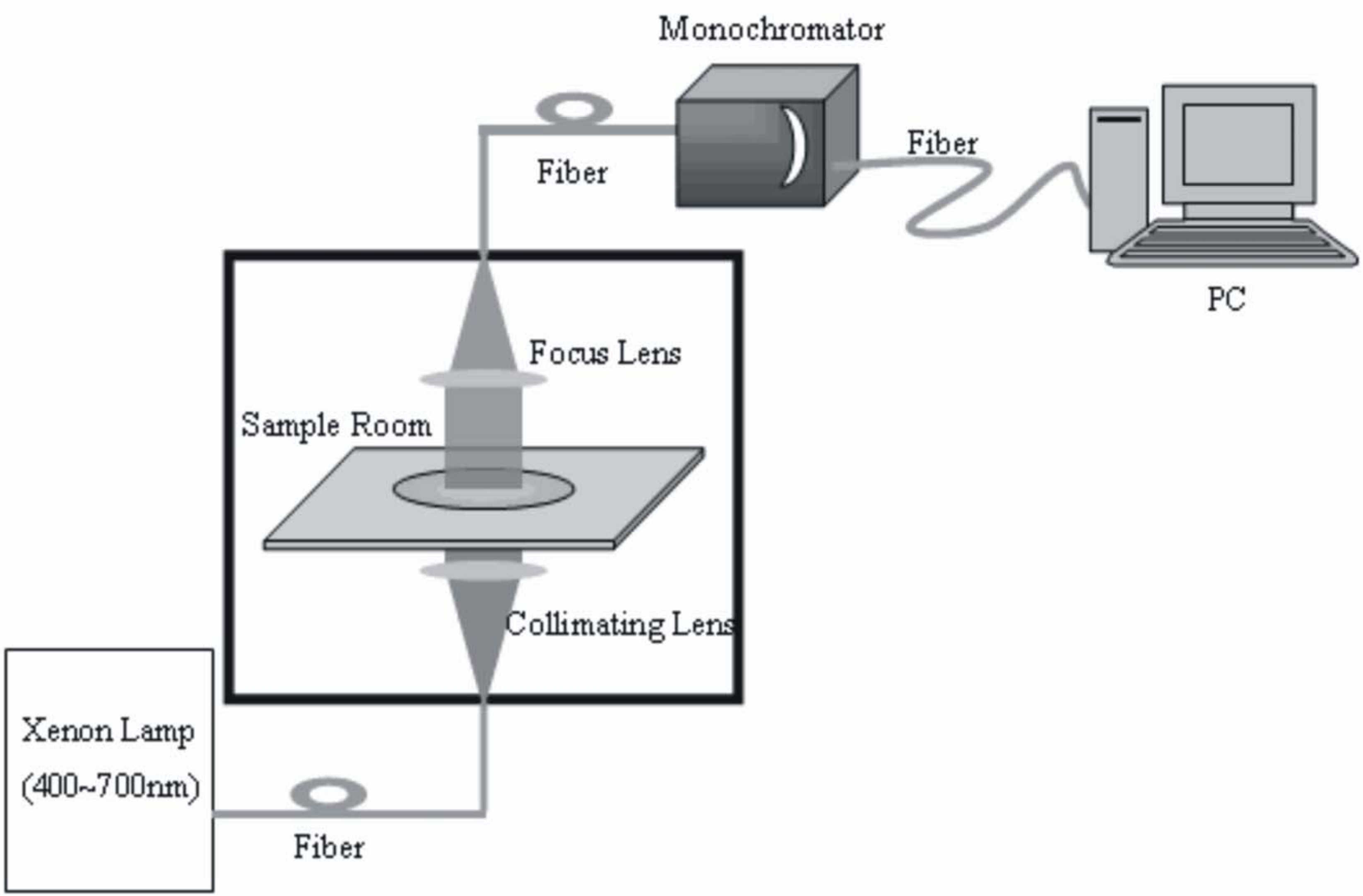

13-4u-3.zfr (300 x 300)
132.45 nm
0.00 nm
2660 nm
1330 nm
0 nm
0 nm
1330 nm
2660 nm


5000 nm
2500 nm
0 nm
0 nm
2500 nm
5000 nm
88.74 nm
0.00 nm


108 nm
81
54
27
0
Z Data
0
445
891
1336
1782
2227 nm
Distance

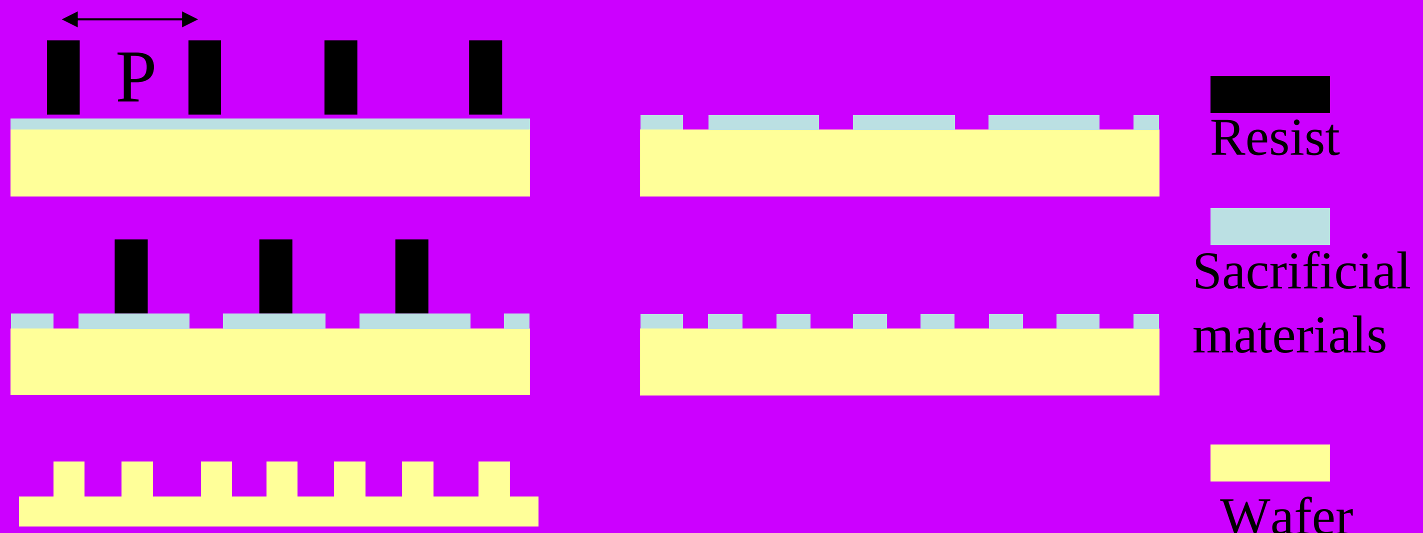

sample material
air
alcohol
Absorbance (OD)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
400
500
600
700
800
Wavelength (nm)


u
Λ
d
t



Experimental setup of the detection system

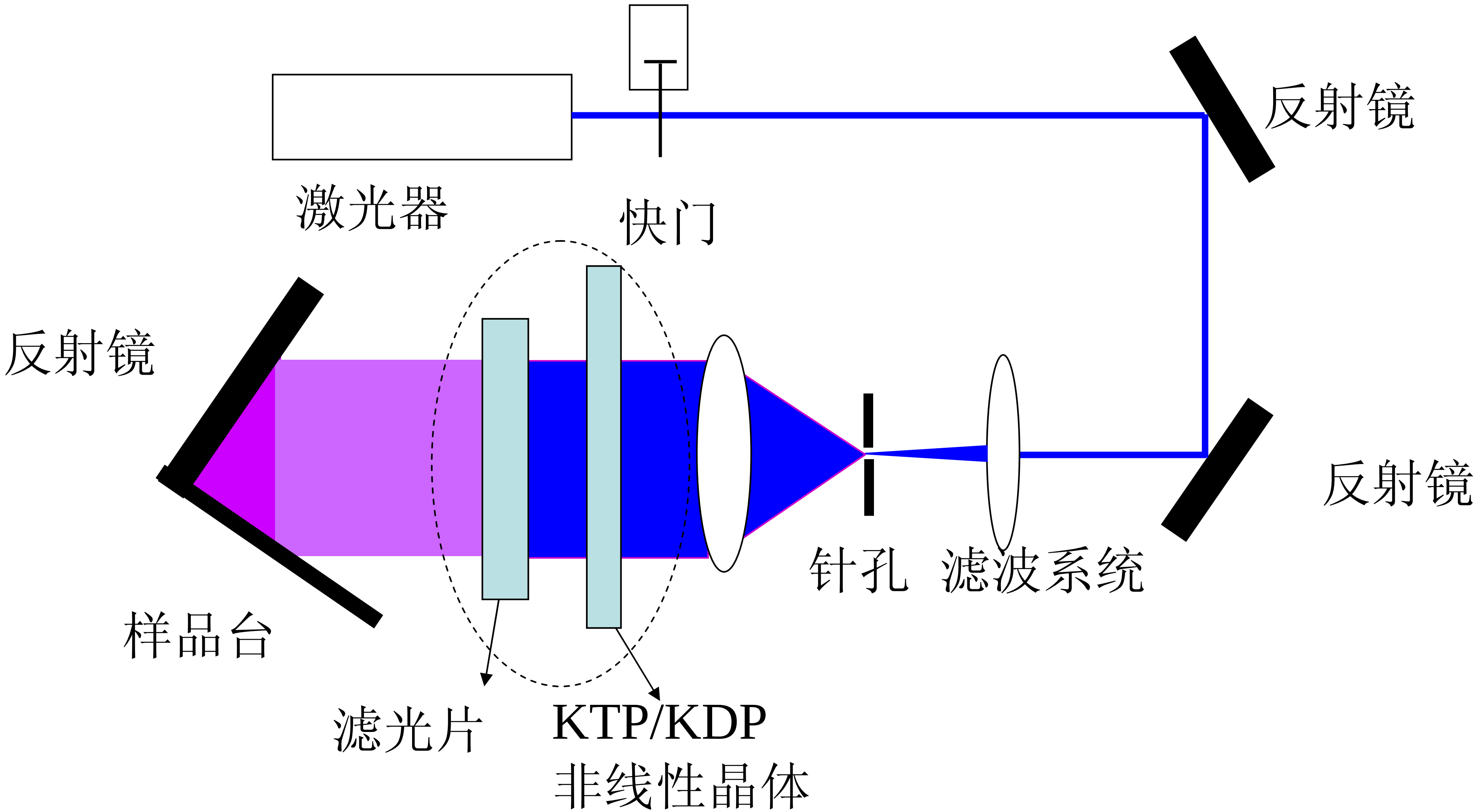
Reducing period of the structures



➢ 通过双曝光、结合刻蚀工艺来实现，基底在第二次曝光之前移动半个周期的距离来实现。

➢移动距离为100纳米的转台。

Reducing exposure wavelength by double frequency of the light source



磷酸二氢钾**(KDP)**,磷酸二氘钾**(DKDP)**基本特性

	KDP	**KD*P**
Molecular formula	KH_2PO_4	KD_2PO_4
wavelength	200-1500nm	200-1600nm
Non-linear coefficiency	d_{36}=0.44pm/V	d_{36}=0.40pm/V

紫外透过,高损伤阈值,双折射系数高等特性

磷酸二氢钾(KDP),磷酸二氘钾(DKDP or KD*P)

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邮编：276017

◇ 紫外干涉滤光片

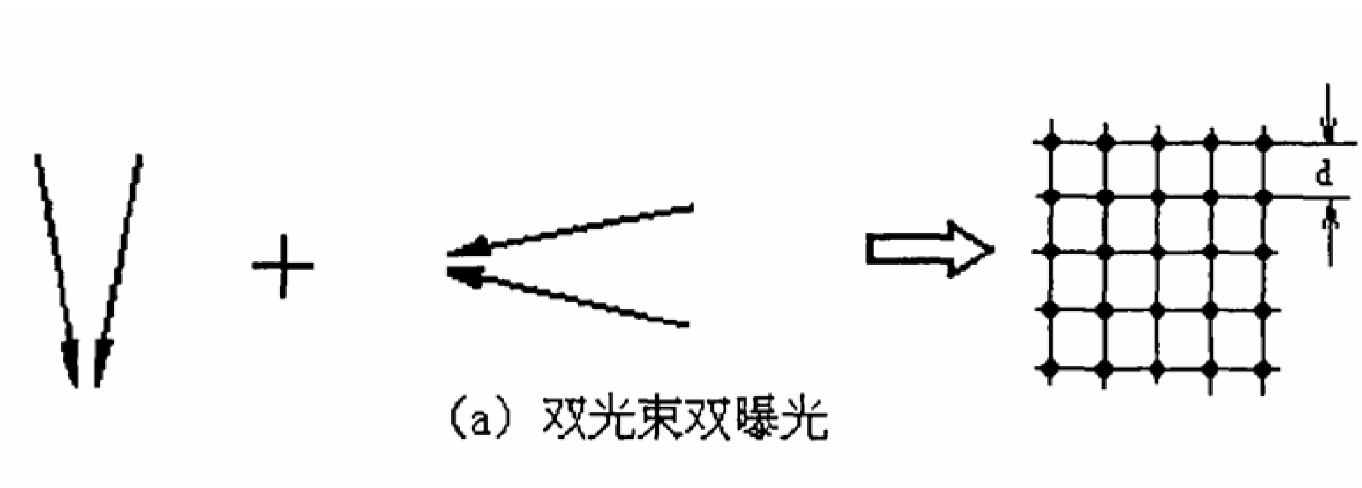
中心波长：220nm-400nm(典型的波长为220mm, 254mm, 280nm, 340nm, 380nm)

中心波长偏差：+/-2nm

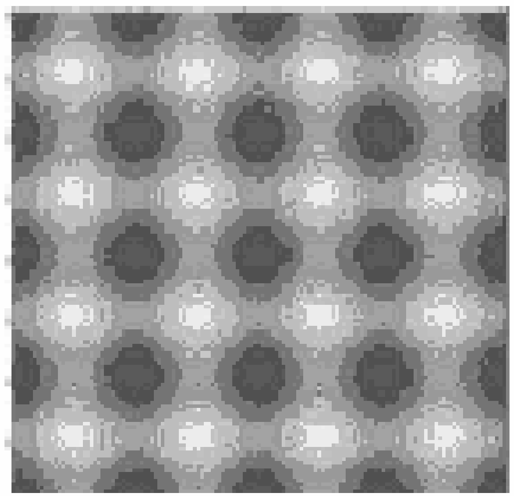
峰值透过率:T>15%-40%(与不同的中心波长有关)

