

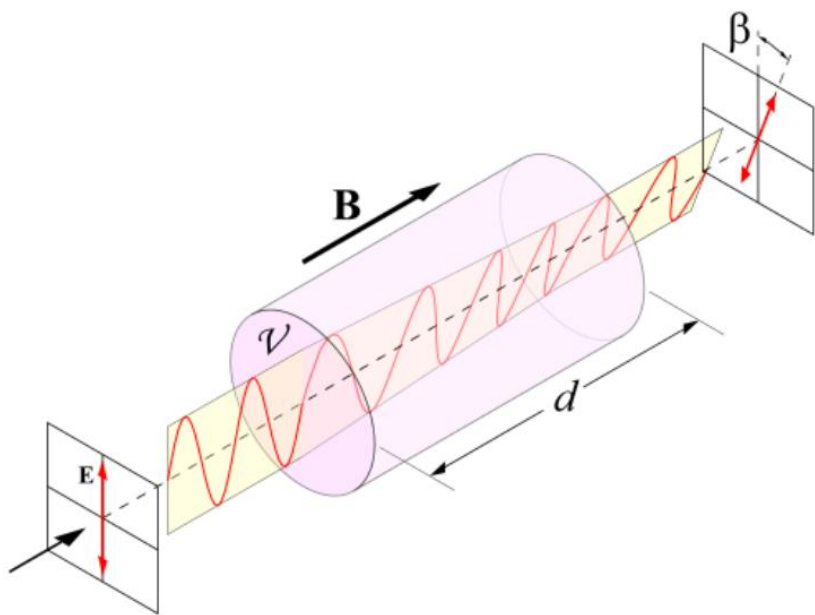
法拉第效应

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指导老师：赵俊，姚红英

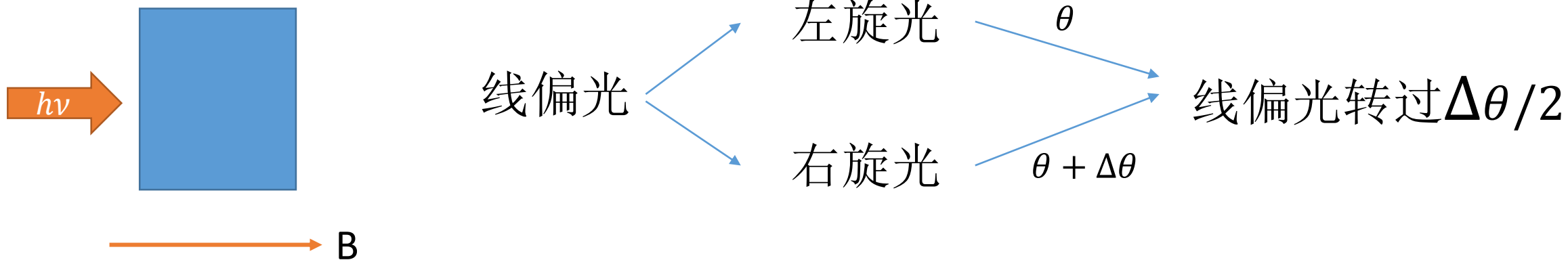
法拉第效应



磁 \longleftrightarrow 光

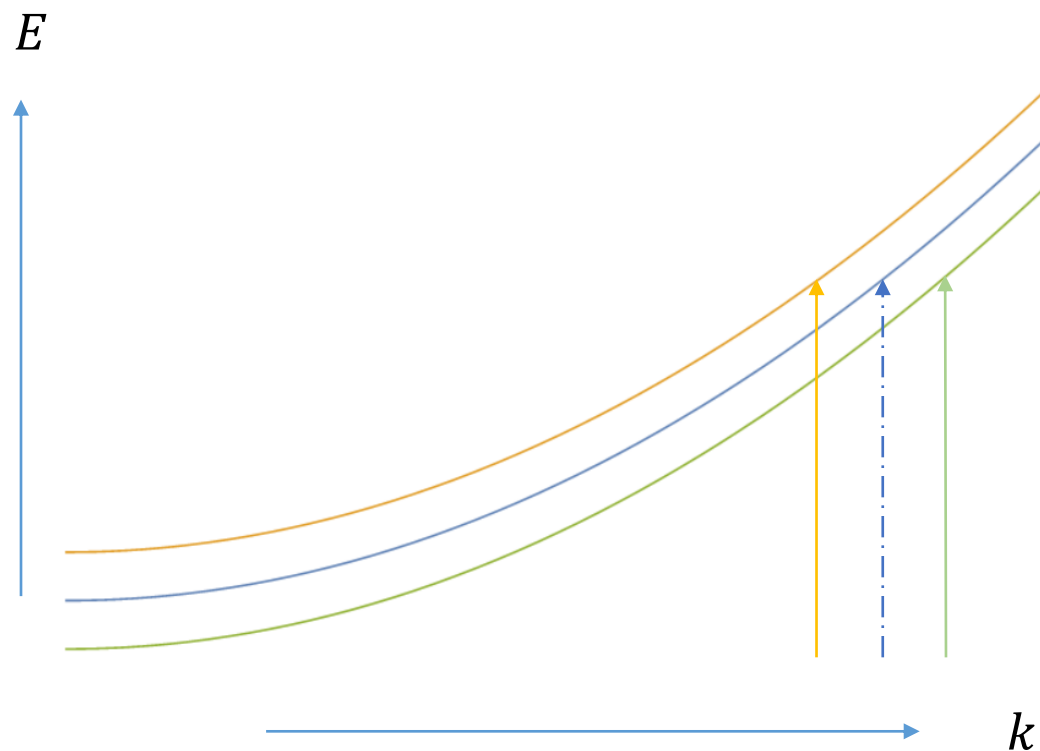
实验原理

磁场 \longrightarrow 晶体手征对称性被破坏 \longrightarrow 左右旋光折射率不同



实验原理

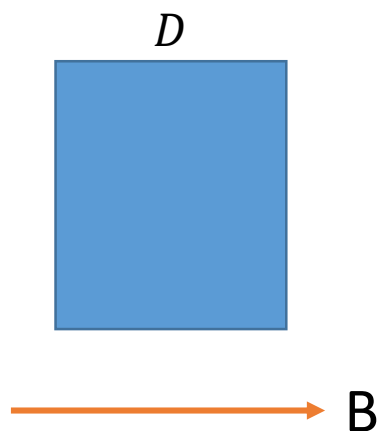
磁场 \longrightarrow 塞曼分裂 \longrightarrow 选择性吸收



$$n_L(\omega) = n\left(\omega - \frac{eB_0}{2m}\right) = n(\omega) - \frac{eB}{2m} \cdot \frac{dn}{d\omega}$$
$$n_R(\omega) = n\left(\omega + \frac{eB_0}{2m}\right) = n(\omega) + \frac{eB}{2m} \cdot \frac{dn}{d\omega}$$

B : 磁场强度
 m : 电子有效质量
 e : 电子电荷

实验原理



$$\Delta\varphi = \frac{\Delta\theta}{2} = \frac{\omega D}{2c(n_R - n_L)} = -\frac{D B e}{2 m c} \lambda \frac{dn}{d\lambda} = V(\lambda) D B$$

$$V(\lambda) = -\frac{e}{2mc} \lambda \frac{dn}{d\lambda}$$

D : 晶体厚度
 B : 磁场强度
 m : 电子有效质量
 e : 电子电荷
 c : 光速

实验设计

- 偏振偏转检验

$$\Delta\varphi = \frac{\Delta\theta}{2} = -\frac{e}{2mc} \lambda \frac{dn}{d\lambda} DB$$

