- principal
  - Superposition
    - interference
    - standing wave
  - Huygen's
    - diffraction
    - diffraction grating

Superposition → { same type, meet }

↓

Interference → { Same frequency, similar A }

↓

Standing wave → opposite direction

↓

Reflecting standing wave → fn

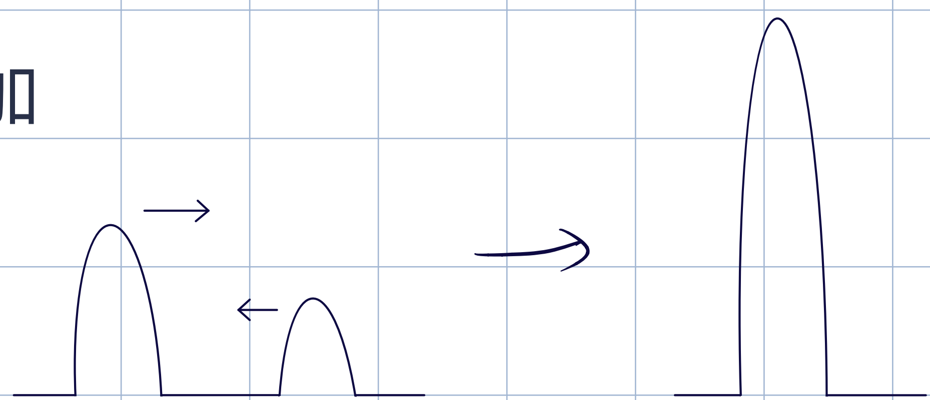
Superposition 干涉

- ## Principal of superposition

When 2 or more waves of the same type meet at a point, the resultant displacement of the oscillations will be vector sum of the individual displacement

- ## 波的叠加

相遇时



同时参与振动　　位移 = 2波之和

当 superposition 的两个波具有 same frequency & amplitude 时 则为 interference

- ## Interference Pattern 干涉图样

干涉是波的特有性质

A pattern of alternating maxima & minima amplitude where the waves combine constructively and destructively at fixed position relative to the sources.

- Condition 有明显干涉的条件

① coherent sources (稳定)

→ same frequency → constant phase difference

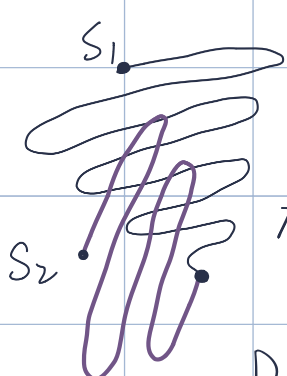
- 出自同一信号 same signal
- 反射波 & 入射波

② 振幅相同

- source with same A
- similar damped (削弱)

↳ 波在传播过程中, A 减小

* 特殊情况：符合上述条件，观察仍不明显



$d_1 > d_2$

↓ $A \propto \frac{1}{d}$

$A_1 < A_2$

↓

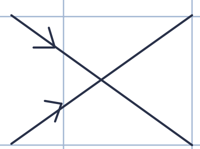
Destructively $A \neq 0$

S_1 点削弱多，amplitude 小于 S_2

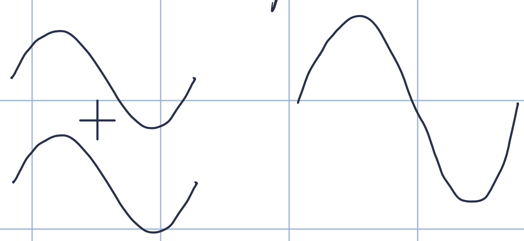
此时无法 coherent.