半带宽: 8+/-2nm

大恒光电



两束光正交双曝光示意图和光强分布的二维等高线图

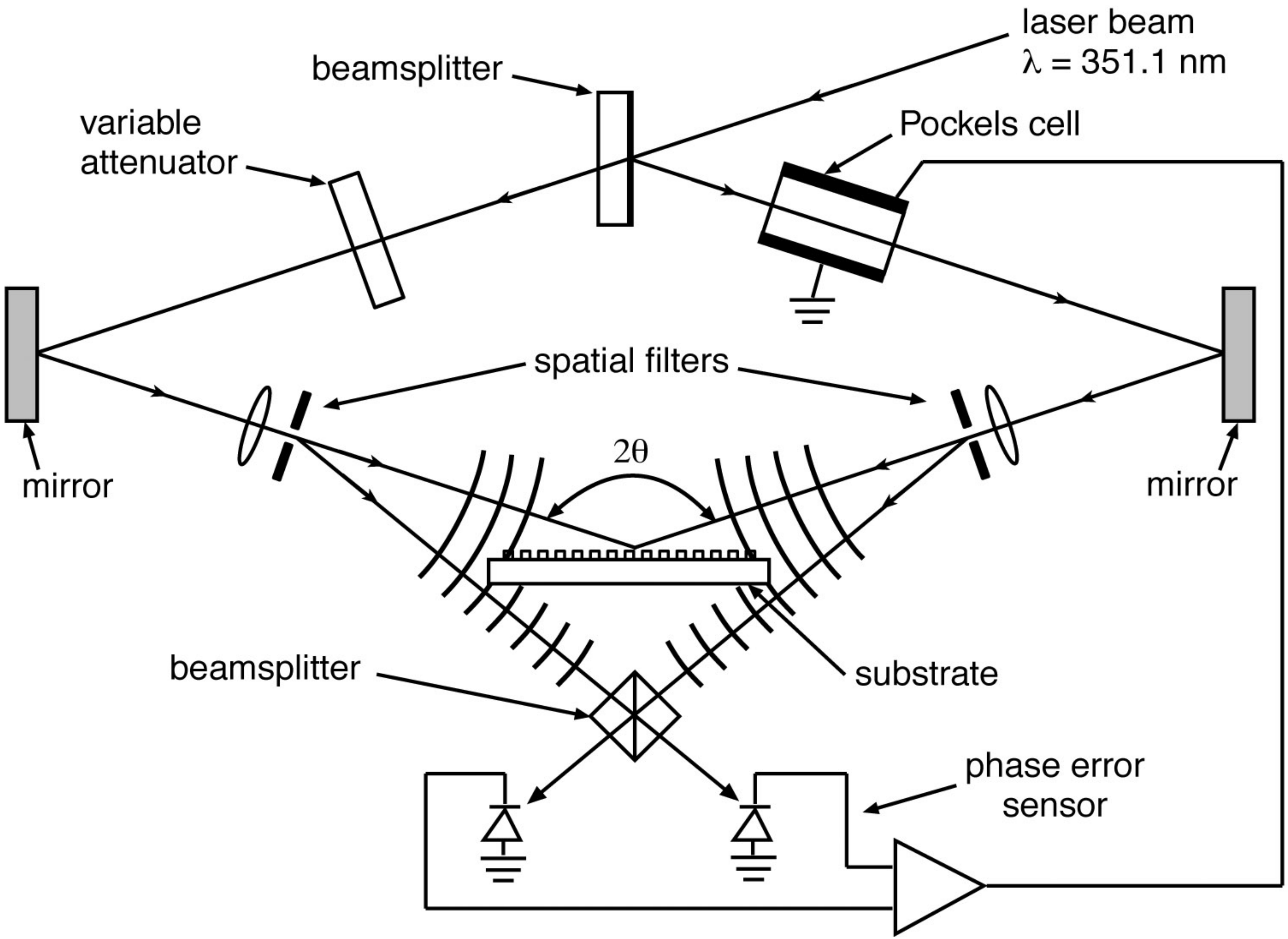


对于任意角度的双曝光和双光束的多次曝光，最后在光刻胶上得到的图形所对应的光强为：

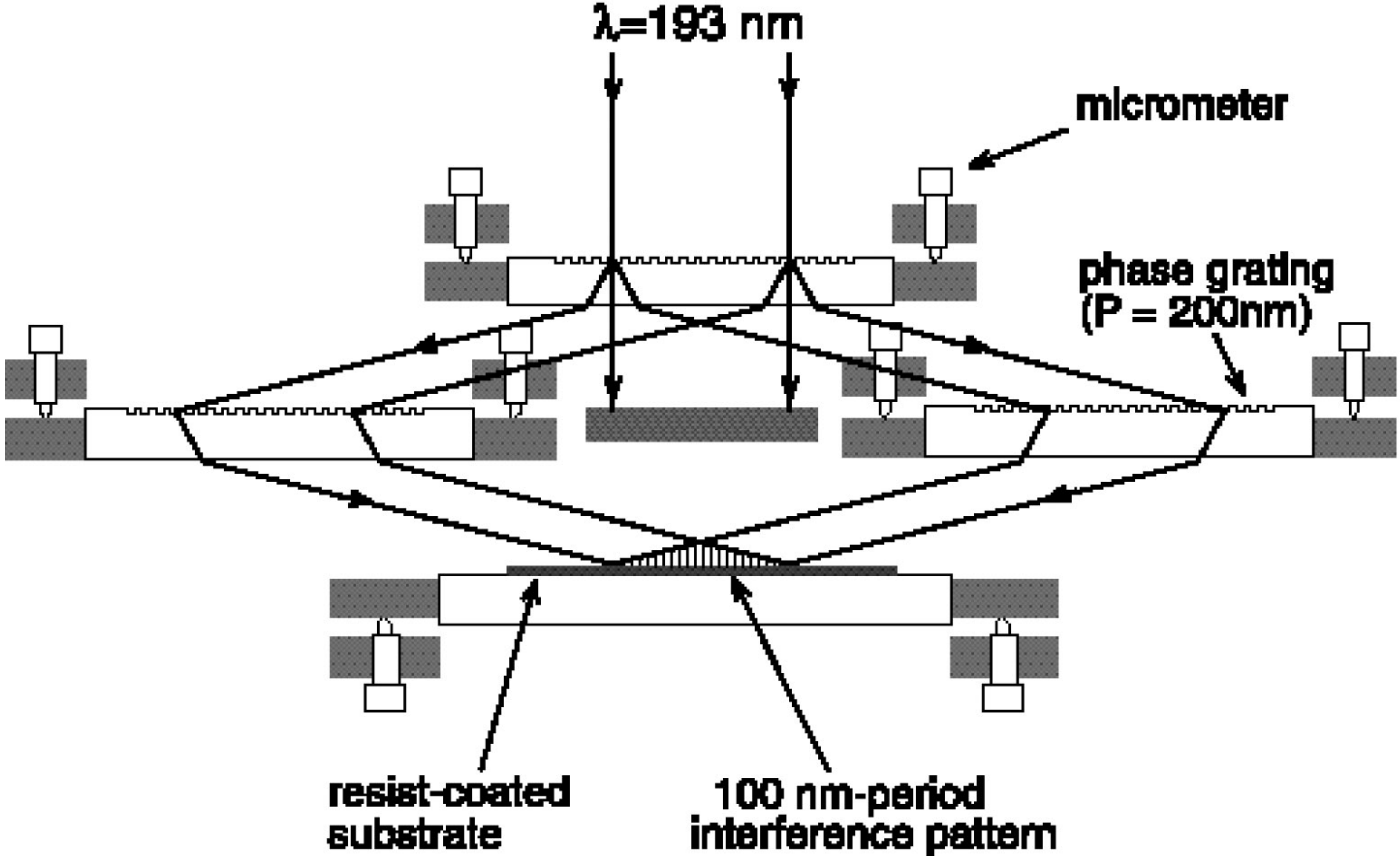
$$I_t = \sum_{i=1}^{n} (\Delta t_i) I_i$$

$$I_i = 2I_0\{1+\cos[\frac{2\pi}{d}(\cos(\alpha_i)x-\sin(\alpha_i)y)+\varphi_i]\}$$

Δt_i为每次的曝光时间，I_i为每次曝光的光强分布。这种情况下，可调节的变量有λ、θ、Δt和位相差φ，通过多次曝光的组合可以产生较为复杂的图形。但是从可操作性考虑，双曝光和三次曝光比较多。

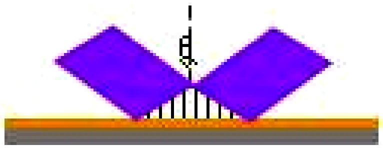


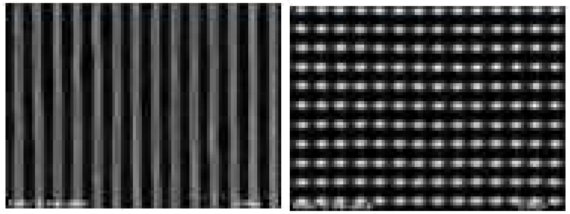
分振幅双光束干涉系统(分光镜分光)



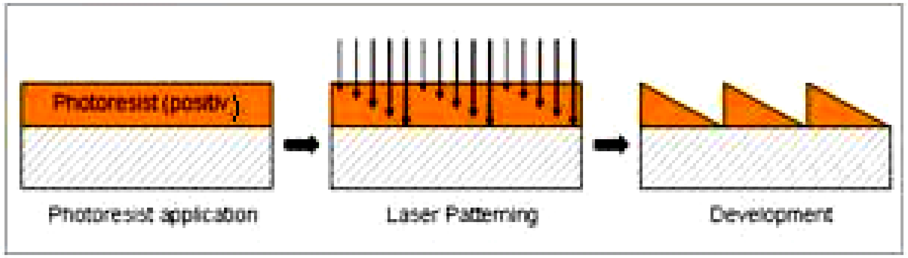
消色差干涉系统(光栅分光)

Interference lithography

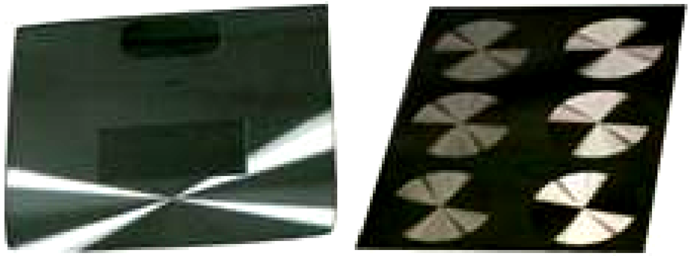




Grayscale lithography



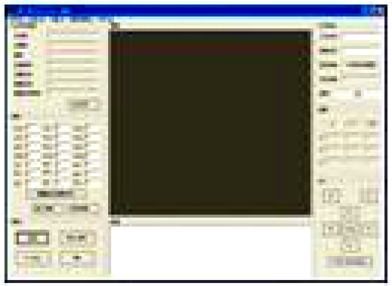
Laser direct writing

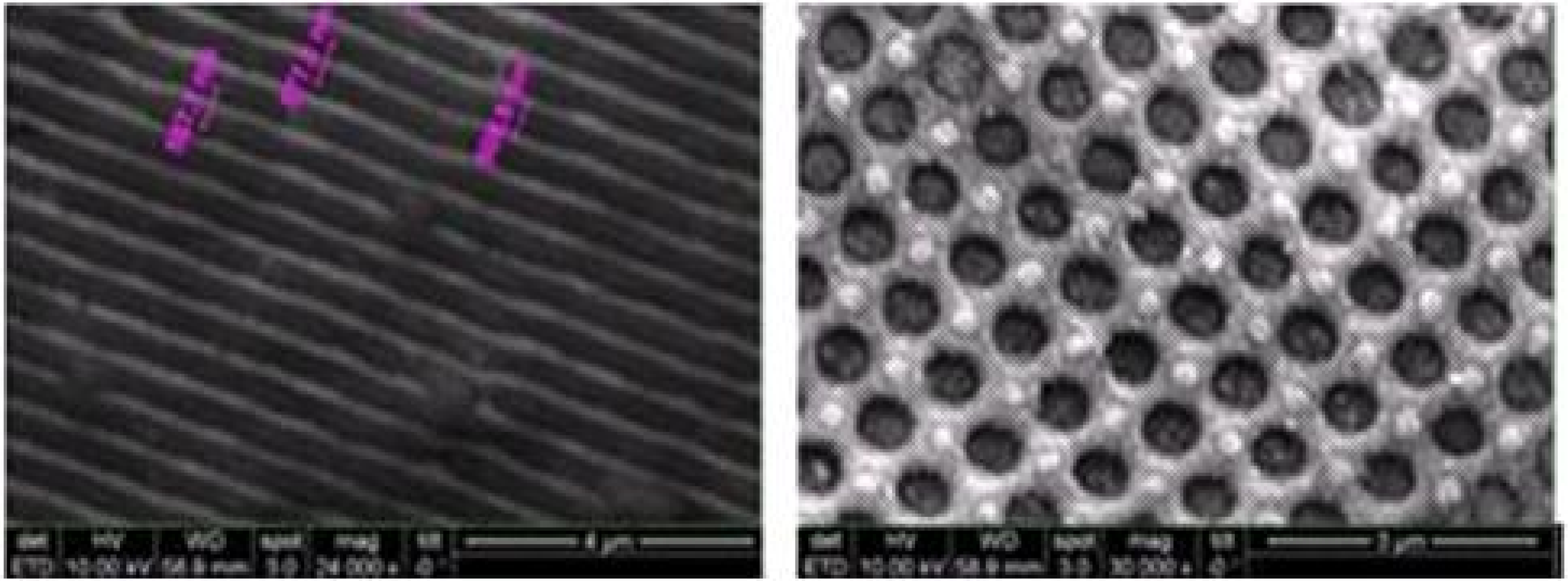


Speciality software

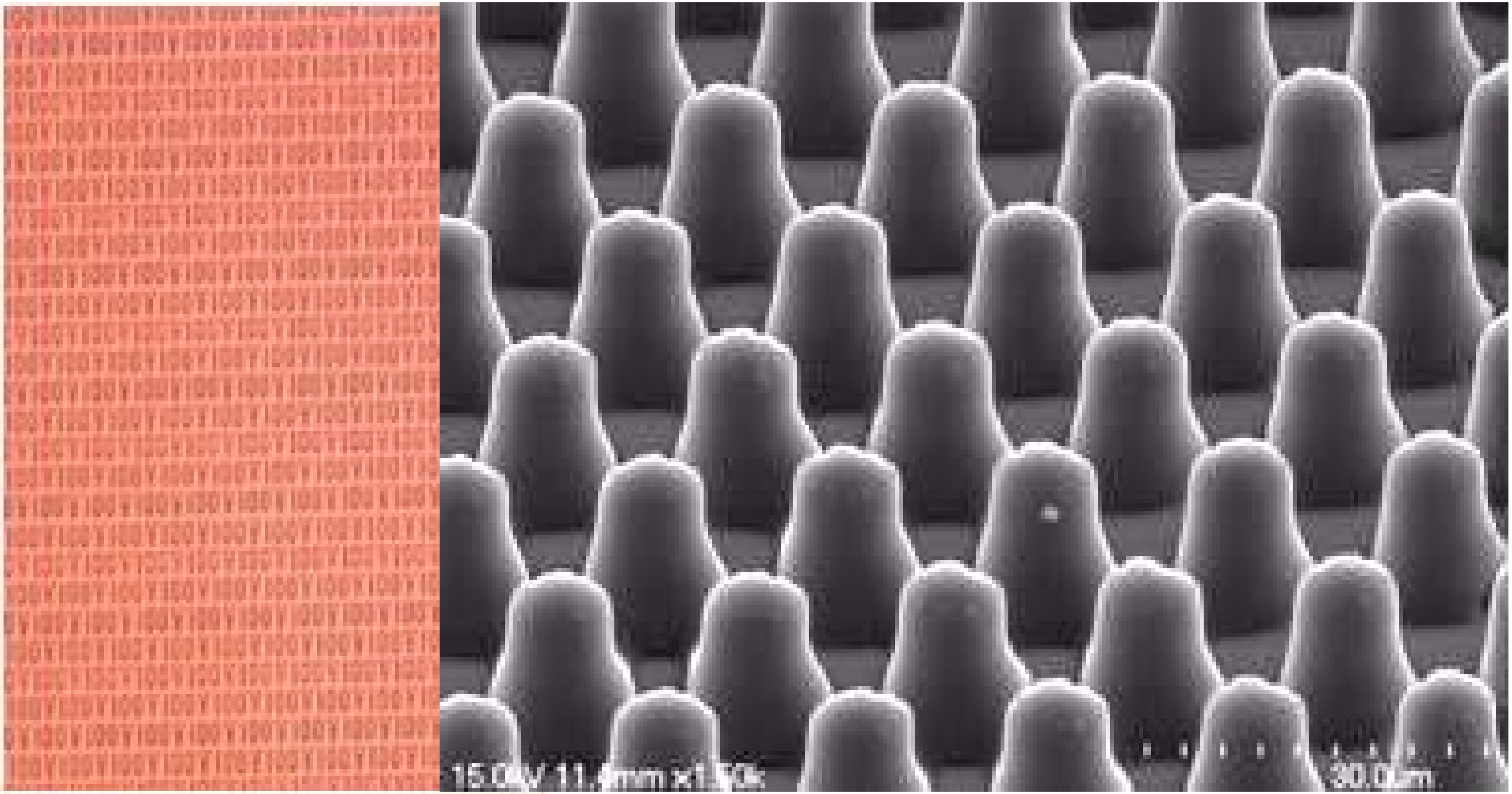
SVG Writer 1.0

- Multiple data input formats (DXF, CIF, GDSII, BMP, ARR)
- optimized path algorithm
- precision control