$$\Delta\varphi \propto B$$

1. 光强不变

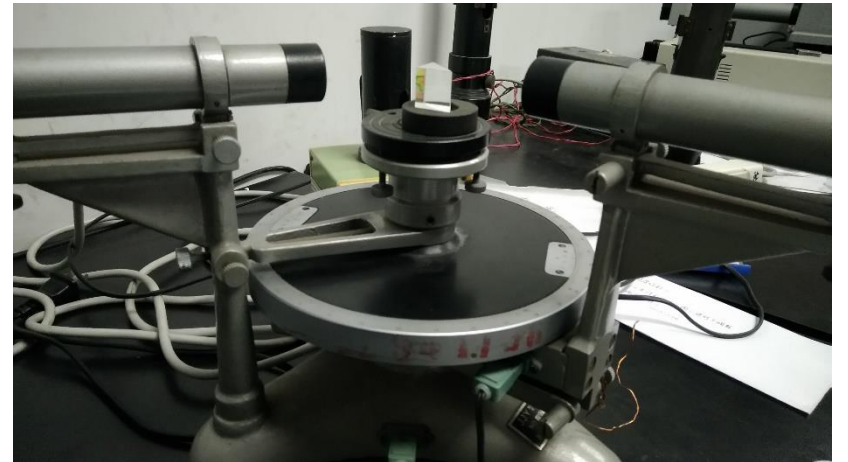
2. 偏转角与磁场成正比

实验设计

- 定量常数检验

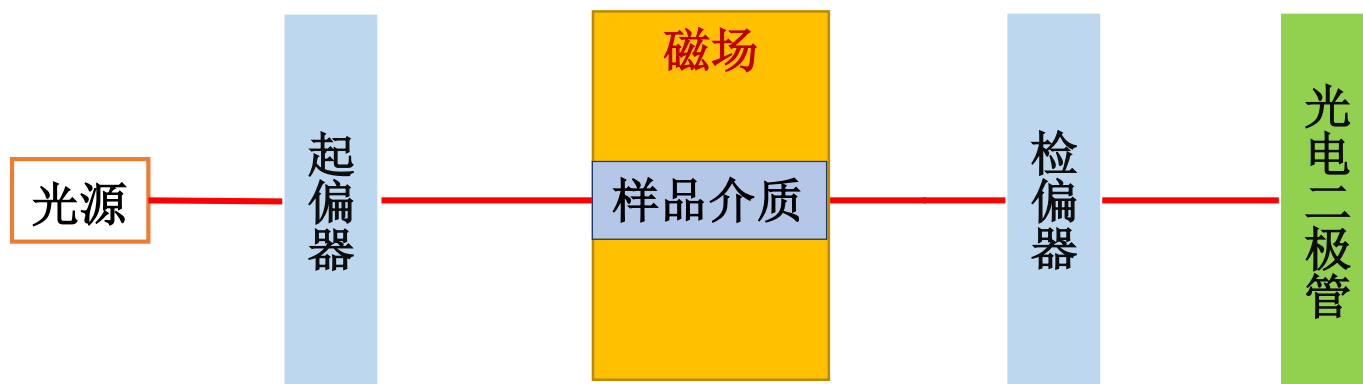
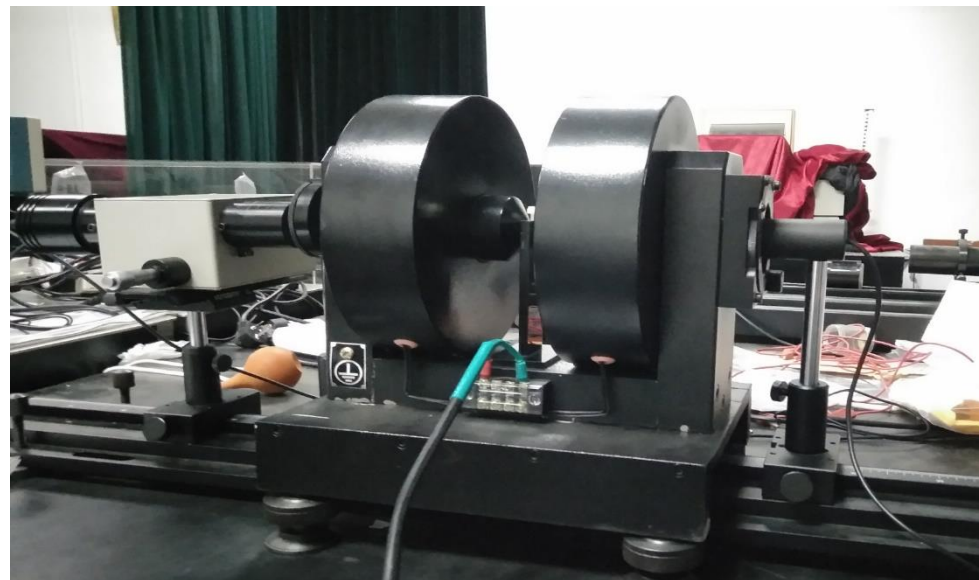
$$\Delta\varphi = \frac{\Delta\theta}{2} = -\frac{e}{2mc} \lambda \frac{dn}{d\lambda} DB$$

分光计 \longrightarrow 折射率@不同波长 $\xrightarrow{\text{拟合}}$ $\lambda \frac{dn}{d\lambda}$



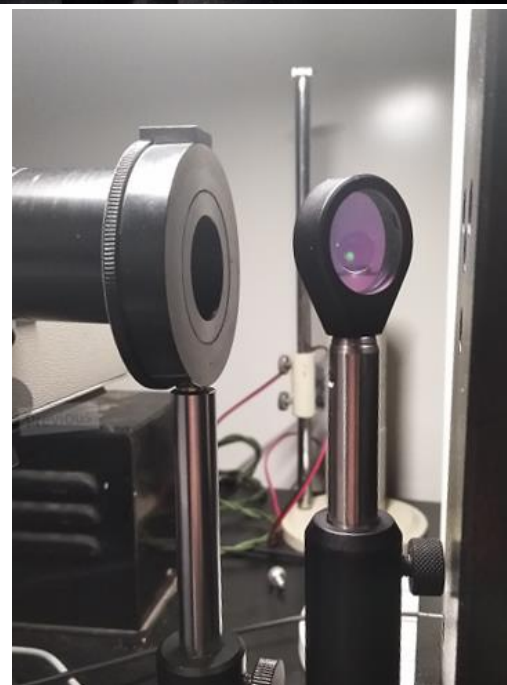
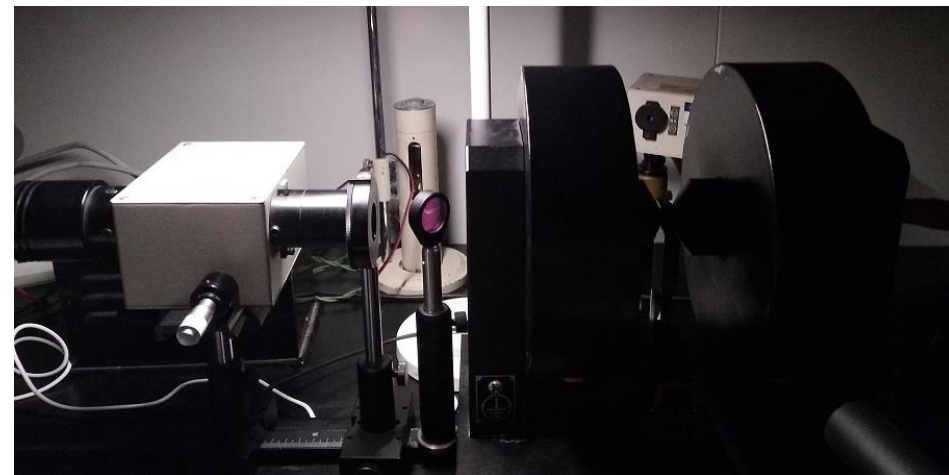
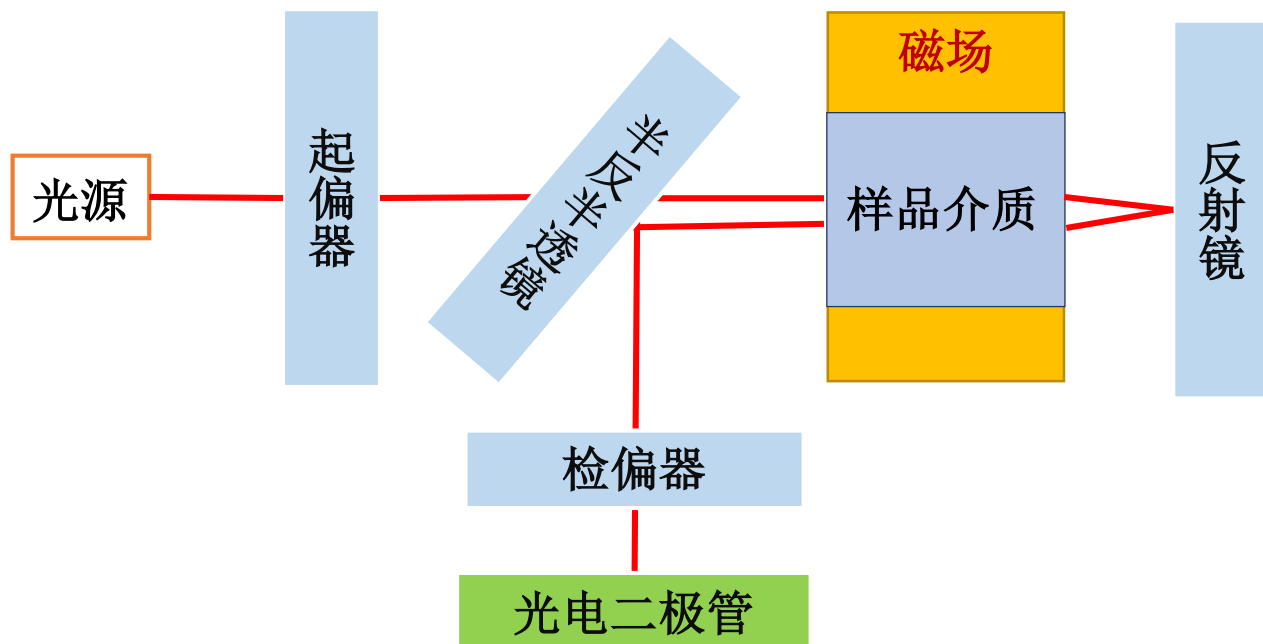
实验设计