• 两种特殊的干涉 主语：粒子

条件：同一 Amplitude. 同一方向. phase difference 隔 π



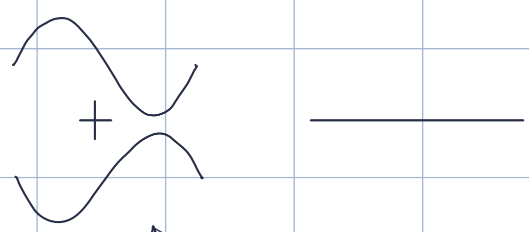
in phase



constructive interference 相长干涉

distance $= n\lambda$

out of phase



↖ s-t 图像

destructive interference 相消干涉

distance $= (n+1)\lambda$

• Explain

path difference $= n\lambda$ (in phase) / $\frac{1}{2}\lambda + n\lambda$ (antiphase)

一点对于两个 sources 的路径差

↓

phase difference $= 0 / \pi$

↓

cons (相长) / destructive (相消) interference

↓

A max / A mini

- Application

① interference of 2 coherent sources

Q: wavelength 变小. 图像怎么变?

ep. 杨式双缝实验. 求可见光波长

② interference of 2 reflected sources

ep. 读光盘. 泡泡

分析频率不一样的两个波的干涉

different f → changing phase difference with t

↳ same / greater / smaller

分析频率变化的两个波的干涉

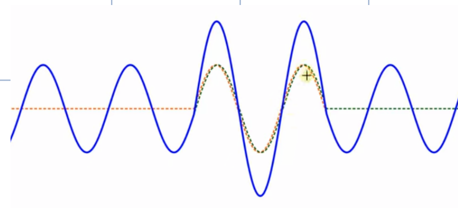
change f with time → path difference = kλ

→ phase difference

↳ constant / increasing / decreasing

Stationary wave 驻波

= Standing wave



def.

- Stationary/Standing wave: Continuous wave traveling in the opposite direction will superpose continuously and produce nodes and antinodes. This can set up a stationary wave pattern.

- Coherent: Wave with the same frequency and a constant phase relationship.

频率、振幅相同，方向相反

关联

不同 VS. progressive (= longitudinal) 行波

	驻波 stationary	行波 progressive
E transfer	storing	transfer
Amplitude	0~Amax	constant
Phase	in phase	不同