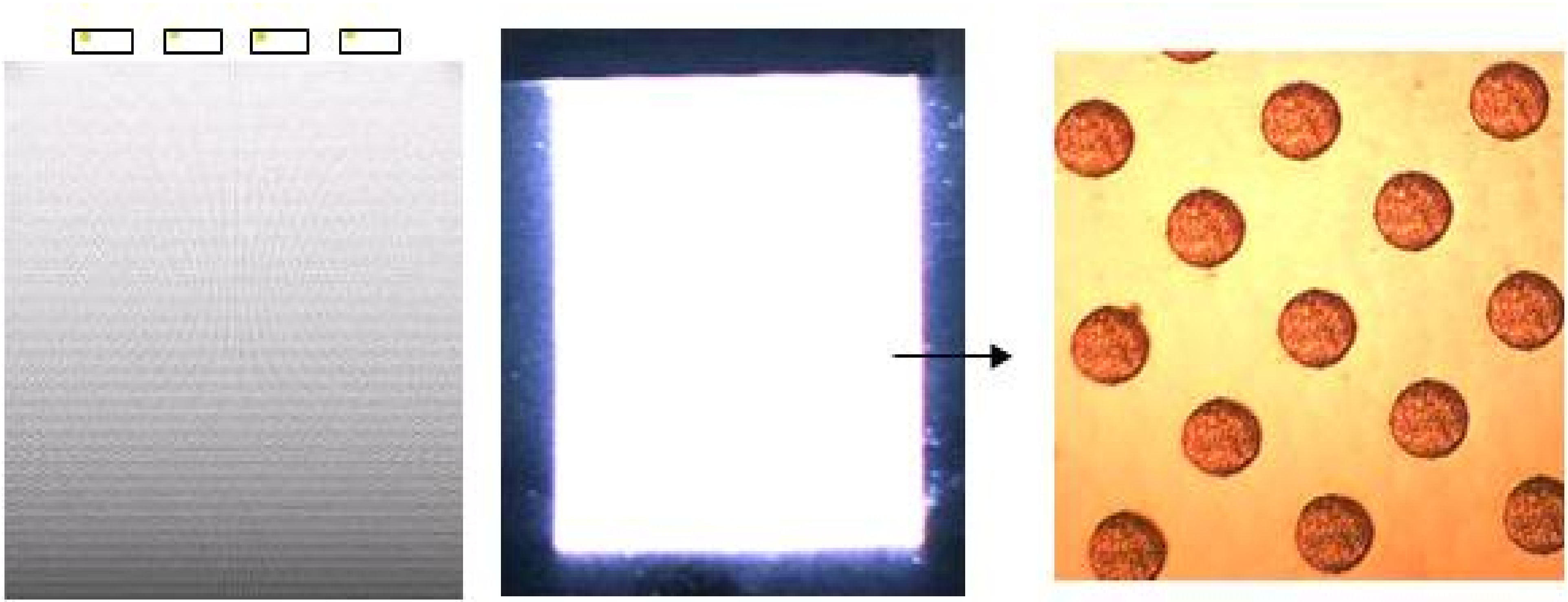




在GaN上紫外激光干涉直写光子晶体 GaN photonic crystal patterning



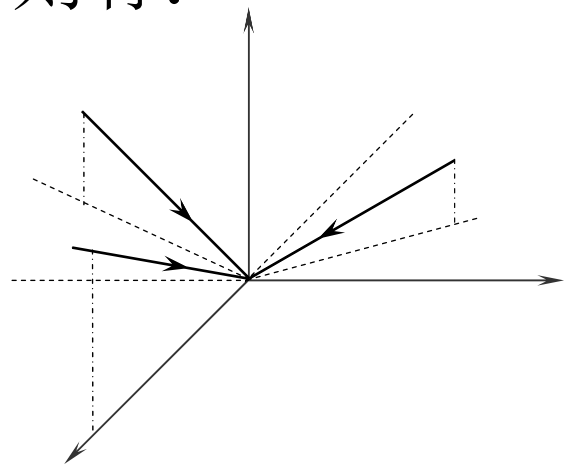
灰度光刻阵列图形grayscale lithography: fresnel lens and micro-pattern fabrication



导光板 light guide plate

Three-beams exposure

设k的方向余弦为$(\cos\alpha, \cos\beta, \cos\gamma)$，则有：



$$E_1 = A_1 e^{i\varphi_1} = A_1 e^{i[k(x\cos\alpha_1 + y\cos\beta_1 + z\cos\gamma_1) - \omega t - \delta_1]}$$

$$E_2 = A_2 e^{i\varphi_2} = A_2 e^{i[k(x\cos\alpha_2 + y\cos\beta_2 + z\cos\gamma_2) - \omega t - \delta_2]}$$

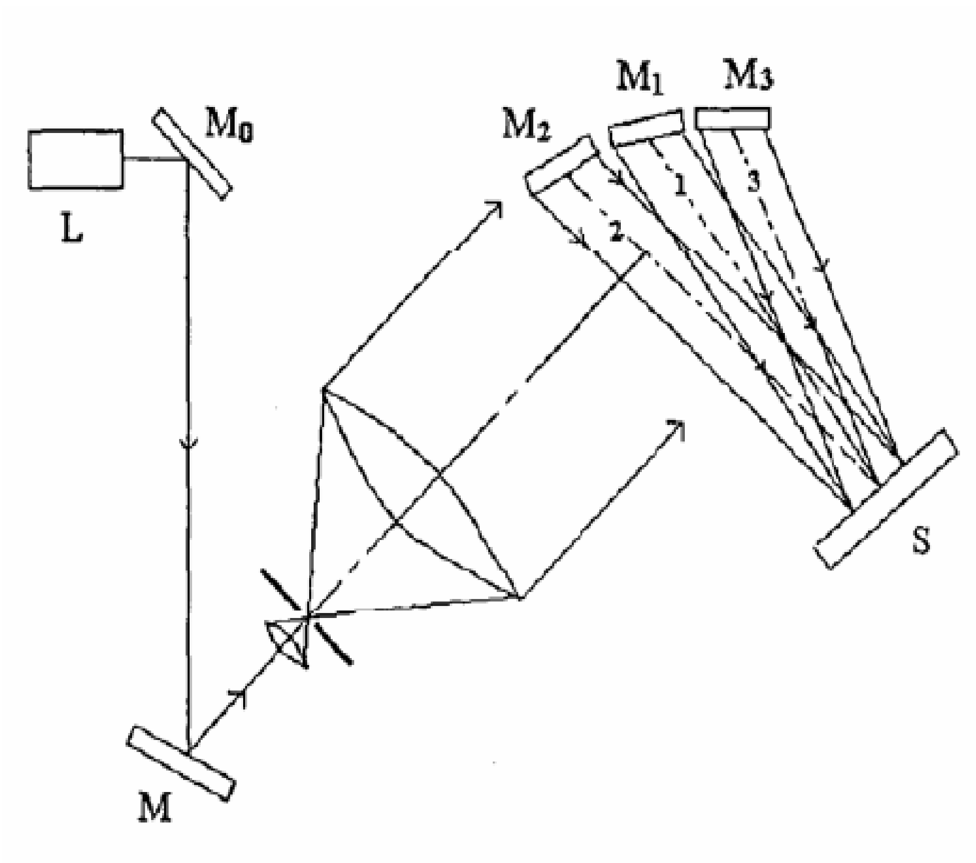
$$E_3 = A_3 e^{i\varphi_3} = A_3 e^{i[k(x\cos\alpha_3 + y\cos\beta_3 + z\cos\gamma_3) - \omega t - \delta_3]}$$

考虑等光强的三束光，干涉得到的光强分布为：

$$I = A^2[3 + 2(\cos(\varphi_1 - \varphi_2) + \cos(\varphi_2 - \varphi_3) + \cos(\varphi_3 - \varphi_1))]$$

其中

$$\cos(\varphi_1 - \varphi_2) = \cos[x(\cos\alpha_1 - \cos\alpha_2) + y(\cos\beta_1 - \cos\beta_2) + z(\cos\gamma_1 - \cos\gamma_2) + (\delta_2 - \delta_1)]$$



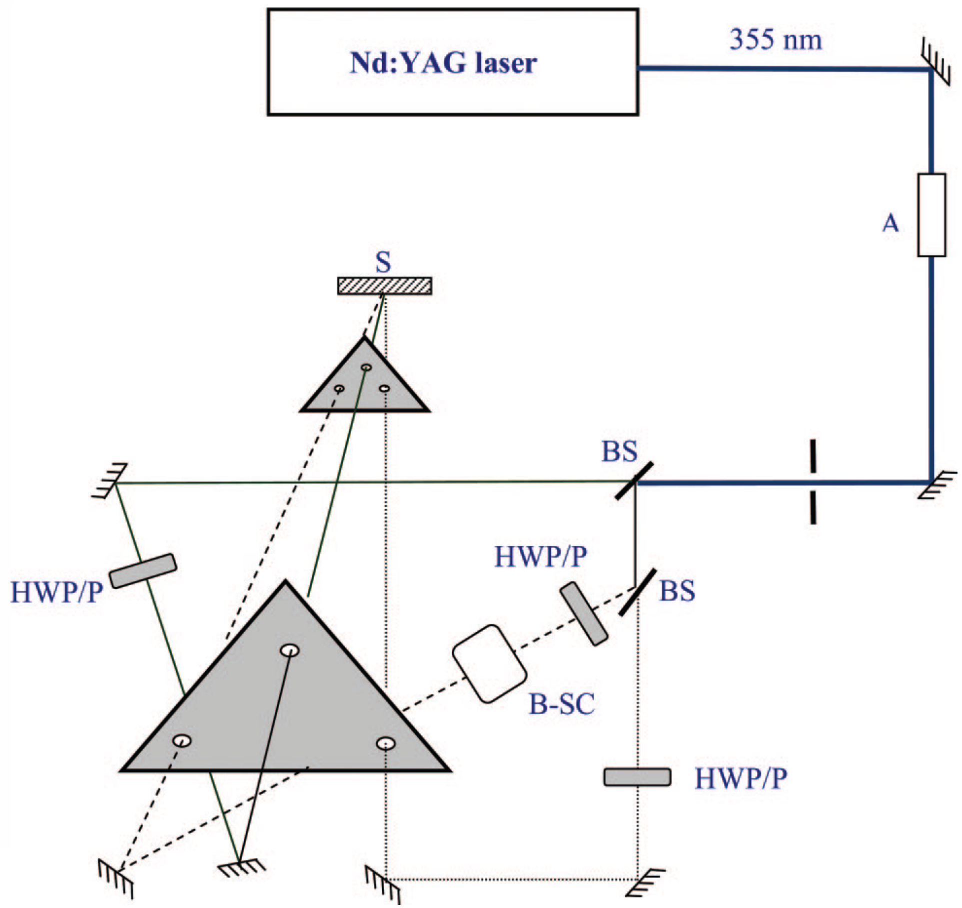
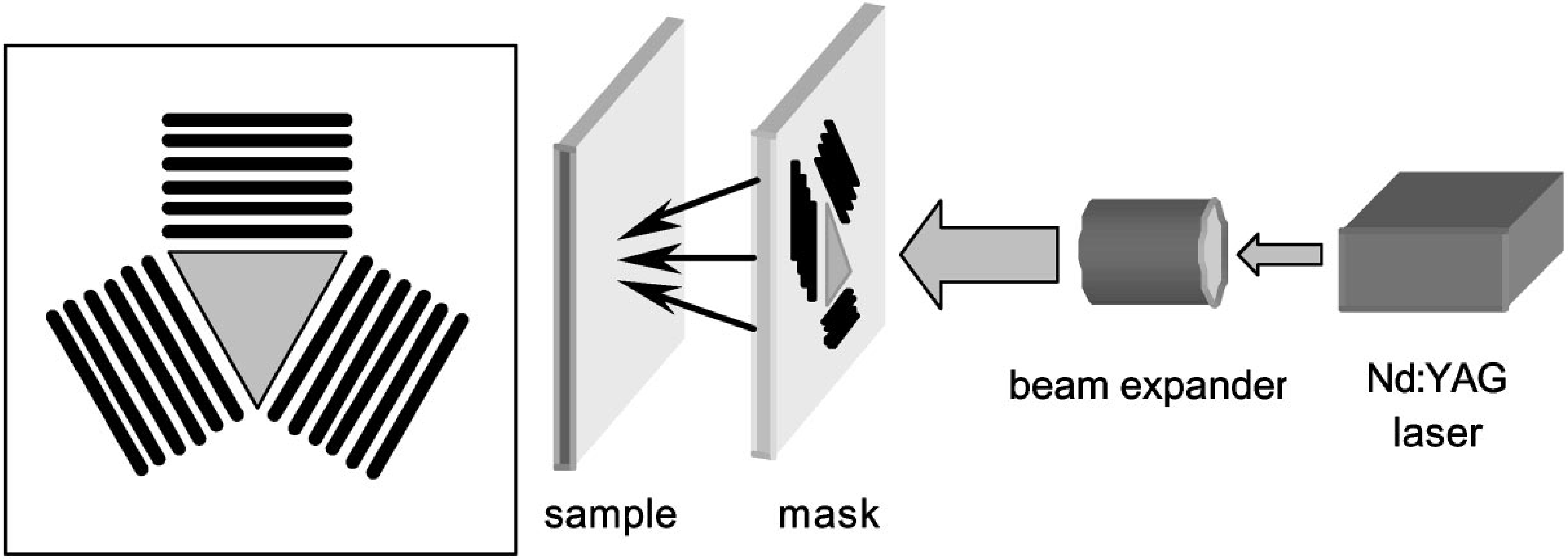