- 透射



实验设计

- 反射



光强太小!

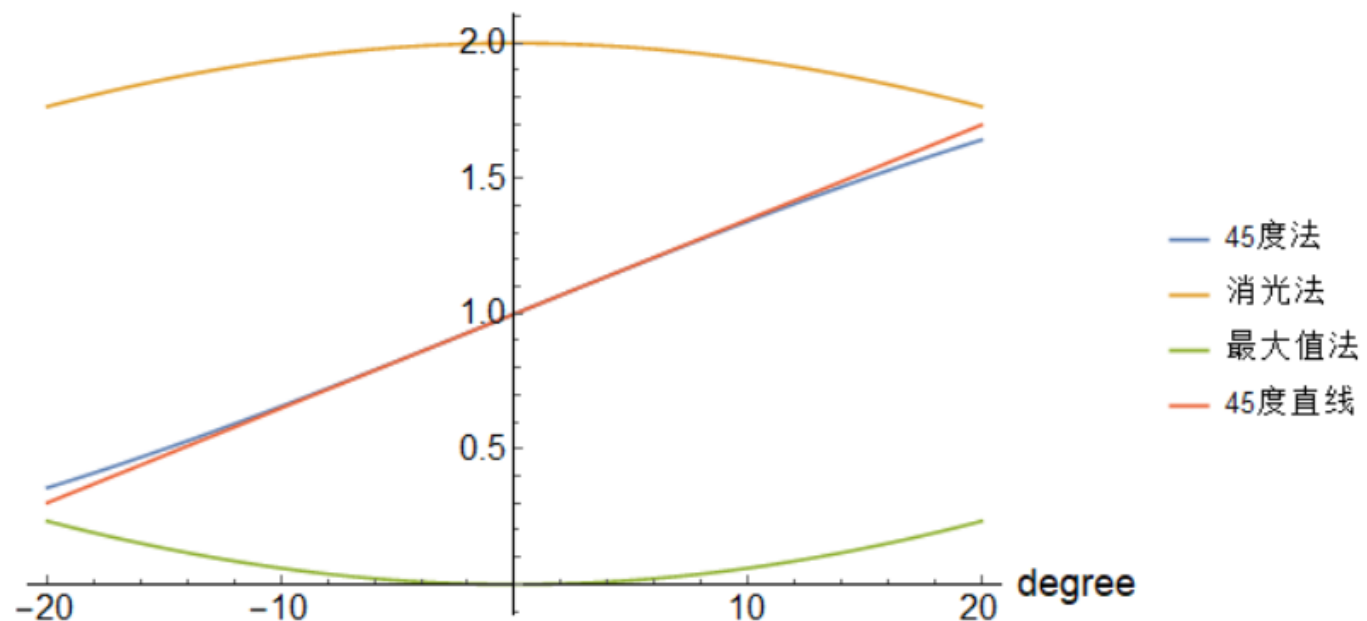
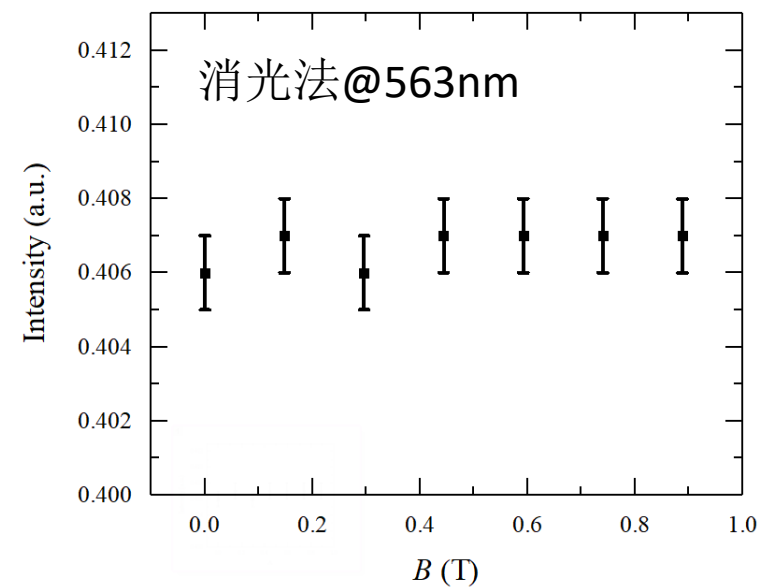
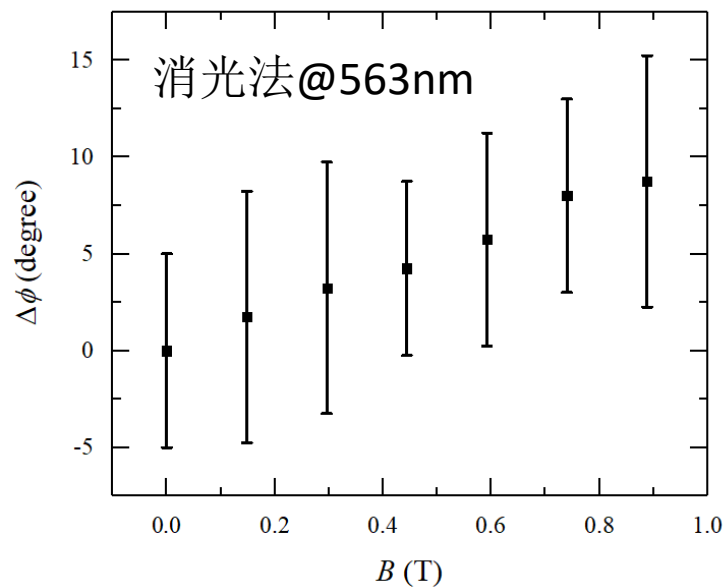
实验设计