← wave motion

← oscillation

相同 VS. interference

- same frequency
- similar amplitude
- superpose
- opposite direction

→ max — A — constructive

→ min — N — destructive

解释 interference/驻波

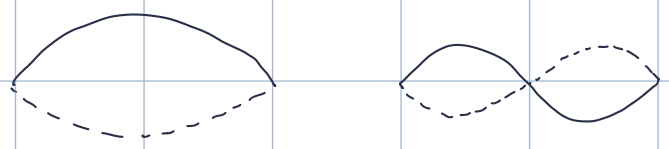
path difference = nλ

↓ 条件 {波源 in phase; 过程中无硬反射/硬反射相消}

in phase

● Conditions 形成反射驻波的条件

① resonant frequencies



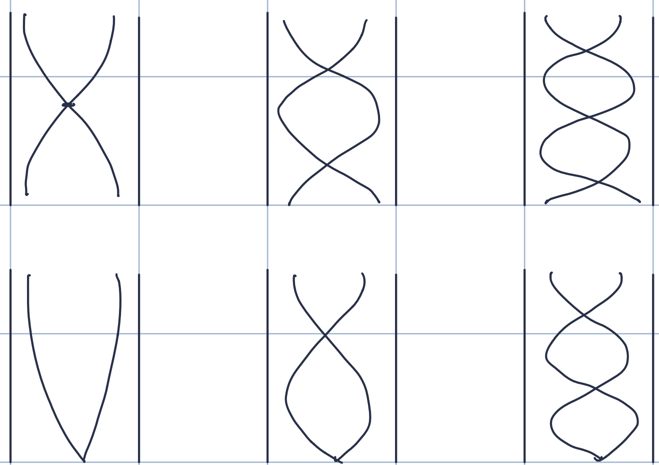
fundamental $f_0 = \frac{v}{2l}$

2nd harmonic $f_2 = \frac{v}{l}$

3rd hamonic $f_3 = \frac{v}{\frac{3}{2}l}$

$$f_n = \frac{nv}{2l}$$

② Phase change in reflection



$$L = \frac{n\lambda}{2}$$

$$L = \frac{(2n-1)\lambda}{4}$$

$$f_n = \frac{(2n-1)v}{4L}$$

大四步

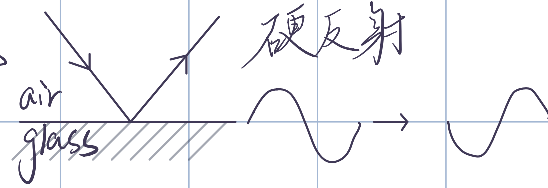
path difference	→ phase difference	→ interference	→ amplitude
$n\lambda$	0	cons	max
$(n+\frac{1}{2})\lambda$	π	des	mini

适用条件：① 无反射

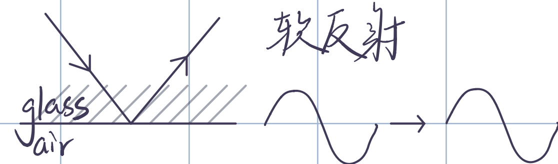
② 波源无波损（波损在硬反射之后出现）

有波损：phase 与 distance 不成正比
无法以 path difference 为起点

硬反射



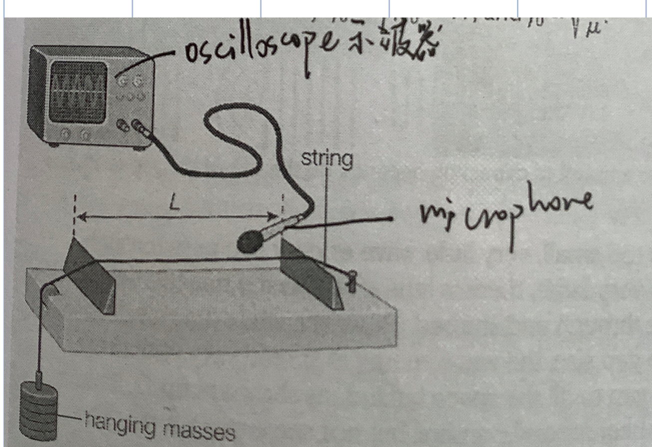
软反射



Wave speed

$$V=\sqrt{\frac{T}{\mu}}$$

$$f_0=\frac{1}{2L}\sqrt{\frac{T}{\mu}}$$ (fundamental frequency)



测绳子fundamental frequency的影响因素

① $f_0\propto\frac{1}{L}$ 改变弦的长度

② $f_0\propto\sqrt{T}$ 改变弦的质量

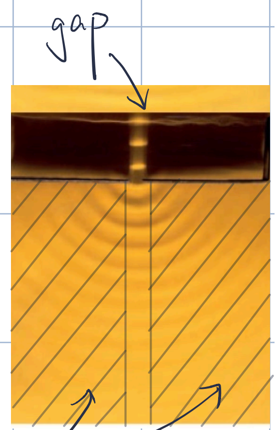
③ $f_0\propto\sqrt{\frac{1}{\mu}}$ 改变弦的直径

→ 单位 kgm^{-1}

Diffraction 衍射

- def.