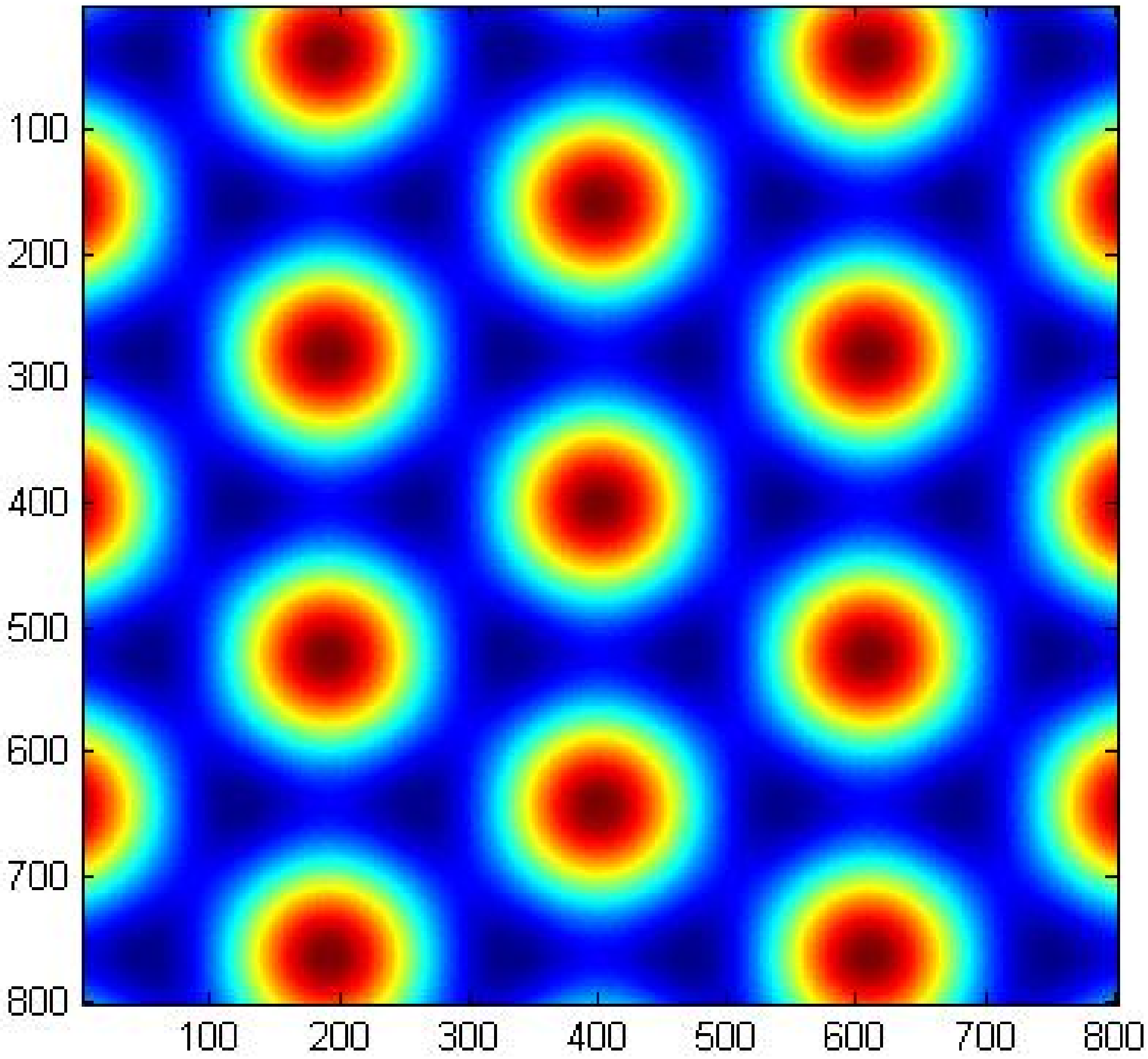
图14：分波前三光束干涉系统

图15：分振幅三光束干涉系统

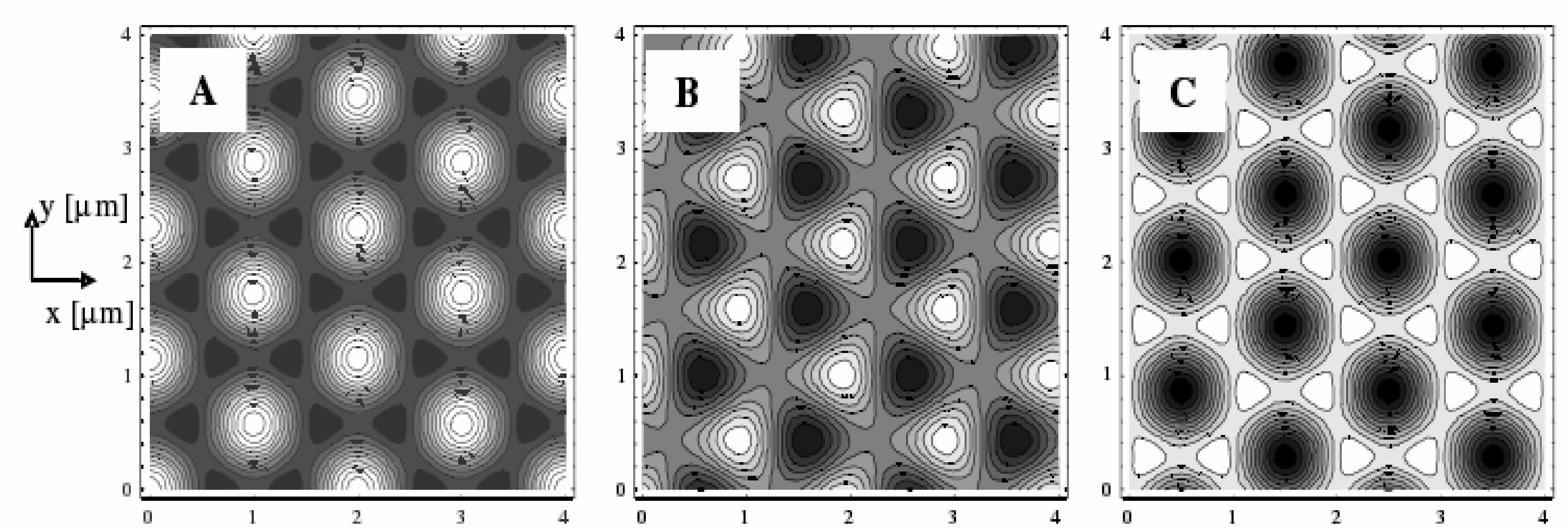


(a) (b)

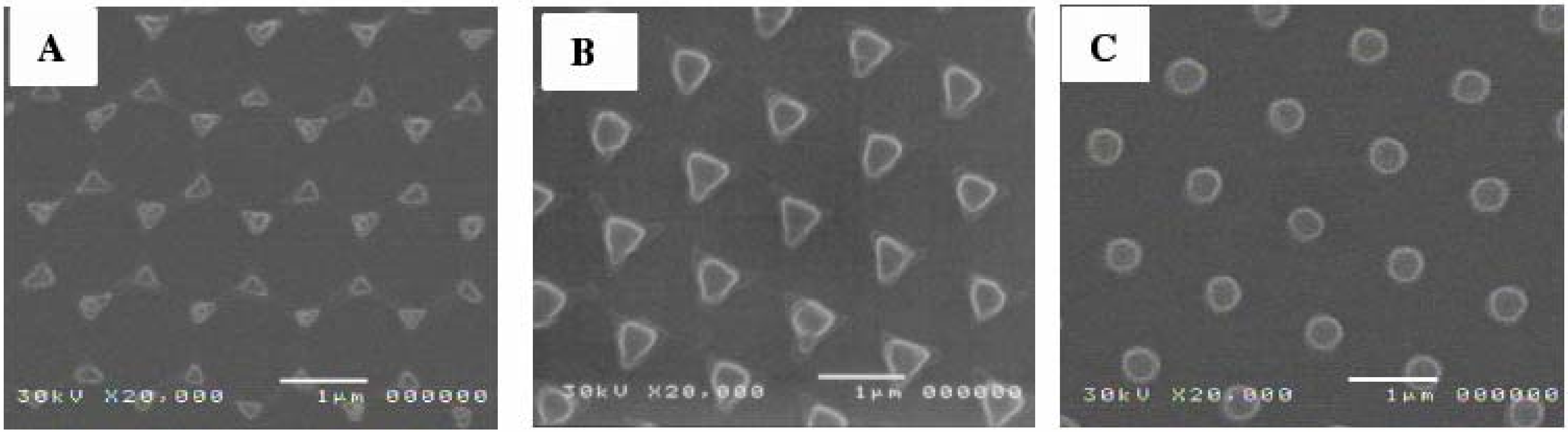
Schematic diagram of experimental system



Equalized three beams interference generated pattern



三次曝光的光强分布图。每次曝光的夹角为60度。(a)位相差φ3＝0；(b)φ3=π/2；(c) φ3＝π。φ1和φ2始终为0。



对应于上图的曝光结果

Four-beams exposure

用四束单色单色相干光以各自的角度同时照射到涂有光致抗蚀剂的基片表面。设基片置于xoy平面内

$$E_n = A_n e^{i\varphi_n} = A_n e^{i[k(x\cos s\alpha_n + y\cos\beta_n + z\cos\gamma_n) - \omega t - \delta_n]}$$

当各束光的光强相同时

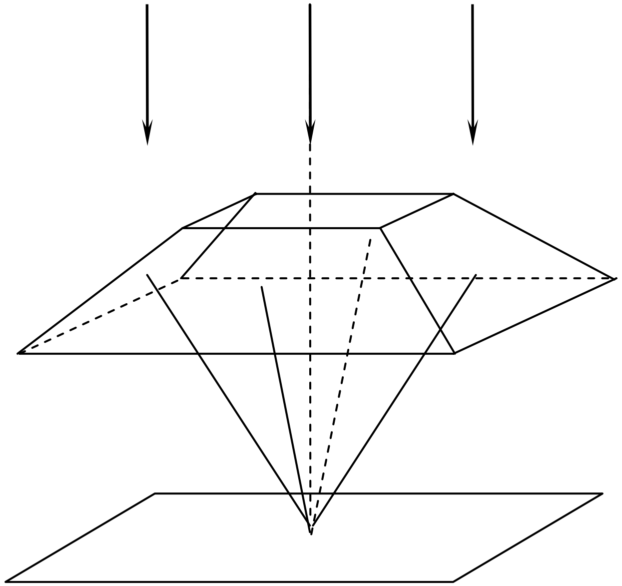
$$I = 2A^2[2 + \cos(\varphi_1 - \varphi_2) + \cos(\varphi_2 - \varphi_3) + \cos(\varphi_3 - \varphi_4) + \cos(\varphi_4 - \varphi_1)]$$

其中

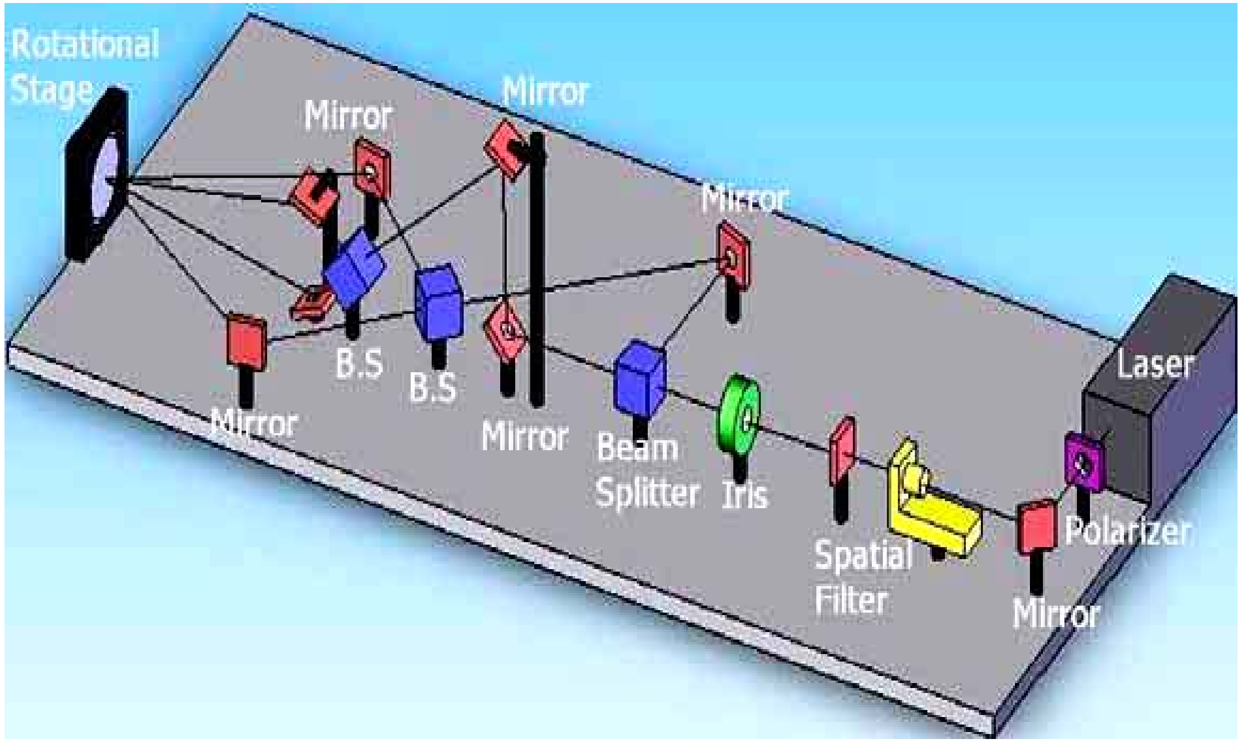
$$\cos(\varphi_n - \varphi_m) = \cos[x(\cos\alpha_n - \cos\alpha_m) + y(\cos\beta_n - \cos\beta_m) + z(\cos\gamma_n - \cos\gamma_m) + (\delta_m - \delta_n)]$$