- 检验方法

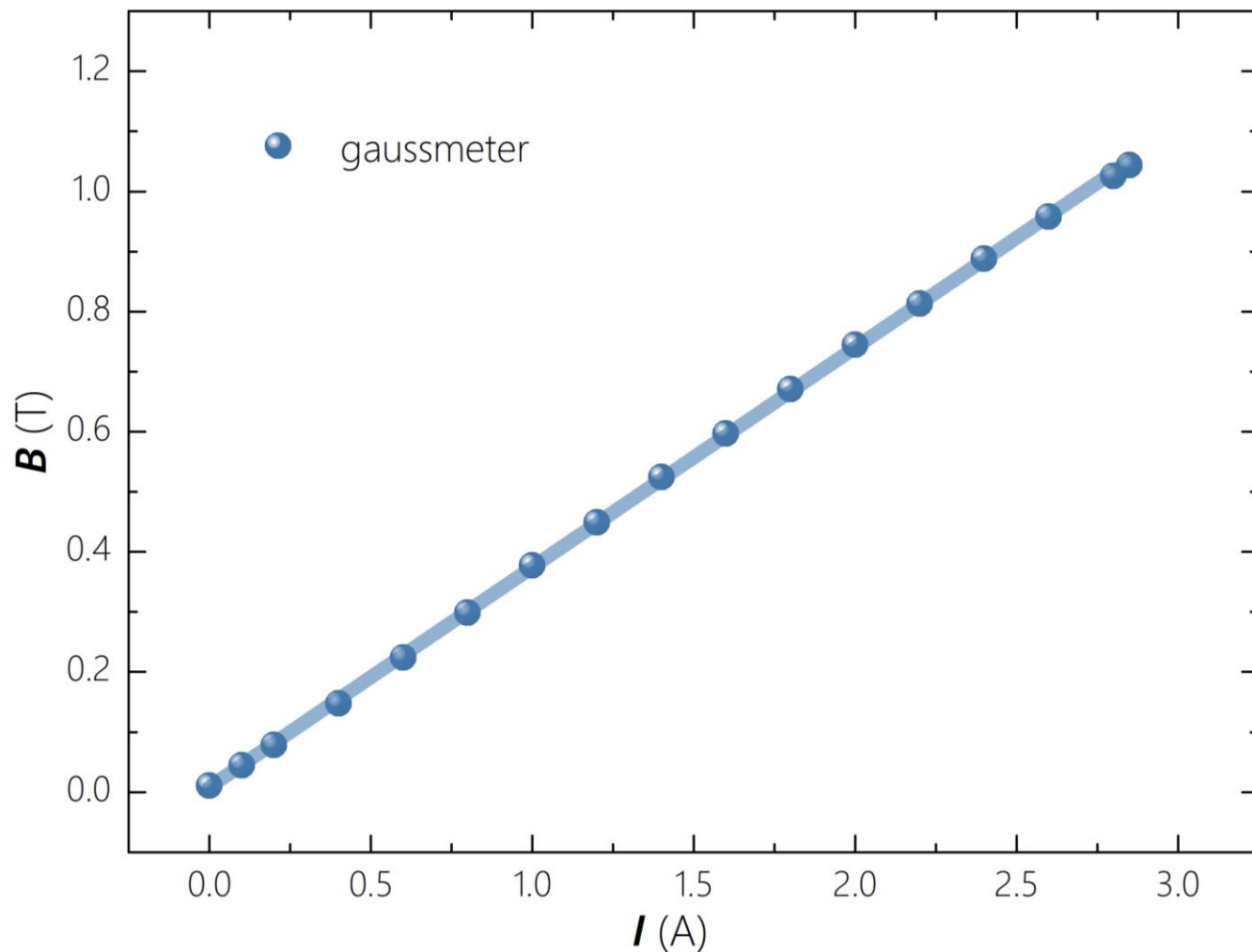
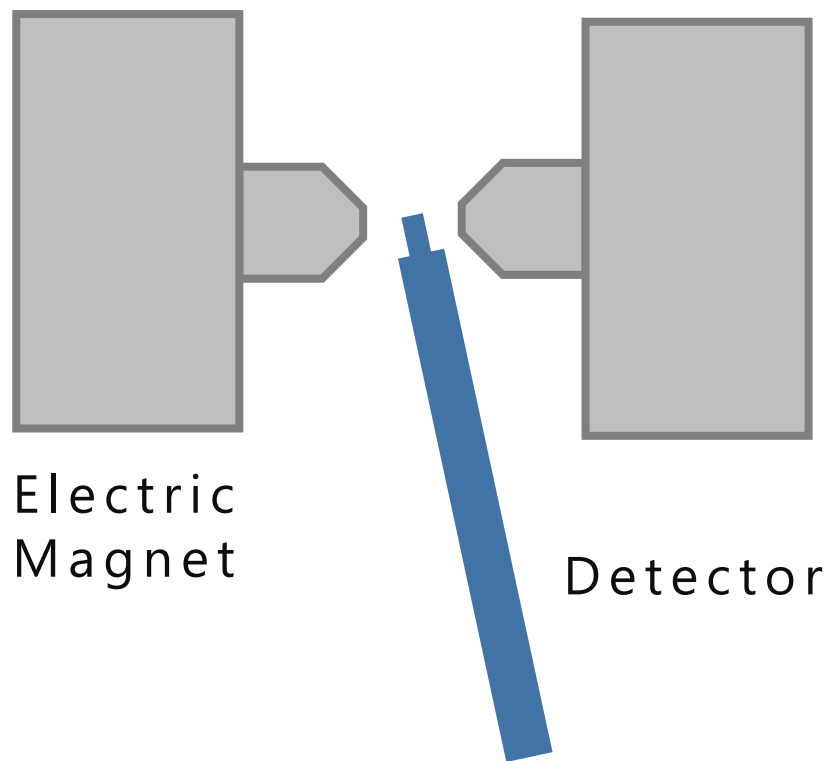
$$U(\theta) = U_0 \cos^2 \theta$$

$$\frac{dU}{d\theta} = -U_0 \sin 2\theta$$

@45度 $\Delta U = \frac{dU}{d\theta} \Delta\theta \propto B$

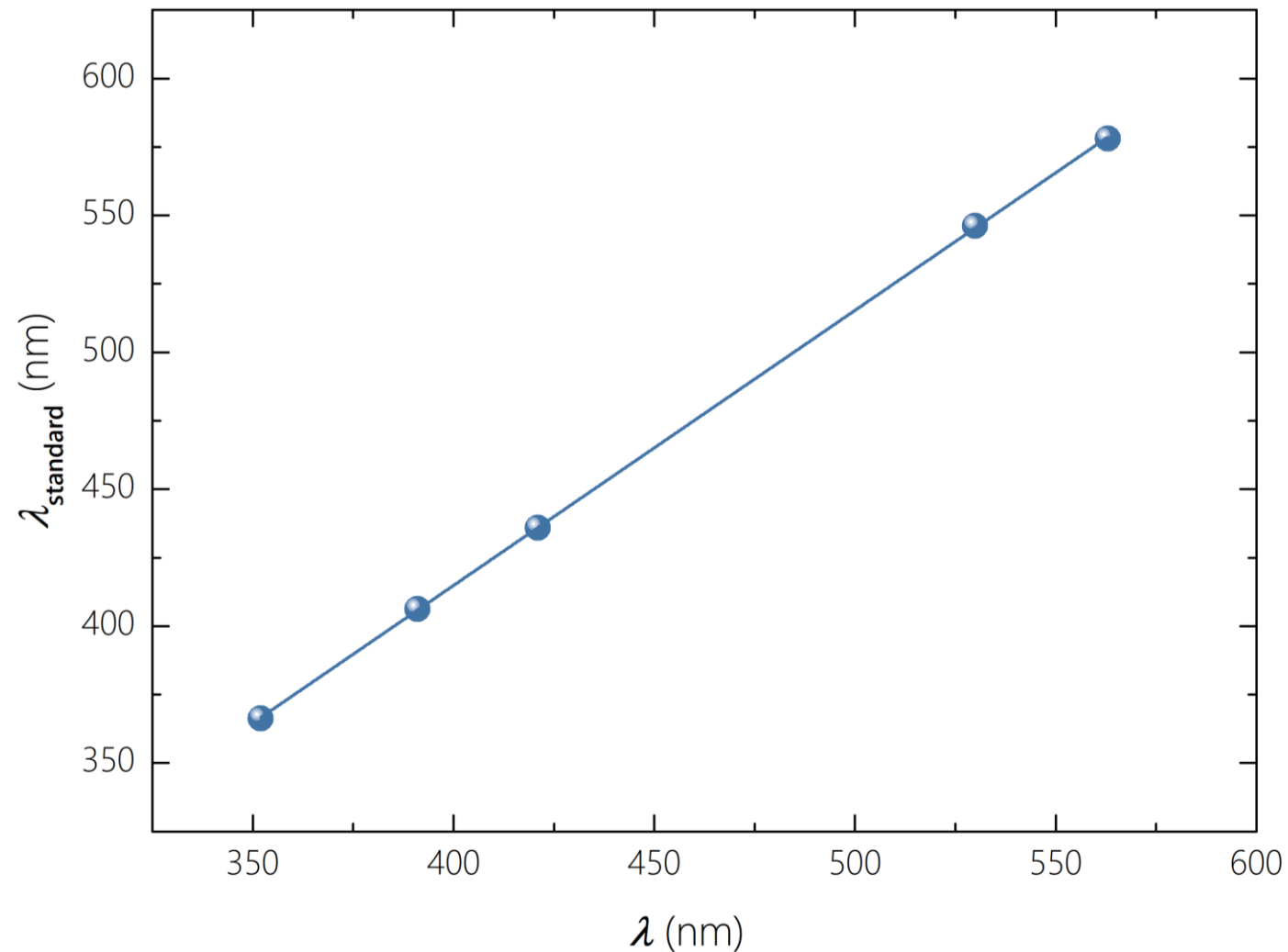
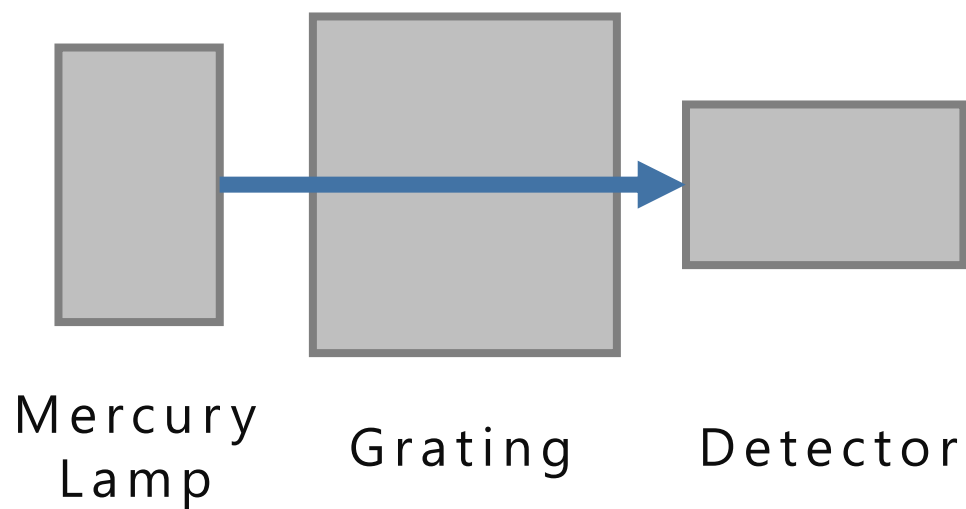