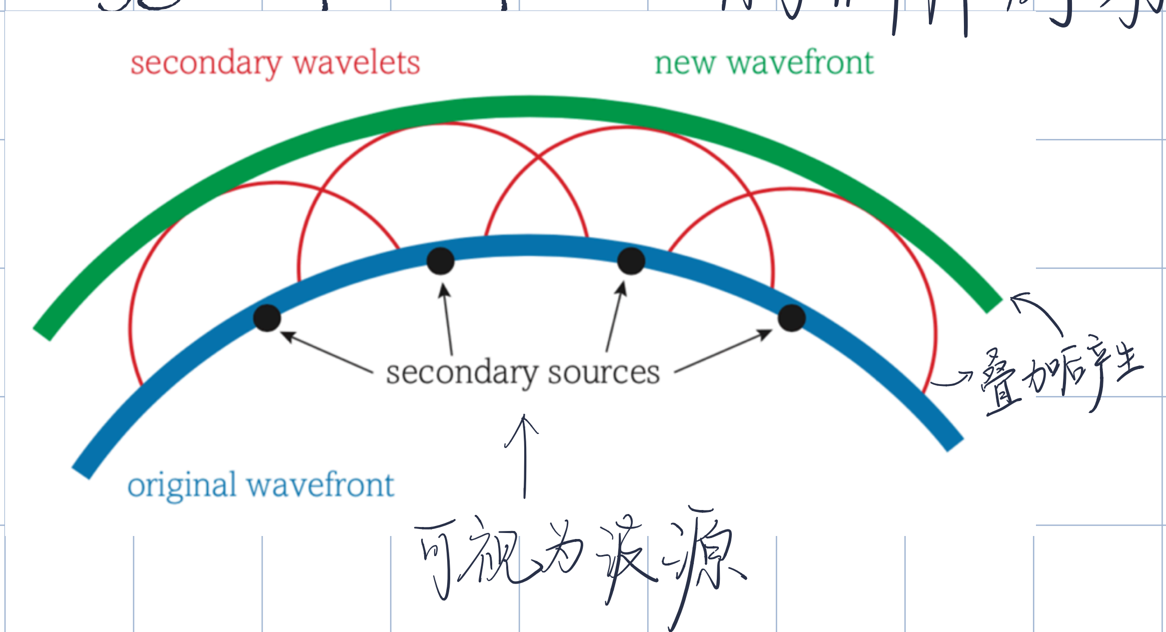
(与 interference & stationary 一样，都为现象)



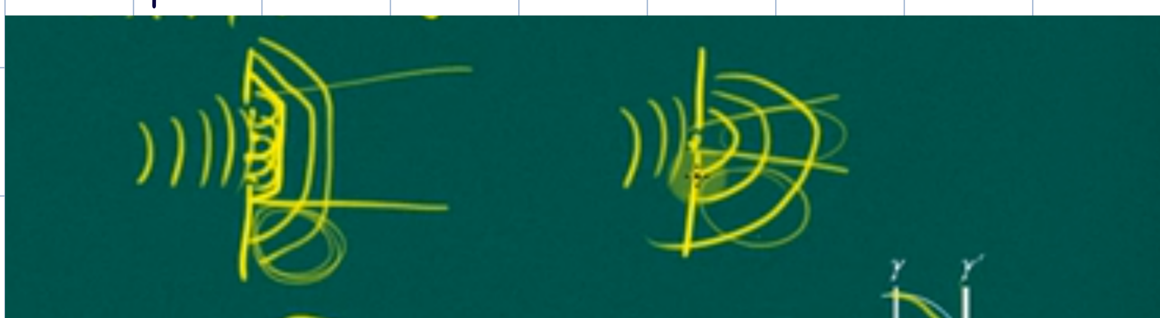
是什么 The wave energy spread out into "shadow" region