当四束光在两个正交的平面内入射，并且入射角相同时，光强的分布可以简化为：

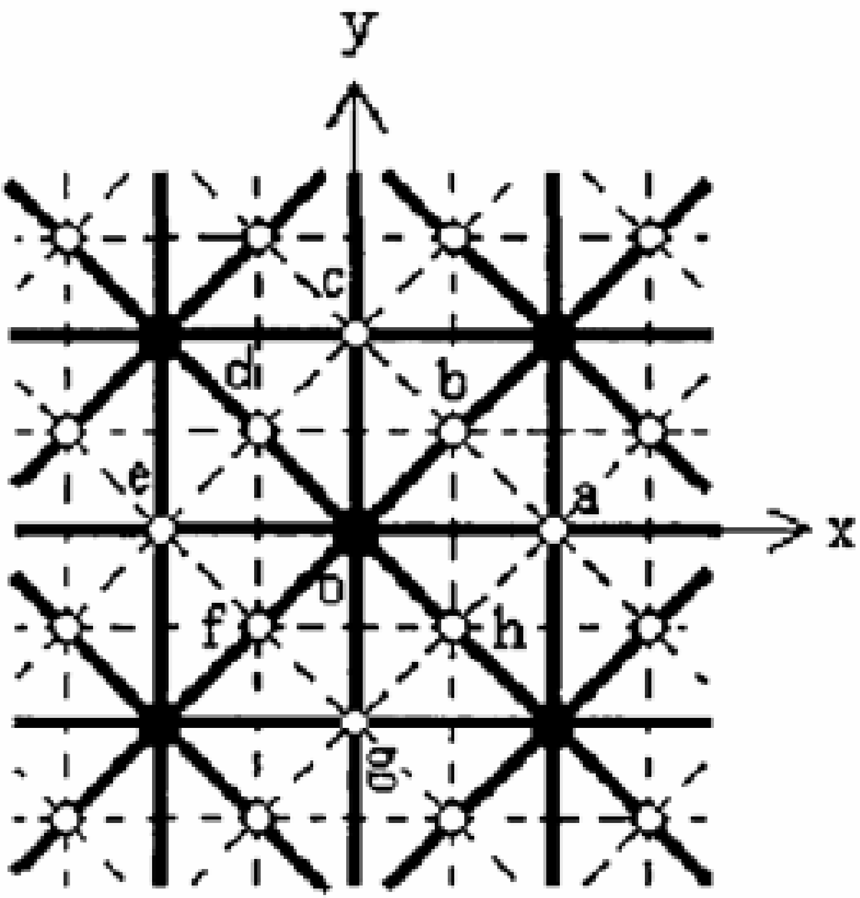
$$I = 2A^2\{2 + \cos(2kx\sin\theta) + \cos(2ky\sin\theta) + 2\cos[k(x-y)\sin\theta] + 2\cos[k(x+y)\sin\theta]\}$$

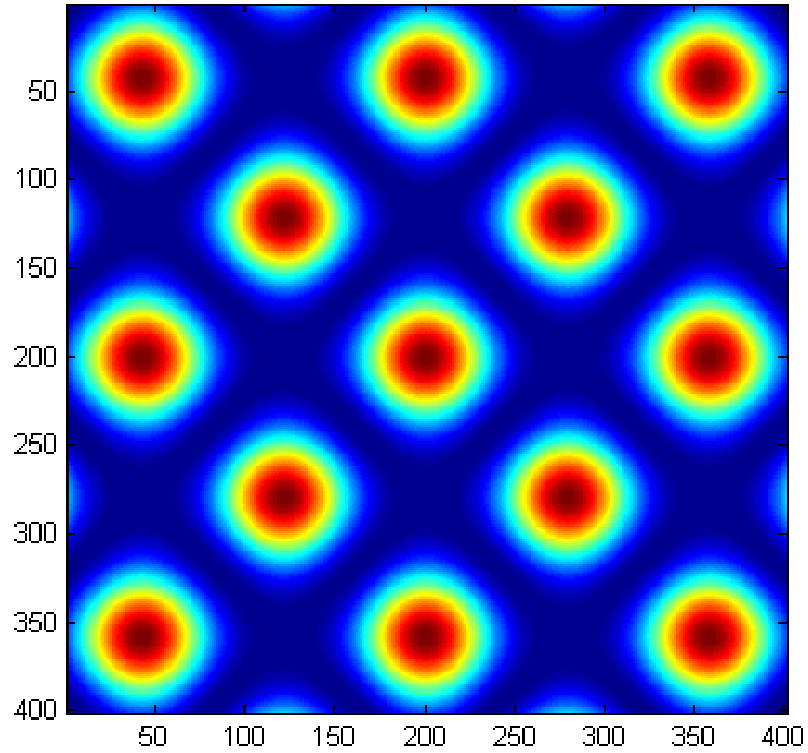


Schematic diagram using four-beams

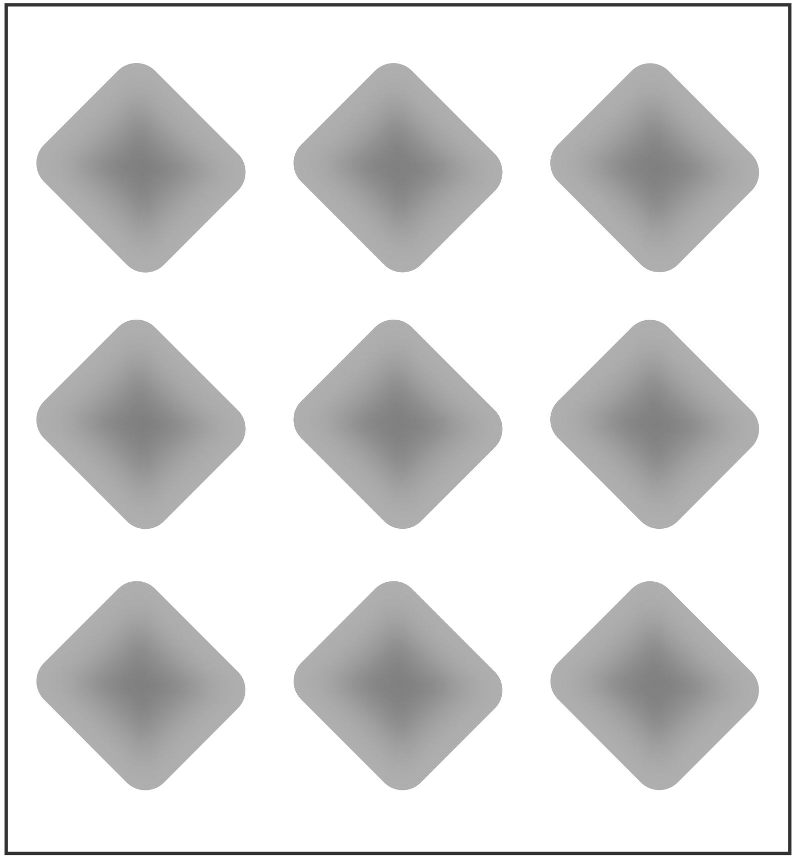


Experimental system of the four-beams interference lithography

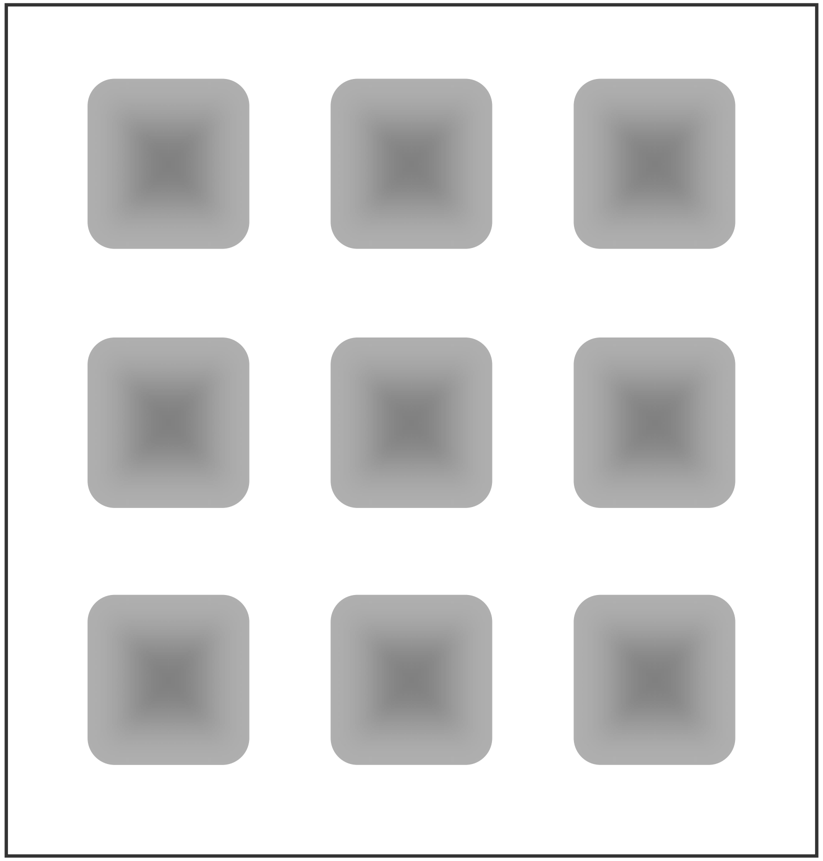




Four-beams interference produced pattern with equal intensity distribution

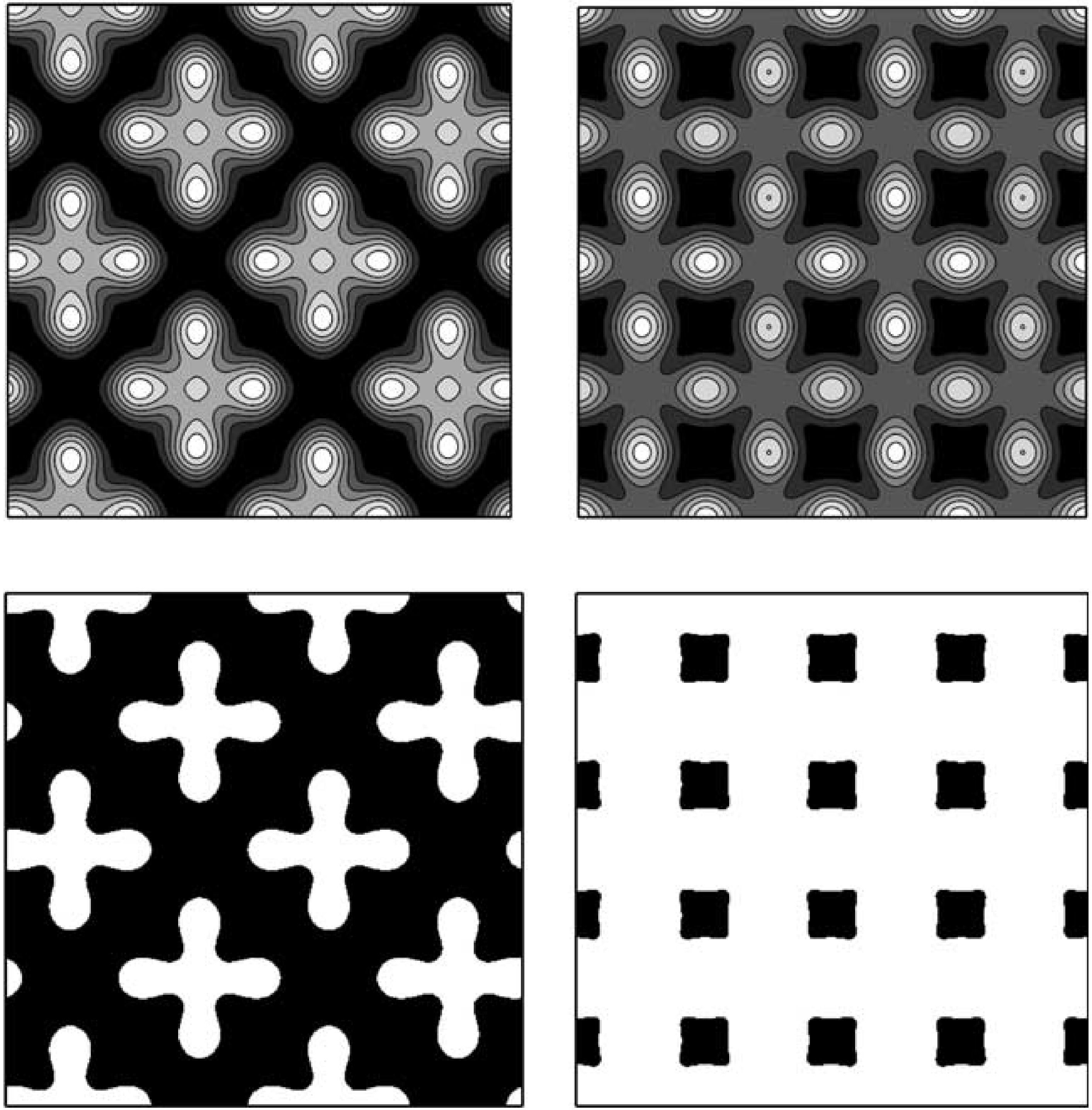


(a)



(b)

(a) Dual-beam interference； (b) four-beams interference



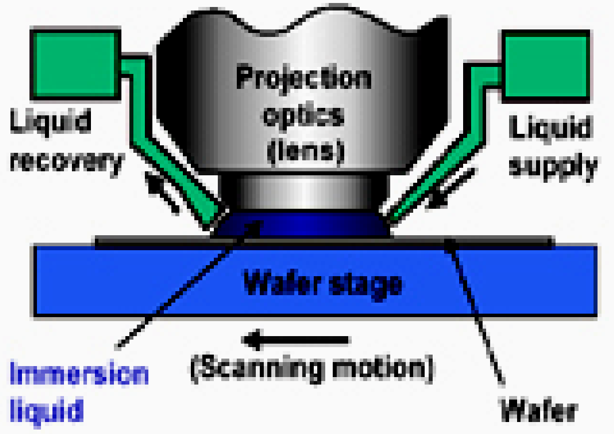
Patterns generated by eight-beams exposure