实验分析



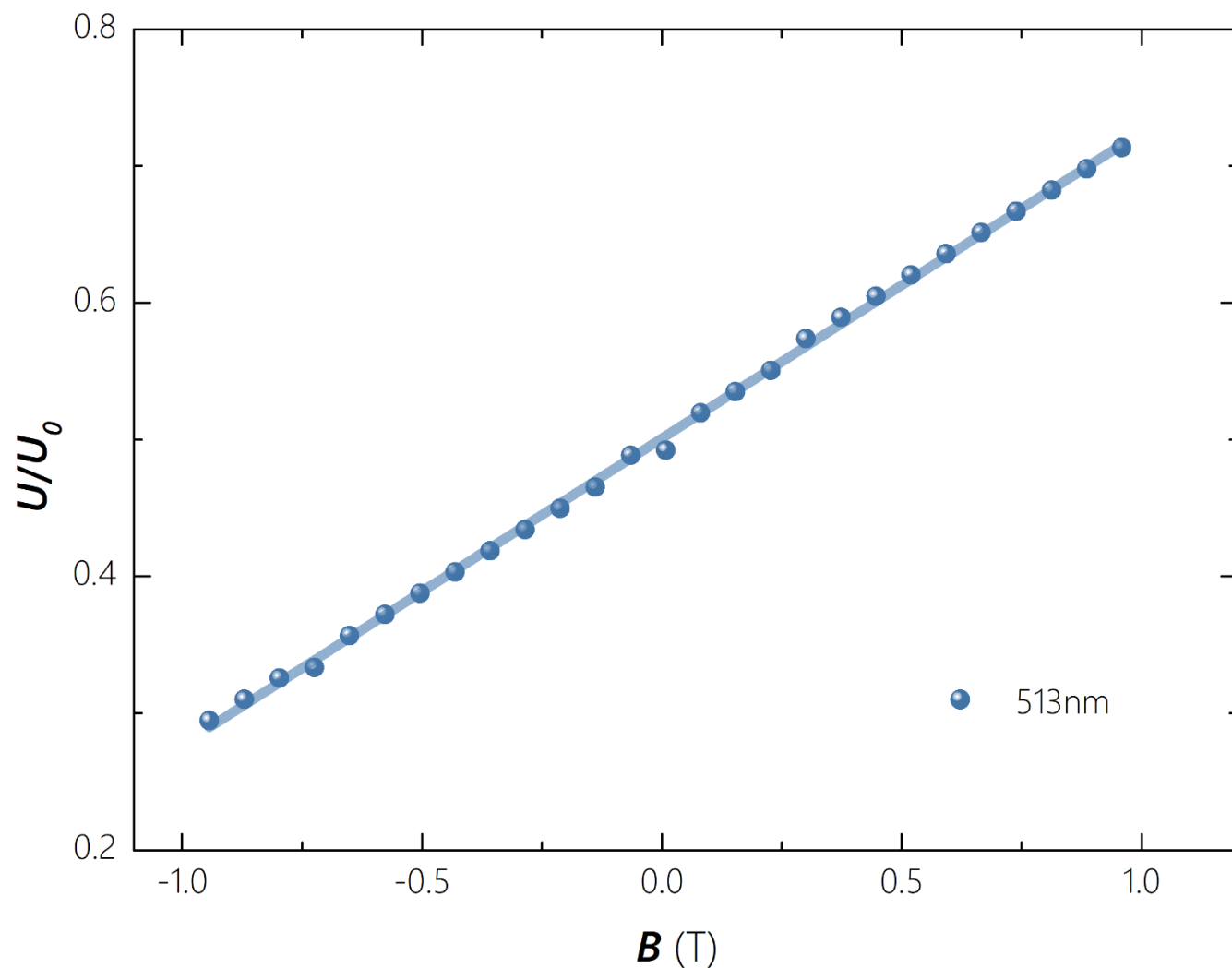
$$B = [(3.656 \pm 0.011) \times 10^{-1} I(\text{A}) + (8.0 \pm 1.8) \times 10^{-2}] (\text{T})$$

实验分析



$$\lambda_{\text{standard}} = [(1.004 \pm 0.003)\lambda(\text{nm}) + (13.0 \pm 1.4)](\text{nm})$$