何时出现 When a wave passes through a gap or around an obstacle

- Huygen's principal 用于解释衍射



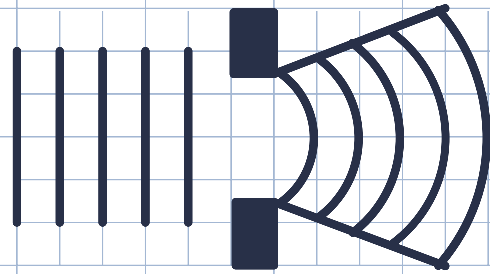
解释衍射



Amount of diffraction

① Wave pass through a **hole**

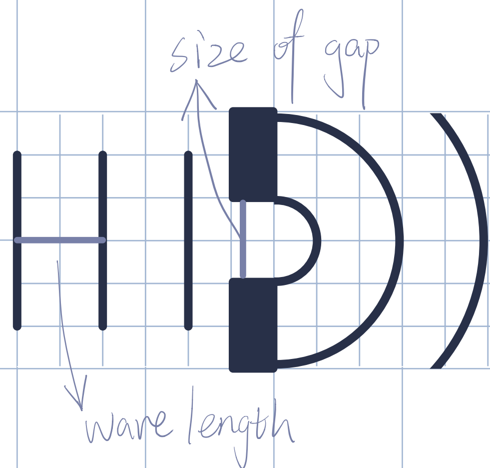
- 若 gap size $> \lambda$ →



gap size 越接近λ，角度越大

- 若 gap size $\approx \lambda$ →

wave front 为半圆



- 若 gap size $< \lambda$

gap size 变小，角度不变，energy 变小

② Wave pass through an **obstacle**

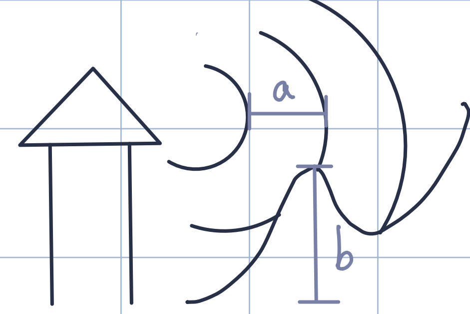
f小 → λ大

size of obstacle↑ (通常≈波长)

→ the amount of diffraction↑

衍射明显

生活中的diffraction



若a≈b,会发生很好的衍射

1. radiowave — hill
2. sound — door

   λsound ≈ 50cm ≈ 门宽

3. Xray — DNA/晶体 (将分子视为obstacle)

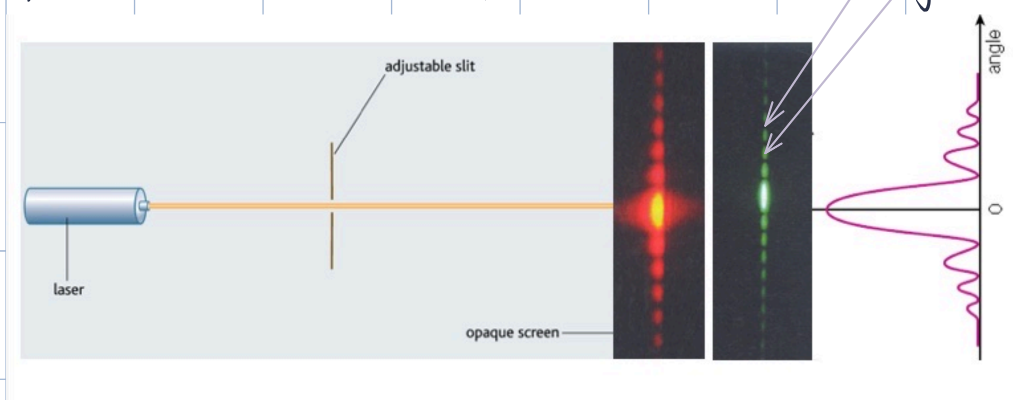
   波长 ≈ 直径 ≈ 10^{-10}m

实验中的diffraction

1. microwave — slit
2. light — slit

单缝衍射:(连续波源,呈像较模糊)