Immersion Lithography
Improving the manufacturing process

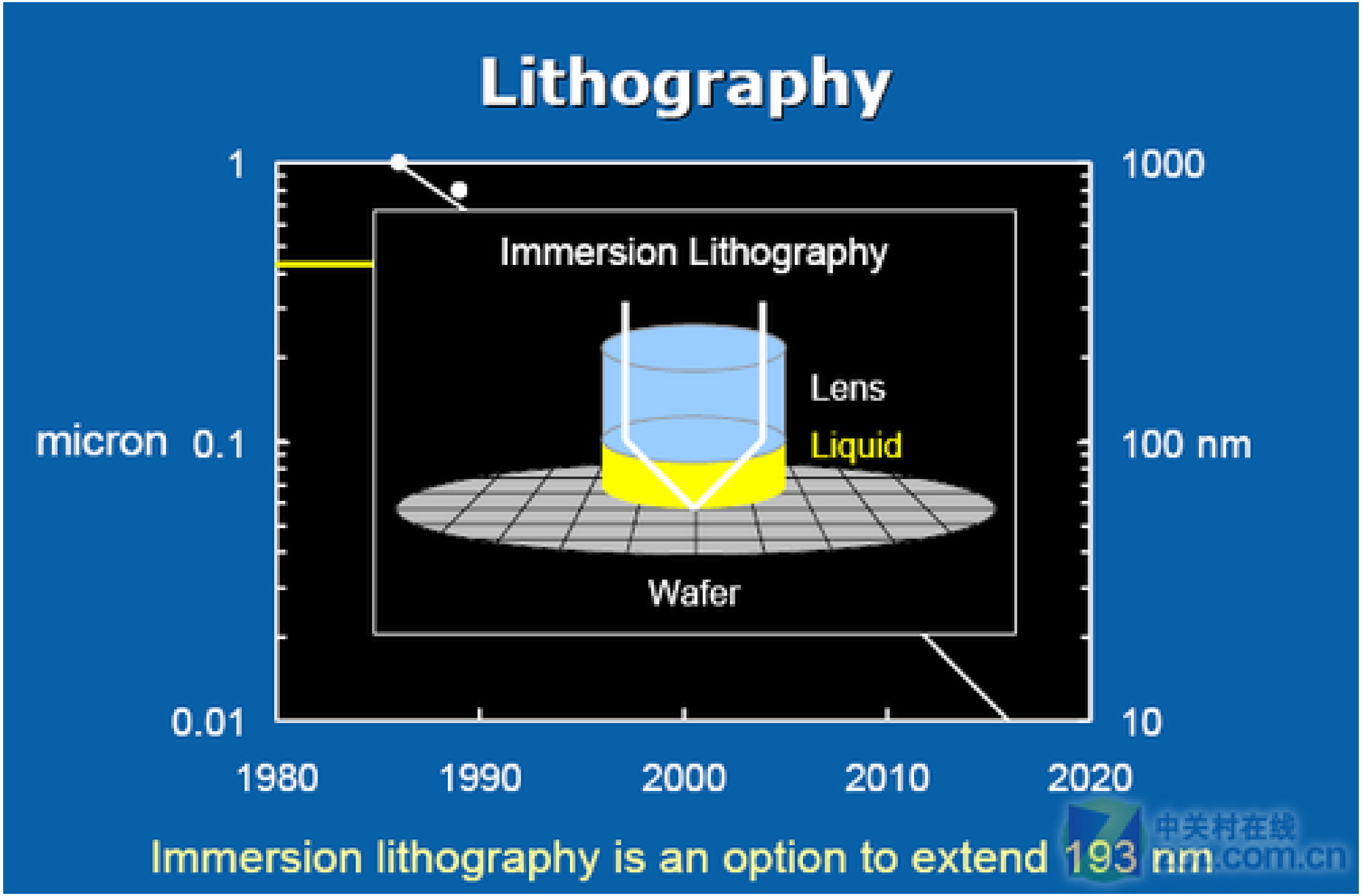
AMD Smarter Choice

Lithography For 45nm

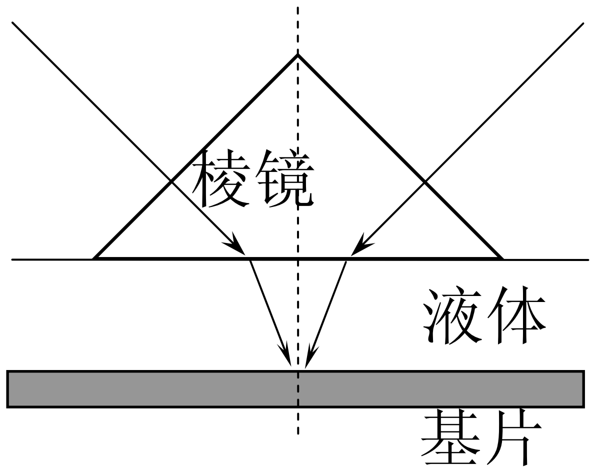
- Immersion effectively decreases wavelength by putting water between the projection lens and the silicon wafer
  - If a fluid of refractive index n fills the space between the lens and the wafer, then the effective wavelength = the vacuum wavelength of the light ÷ by n
  - For air, n is approximately equal to 1.0
  - For water, n is approximately equal to 1.4 because water is denser than air
- Shorter effective wavelengths enable smaller features to be patterned

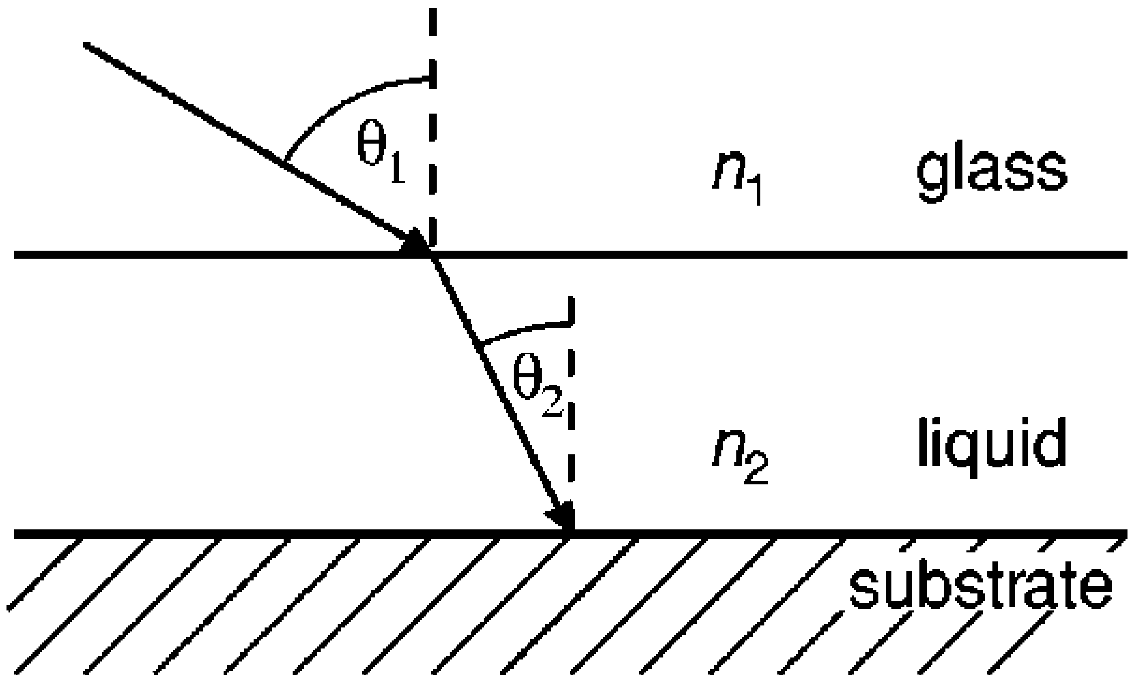


40 percent gain in resolution over conventional lithography


Lithography
1
micron 0.1
0.01
1000
100 nm
10
1980
1990
2000
2010
2020
Immersion Lithography
Lens
Liquid
Wafer
Immersion lithography is an option to extend 193 nm

Immersion photo lithography





浸没式光刻原理图

增加系统的数值孔径,可以将193 nm光刻延伸到45 nm节点以下。

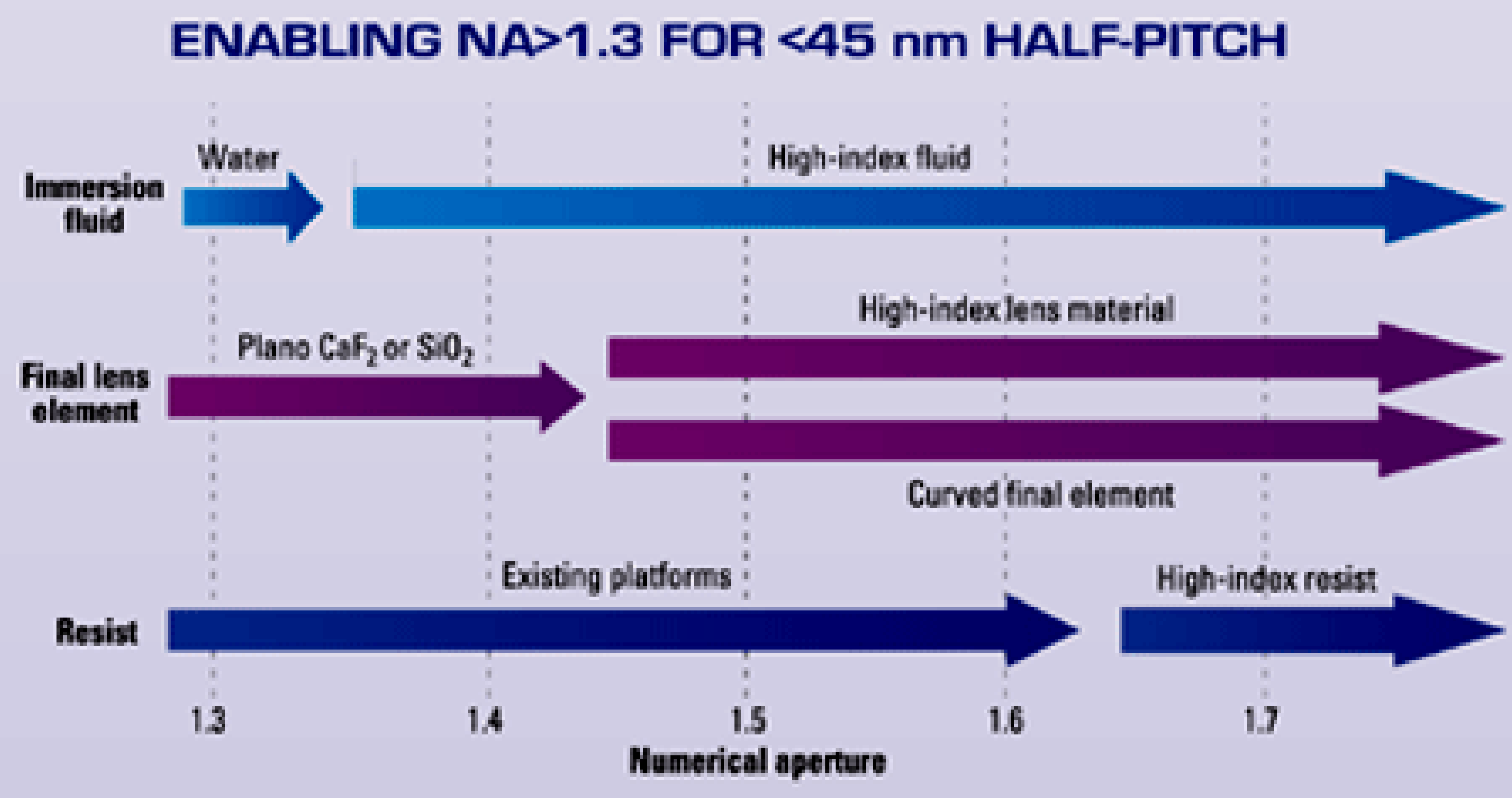
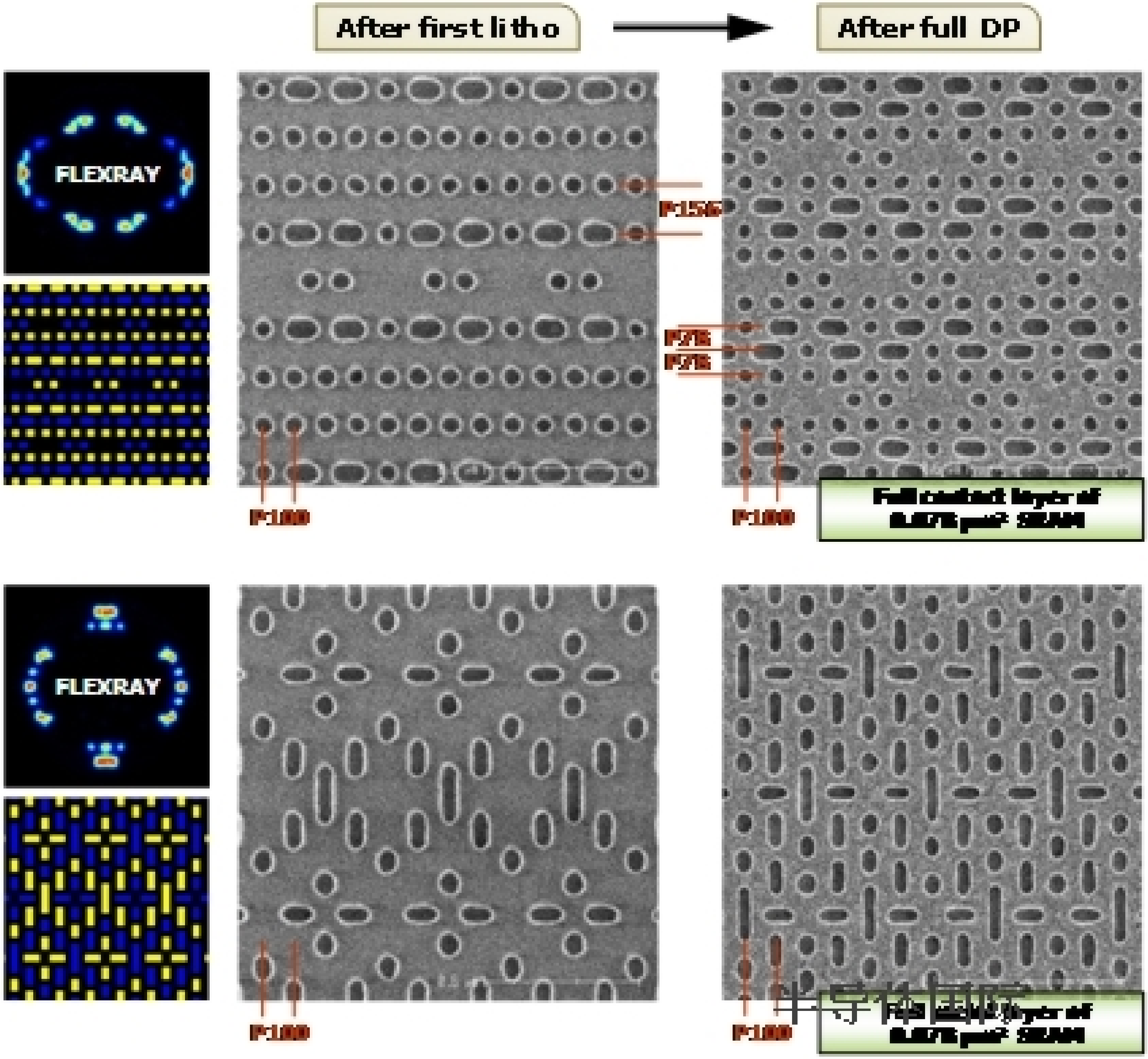