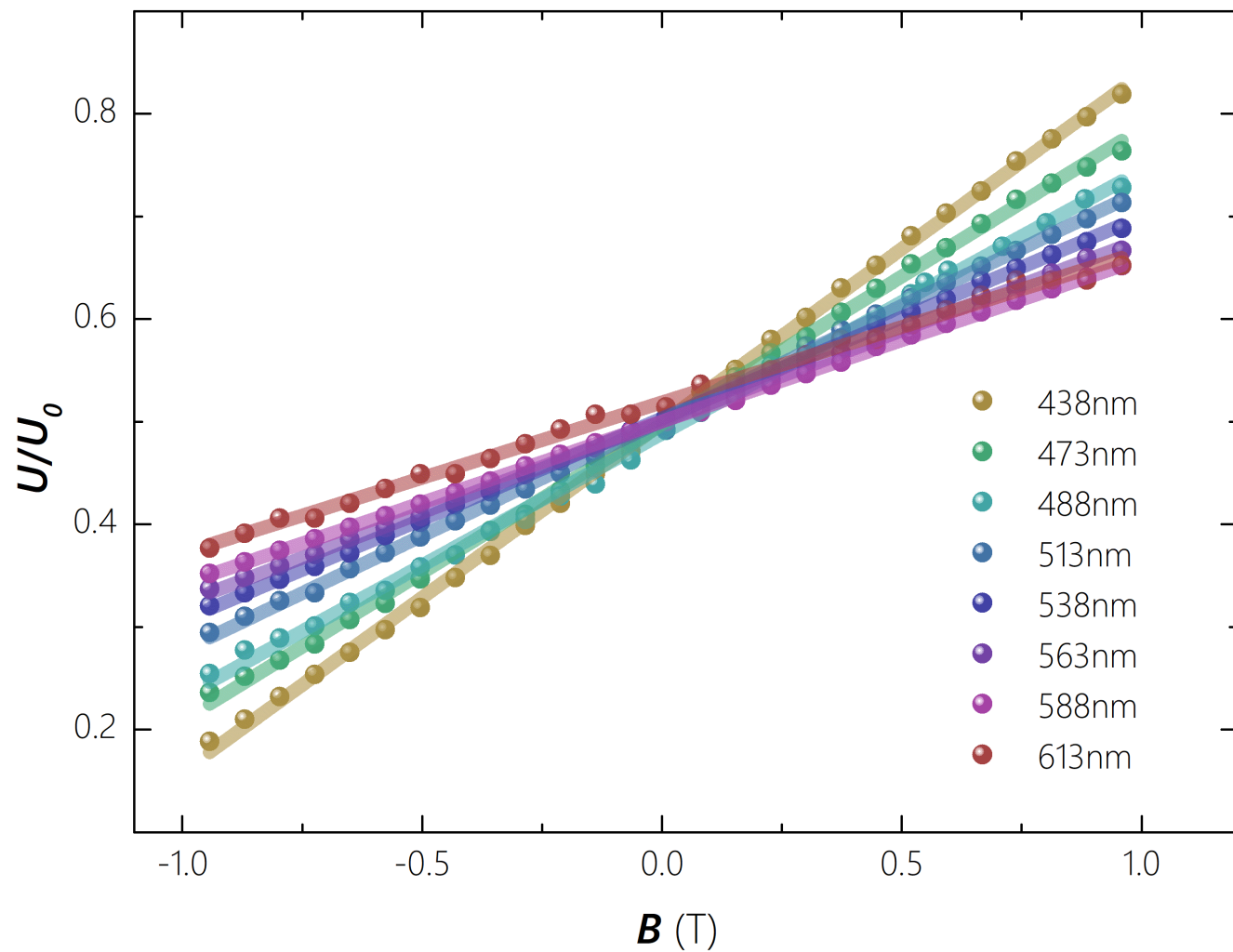
实验分析



@45度 $\Delta U = \frac{dU}{d\theta} \Delta\theta \propto B$

$r^2 = 0.9994$

实验分析

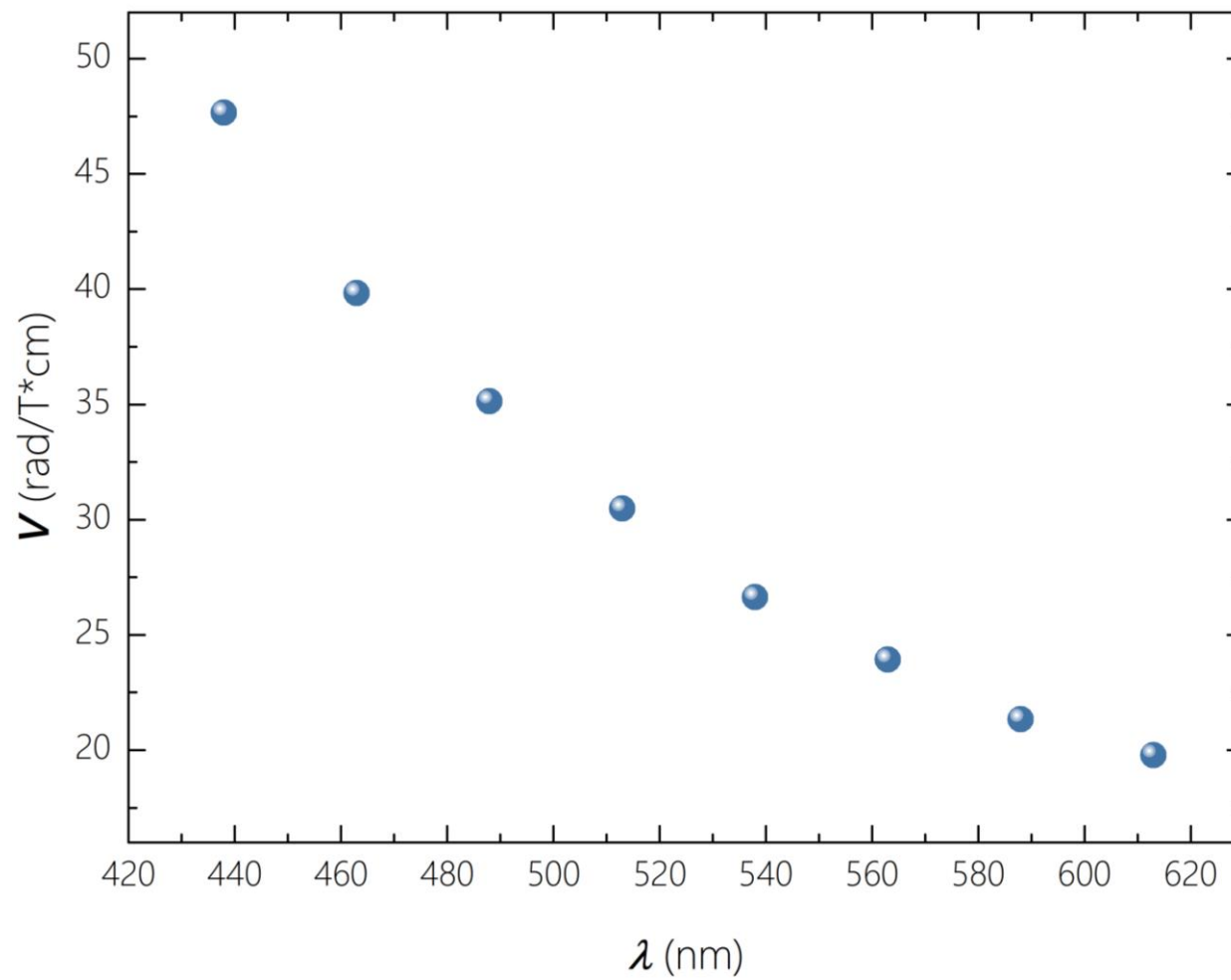


$$\text{@45度} \quad \Delta U = \frac{dU}{d\theta} \Delta\theta \propto B$$

$$\Delta\varphi = \frac{\Delta\theta}{2} = -\frac{e}{2mc} \lambda \frac{dn}{d\lambda} DB$$