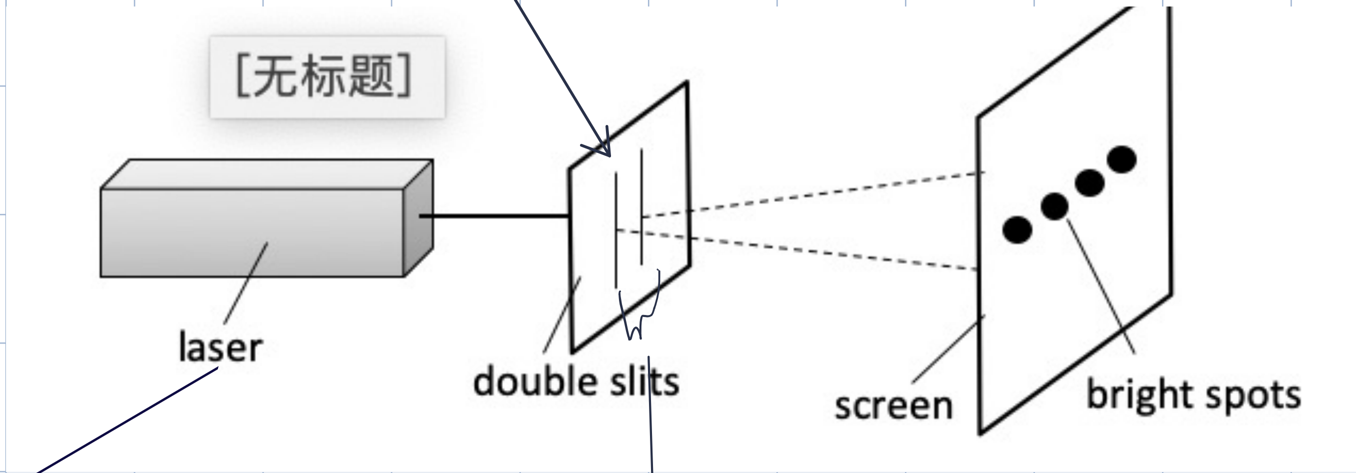
dark: des
light: con



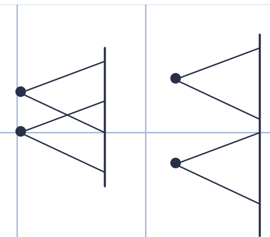
wavelength与slit宽度越接近,diffration better,
light spots和dark spots in宽度越大

双缝干涉：(杨式双缝实验)

缝要窄：宽度要接近 wave length



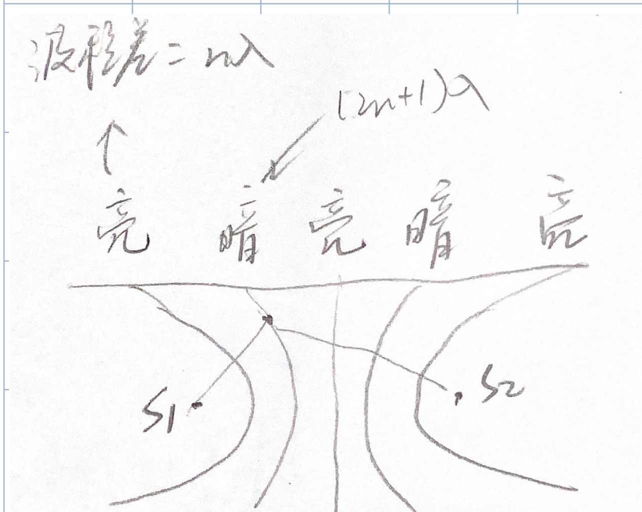
两条缝不能离太远：否则 two waves won't overlap



laser 光的频率稳定

目的：产生相干波源 —— f & p.d 相同

(也可用单色平行光替代)