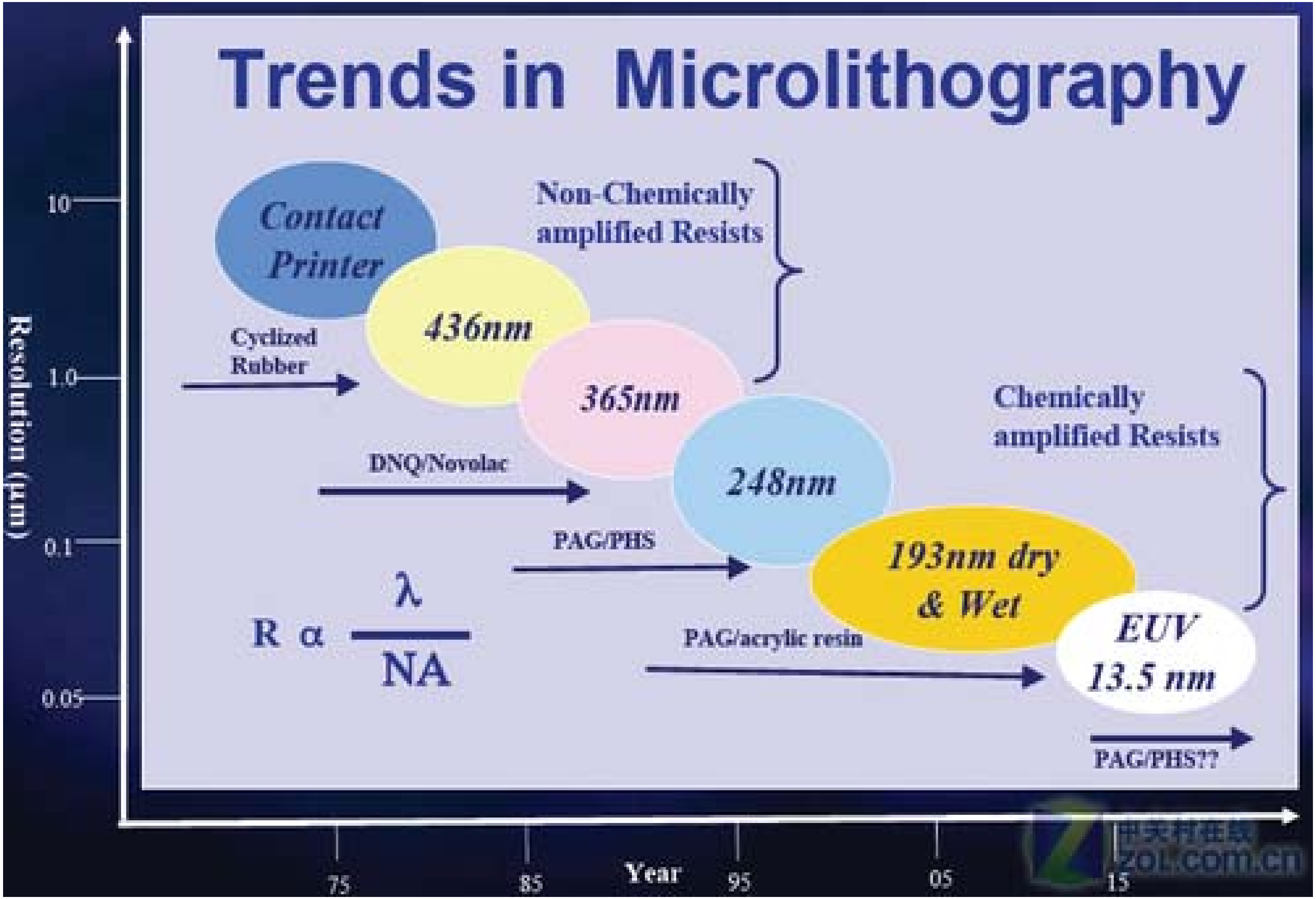
图 2 水作为浸没式光刻技术的液体，理论上数值孔径可以达到 1.3 以上，实现更大 的数值孔径就需要在高折射率液体、光学材料以及光刻胶等领域取得突破性的 进展。(来源：SEMATECH)

提高数值孔径的解决方案

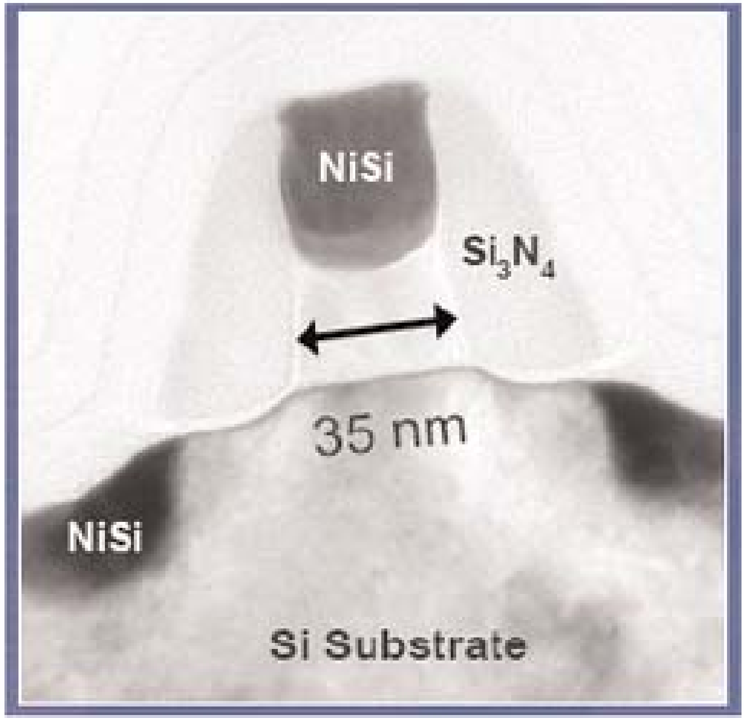
- 水＋平面镜头＋石英光学材料：~1.37
- 第二代浸没液体＋平面主镜头＋石英光学材料：~1.42
- 第二代浸没液体＋弯曲主镜头＋石英光学材料：~1.55
- 第三代浸没液体＋新光学镜头材料＋新光刻胶：~1.65
- 第三代浸没液体＋新光学镜头材料＋新光刻胶＋半场尺寸：~1.75

来源 Advanced Mask Technology Center

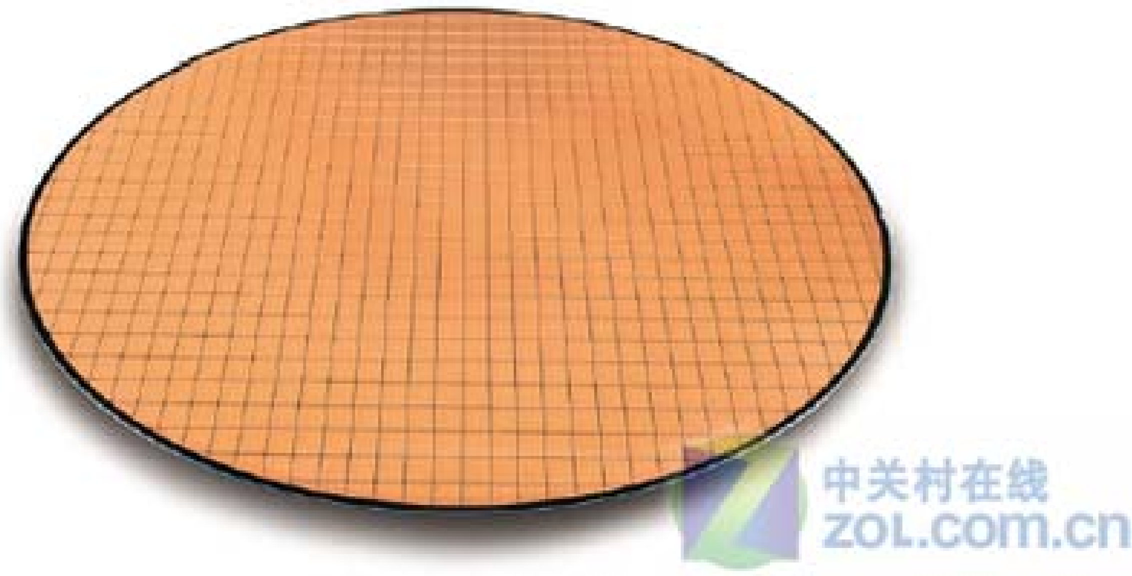

After first litho
After full DP
FLEXRAY
P156
P78
P78
P100
P100
Full contact layer of
FLEXRAY
P100
P100



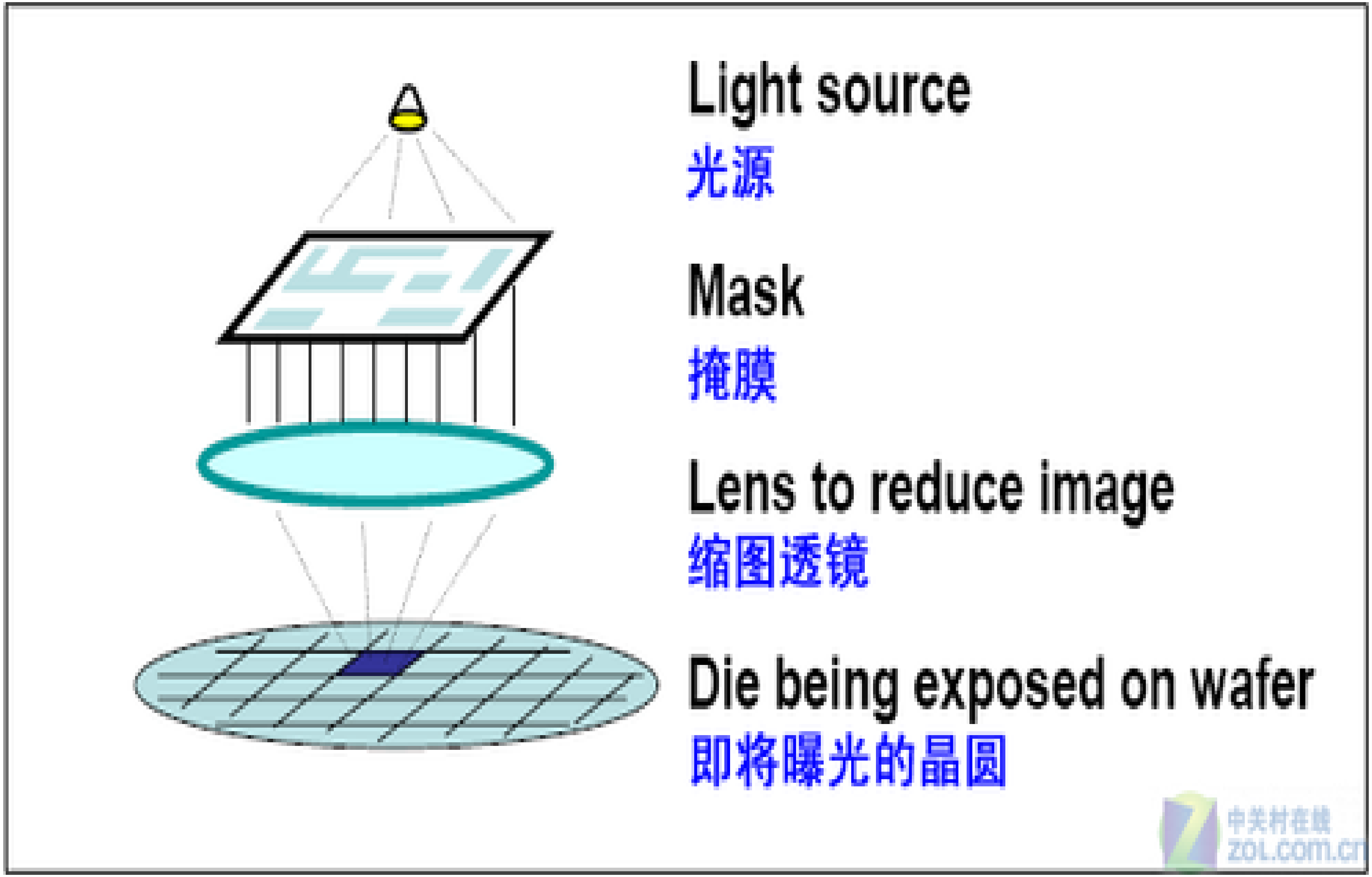
Trends in Microlithography
Contact Printer
436nm
365nm
248nm
193nm dry & Wet
EUV 13.5 nm
Non-Chemically amplified Resists
Chemically amplified Resists
Cyclized Rubber
DNQ/Novolac
PAG/PHS
PAG/acrylic resin
PAG/PHS??
R α λ / NA
Resolution (μm)
10
1.0
0.1
0.05
Year
75
85
95
05
15