现象：

① 干涉条纹明暗，间距相同

② 同一双缝，波长越长，两点距离越大

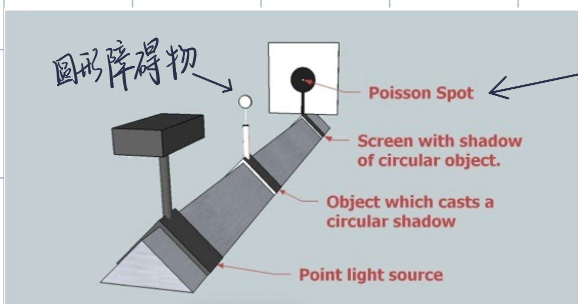
3. light — spot

单缝与双缝的区别

单缝：衍射　明暗相间不均匀　中间亮，光圈大

双缝：干涉　间隔相近

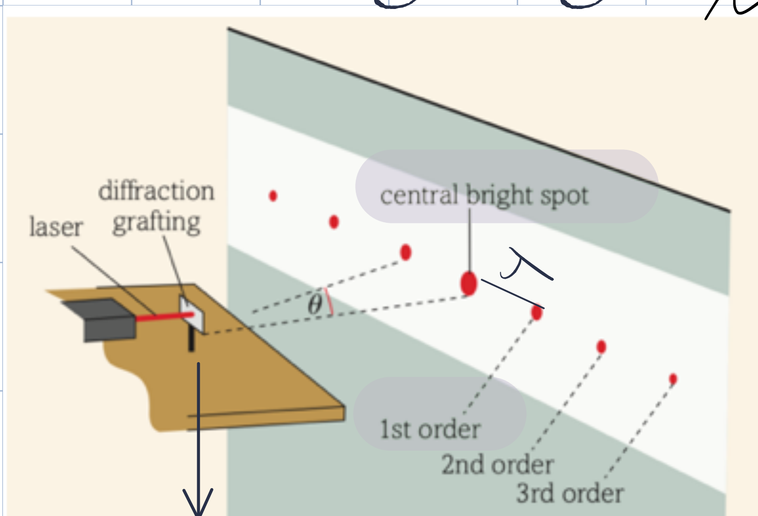
4. light — round obstacle



中间有亮点（泊松光斑）

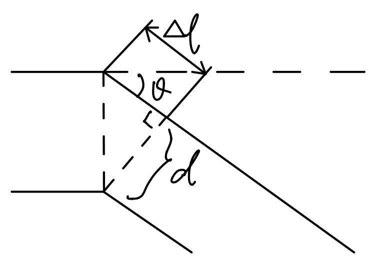
障碍物越大，泊松光斑越大

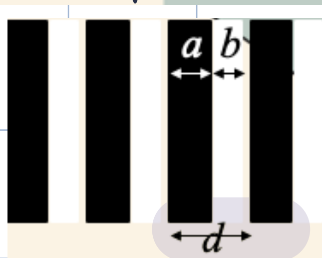
● diffraction grating 光栅衍射



For n^{st} order:

$$n\lambda = d\sin\theta$$





几条波通过几微米的缝

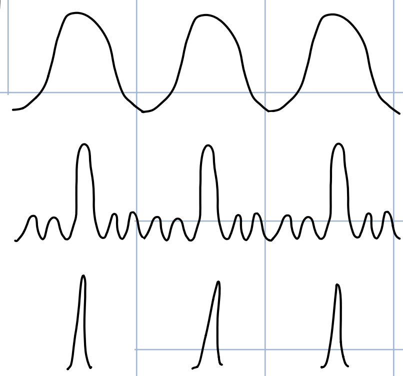
走直线射入几米处的屏幕上形成亮斑

- 与双缝的区别

2 slits

6 slits

几万条



← 因为能量集中，边缘sharp

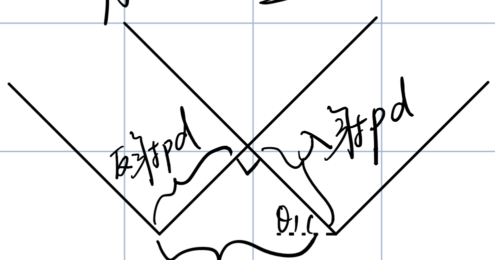
- spectrum 光谱

现象：红光和紫光在第一个波长时，位置不同

n=0 不发 spetrum，因为没有多种颜色光线

- 反射光栅

应用：光盘



相邻两个反射点的距离

path difference：

$d(\sin\theta_1 \pm \sin\theta_2)$