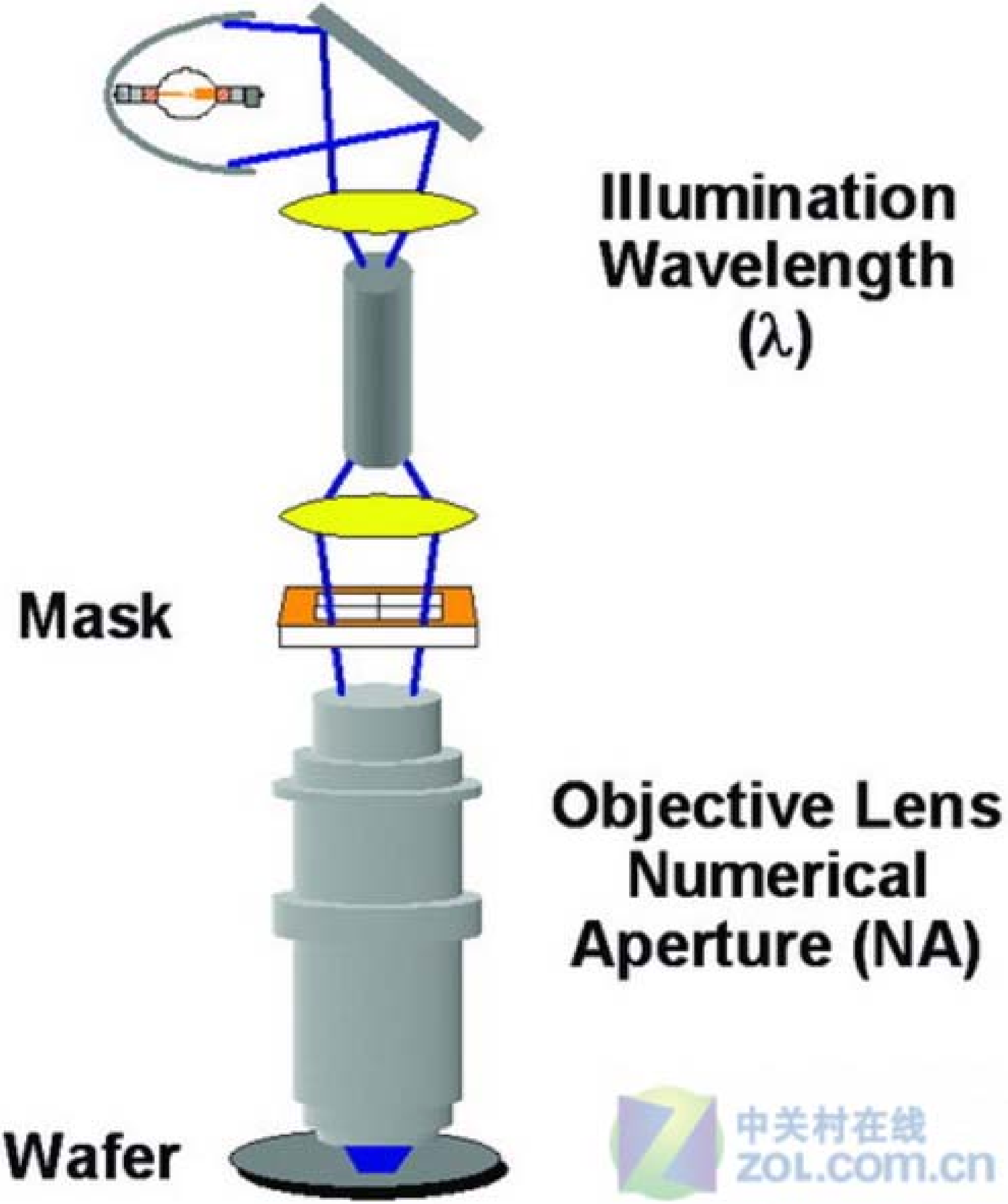


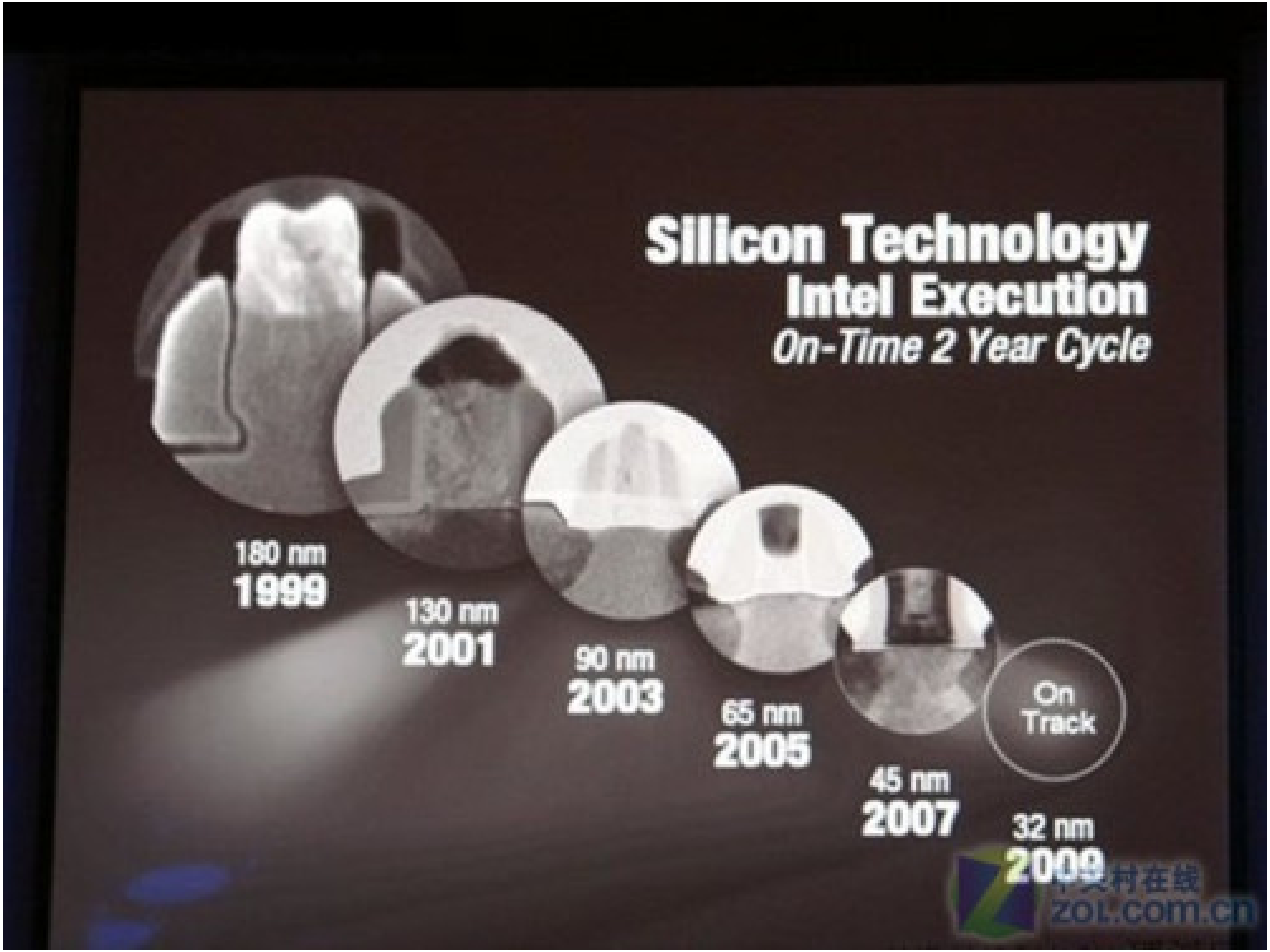
300mm wafer from Intel and transistor with 65nm feature size

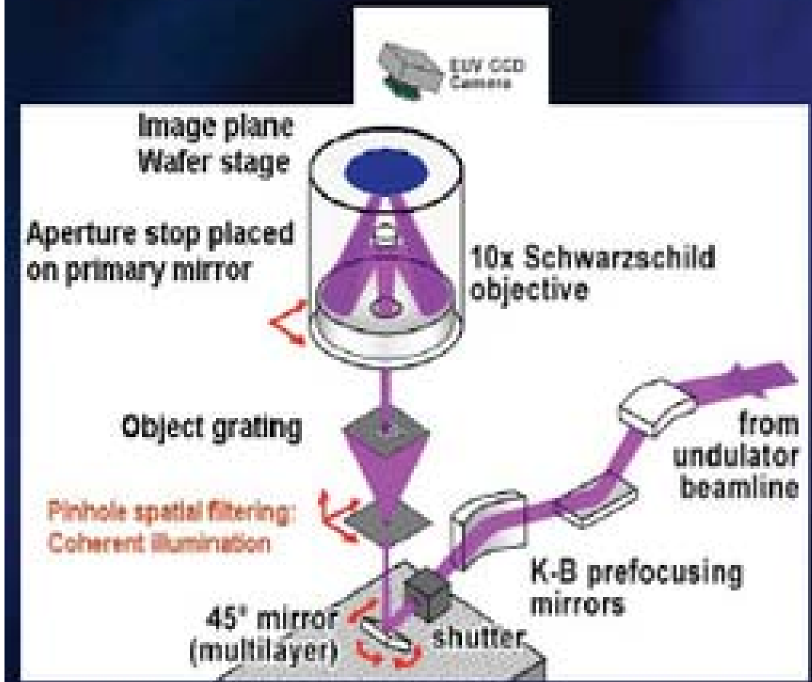


450mm wafer


Light source
光源
Mask
掩膜
Lens to reduce image
缩图透镜
Die being exposed on wafer
即将曝光的晶圆


Illumination
Wavelength
(λ)
Mask
Objective Lens
Numerical
Aperture (NA)
Wafer


Silicon Technology
Intel Execution
On-Time 2 Year Cycle
180 nm
1999
130 nm
2001
90 nm
2003
65 nm
2005
45 nm
2007
On
Track
32 nm
2009
zol.com.cn


EUV CCD Camera
Image plane
Wafer stage
Aperture stop placed
on primary mirror
10x Schwarzschild
objective
Object grating
from
undulator
beamline
Pinhole spatial filtering:
Coherent illumination
K-B prefocusing
mirrors
45° mirror
(multilayer)
shutter


中关村在线
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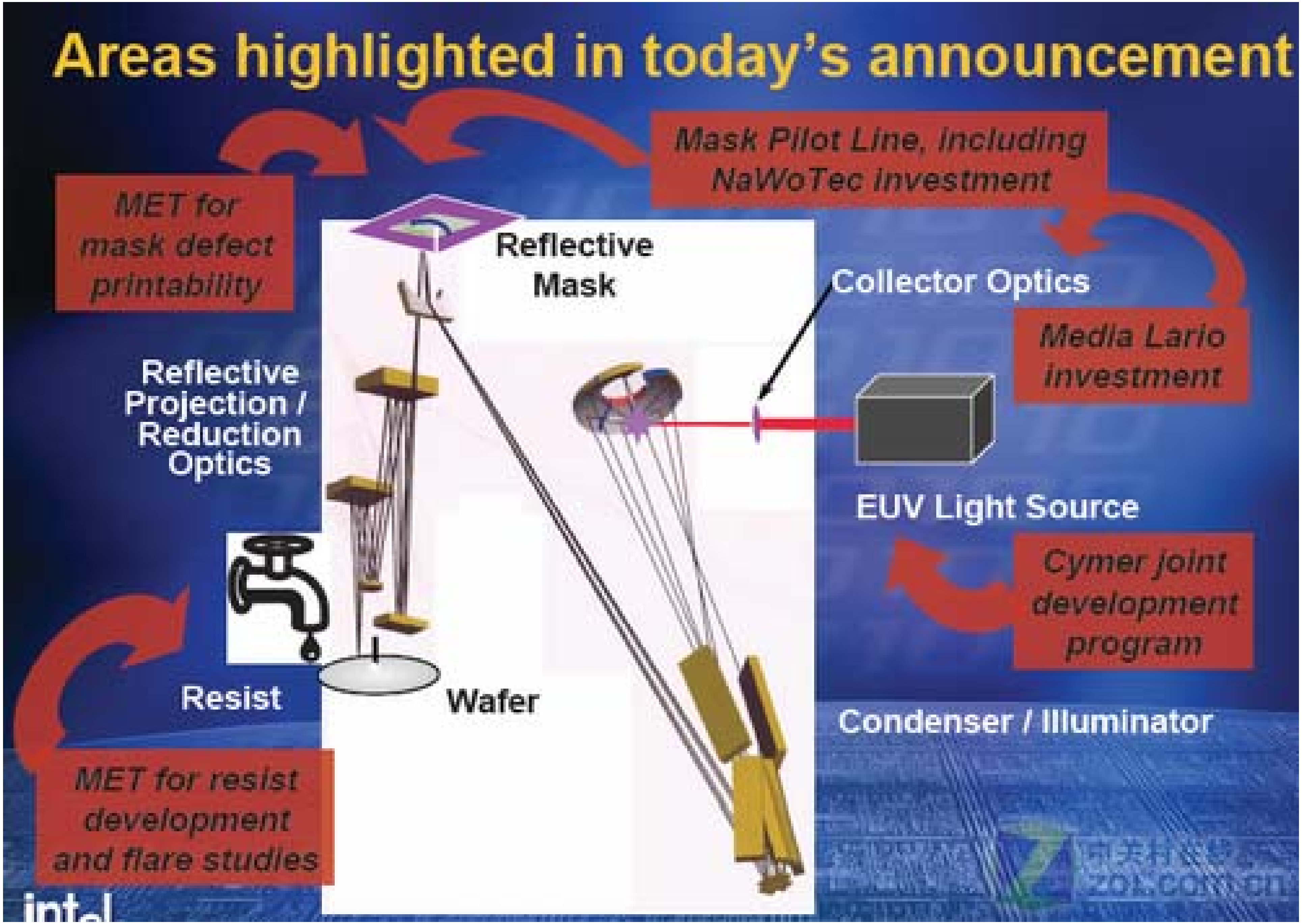
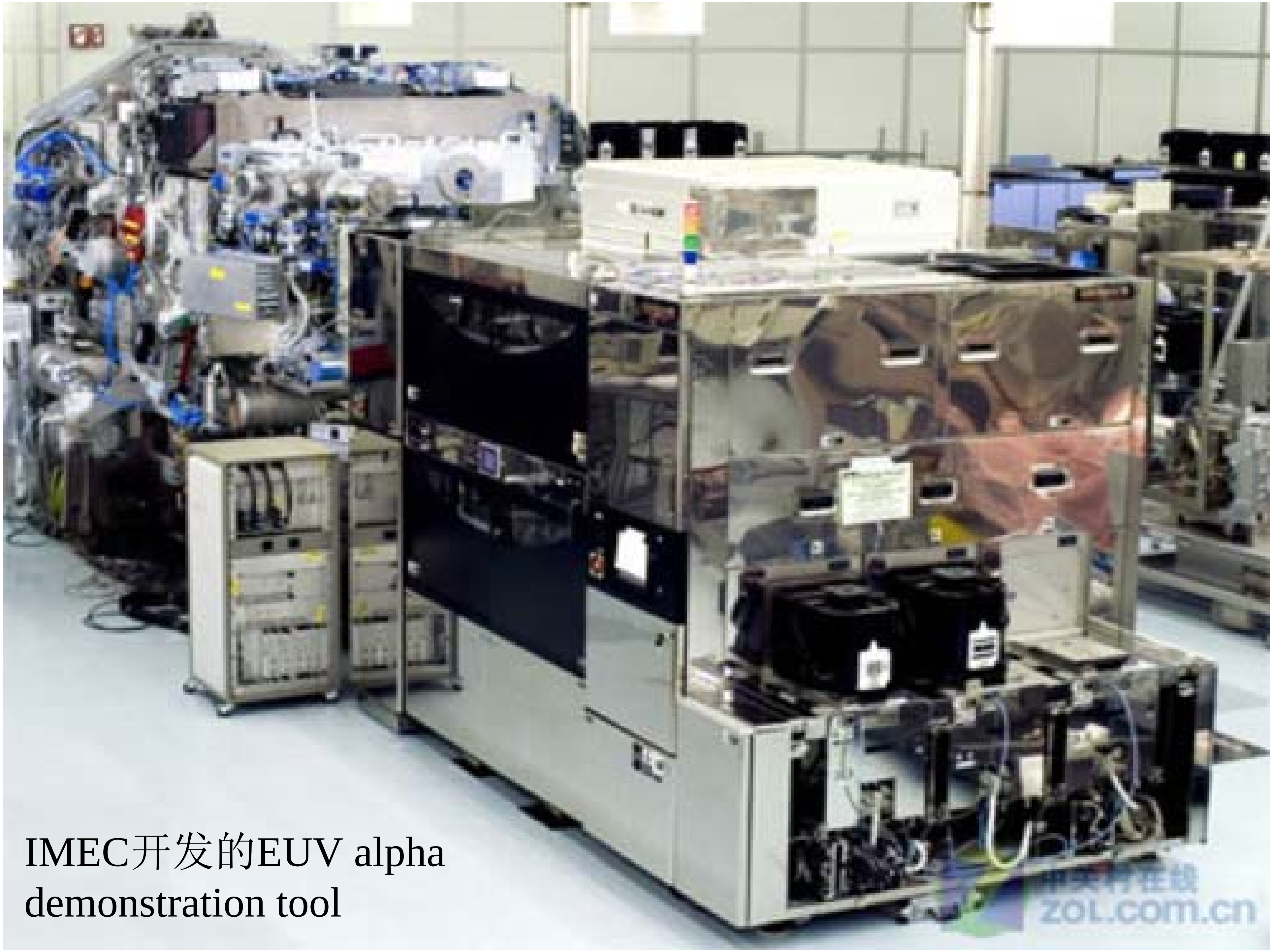

Areas highlighted in today's announcement
Mask Pilot Line, including NaWoTec investment
MET for mask defect printability
Reflective Mask
Collector Optics
Media Lario investment
Reflective Projection / Reduction Optics
EUV Light Source
Cymer joint development program
Resist
Wafer
Condenser / Illuminator
MET for resist development and flare studies



IMEC开发的EUV alpha demonstration tool

谢谢！