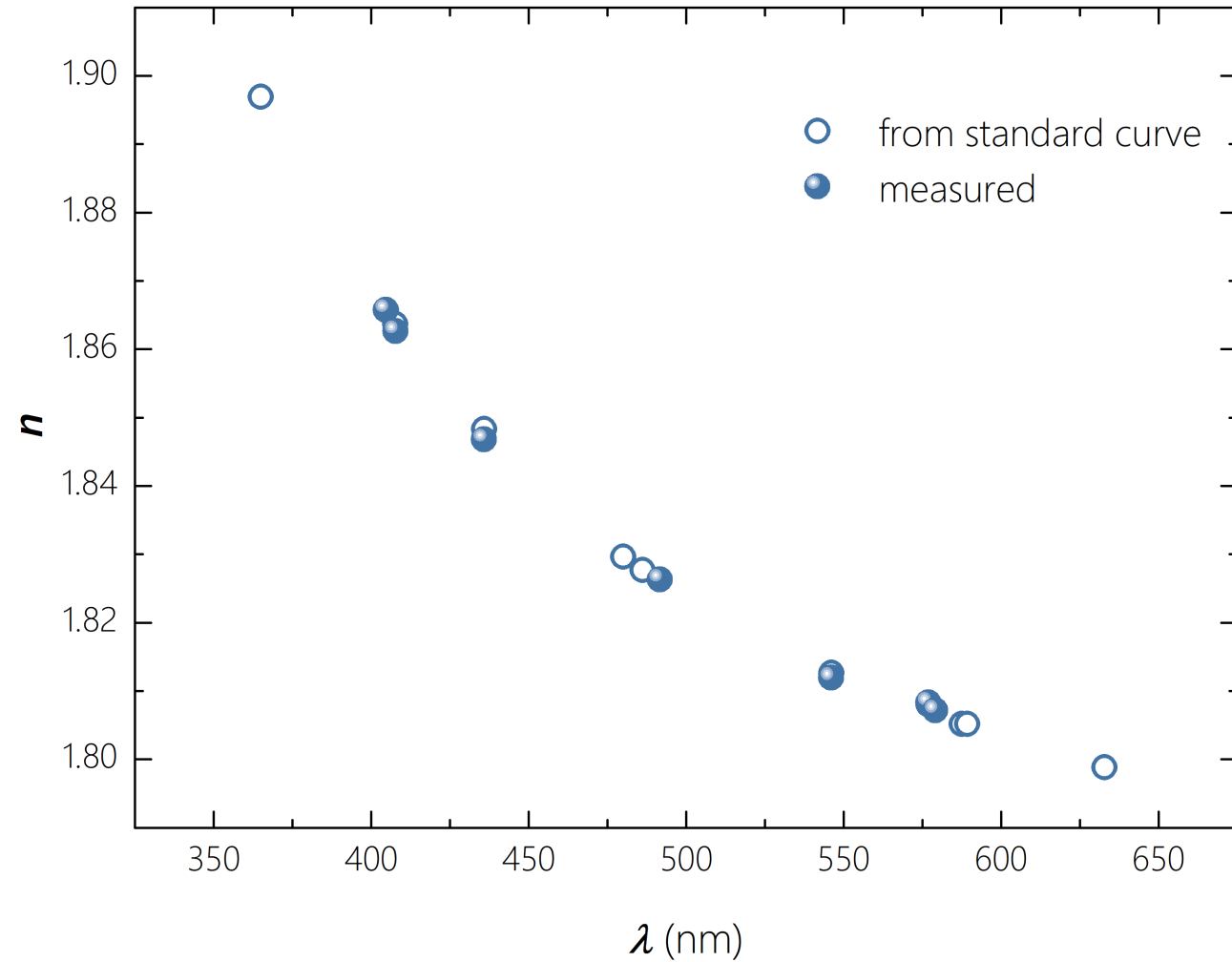
实验分析

V



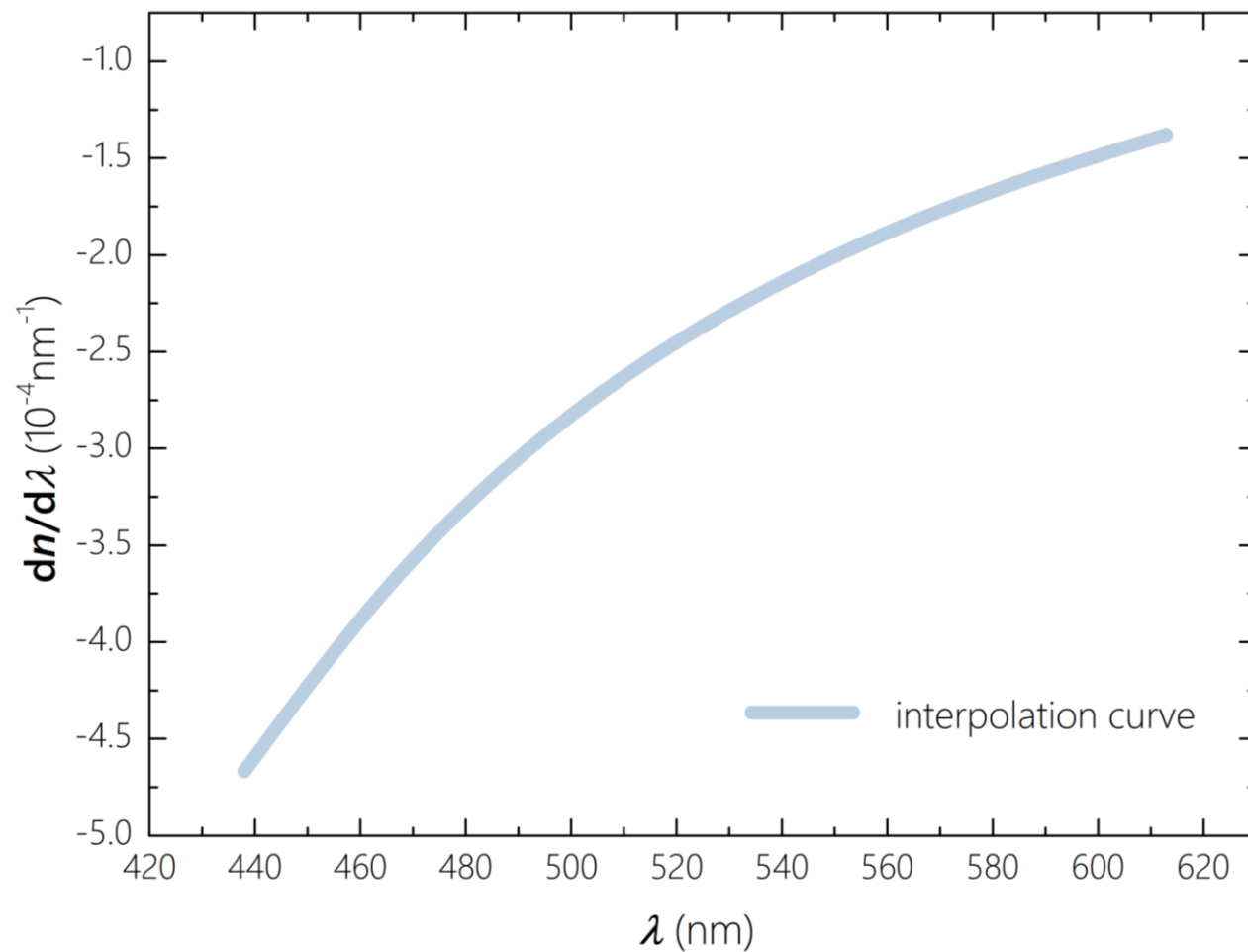
实验分析

$$n \sim \lambda$$



实验分析

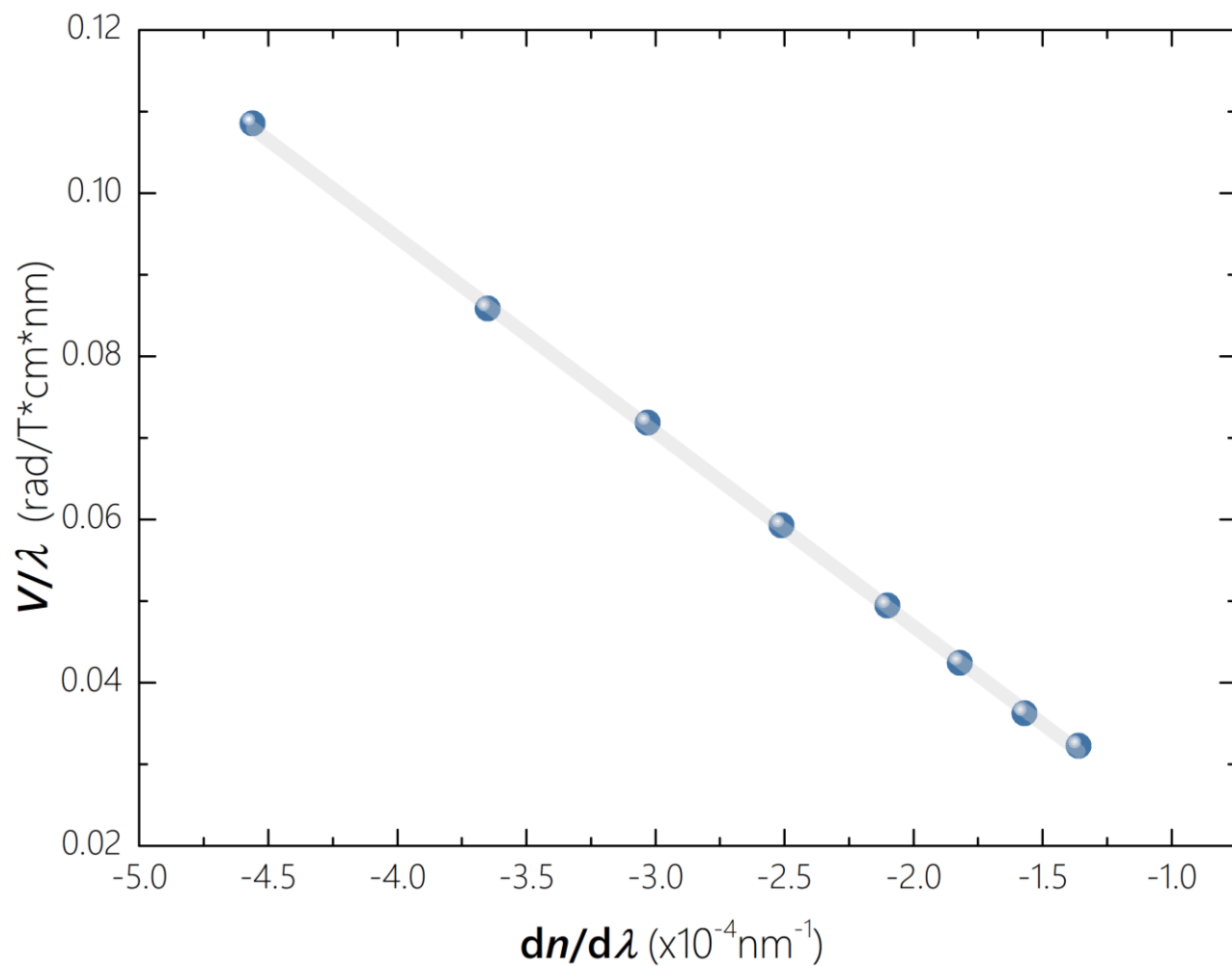
$$dn/d\lambda \sim \lambda$$



Method:
Spline

实验分析

e/m

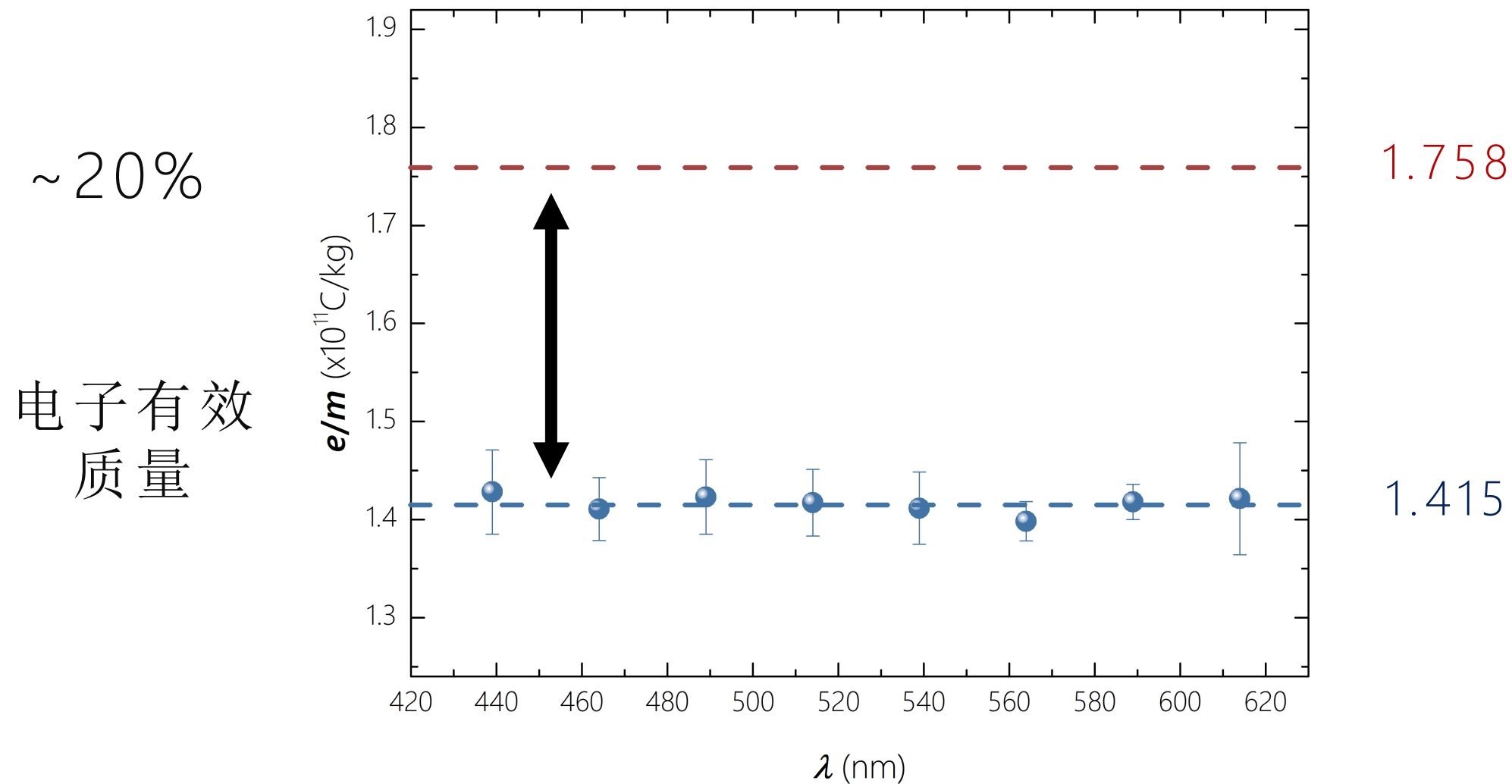


$$\frac{V}{\lambda} = -\frac{e}{2m^*c} \frac{dn}{d\lambda}$$

$$r^2 = 0.9997$$

实验分析

e/m



误差分析

e/m 不确定度

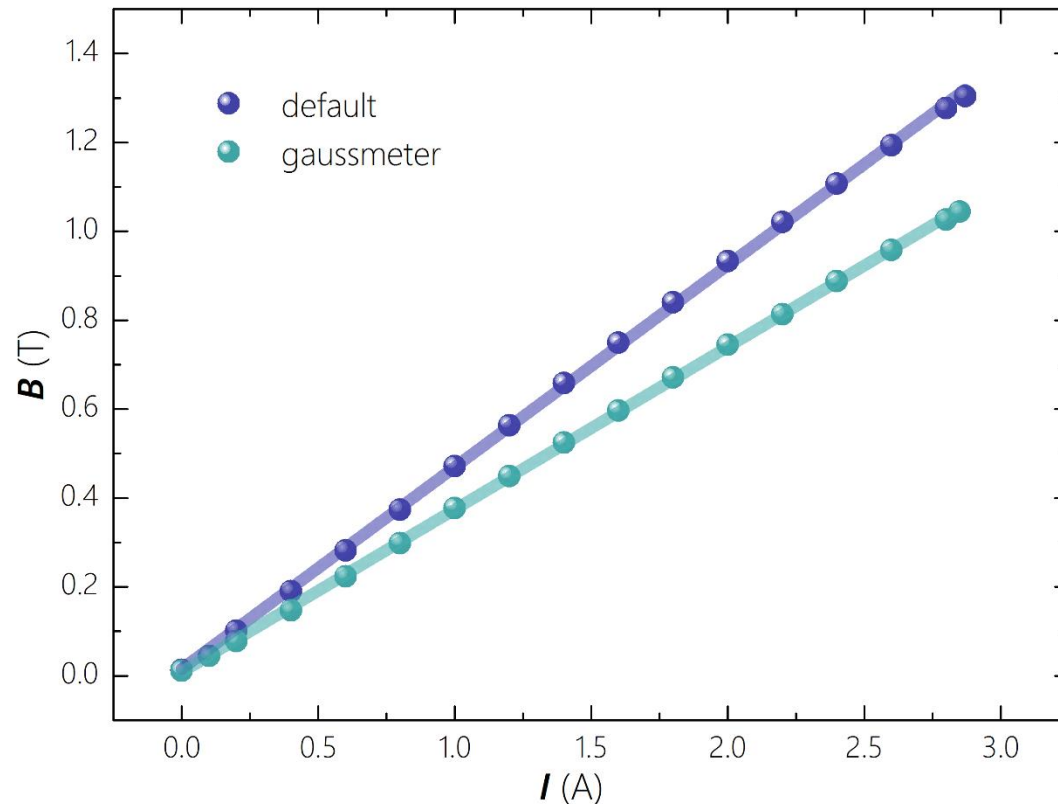
- 旋光角与磁场的关系 $\Delta\varphi = \frac{\Delta\theta}{2} = -\frac{e}{2mc} \lambda \frac{dn}{d\lambda} DB$ $\Delta U = \frac{dU}{d\theta} \Delta\theta \propto B$
- 色散关系 $n \sim \lambda \rightarrow dn/d\lambda \sim \lambda$

$$\frac{e}{m} = -\left(\frac{c}{D}\right) \Delta U \frac{d\theta}{dU} \left(\frac{1}{\lambda B}\right) \frac{d\lambda}{dn}$$

- 拟合(与插值法)不确定度: $\frac{d\theta}{dU}$, λ , B , $\frac{d\lambda}{dn} \sim 2\%$
- 测量不确定度: B

误差分析

e/m 不确定度



核磁共振
永磁体检验

$$\mathbf{B}_{default} = [(4.54 \pm 0.02) \times 10^{-1} I(\text{A}) + (1.5 \pm 0.3) \times 10^{-2}] (\text{T})$$

$$\mathbf{B}_{gaussmeter} = [(3.656 \pm 0.011) \times 10^{-1} I(\text{A}) + (8.0 \pm 1.8) \times 10^{-2}] (\text{T})$$

误差分析

e/m 不确定度

- 旋光角与磁场的关系 $\Delta\varphi = \frac{\Delta\theta}{2} = -\frac{e}{2mc} \lambda \frac{dn}{d\lambda} DB$ $\Delta U = \frac{dU}{d\theta} \Delta\theta \propto B$
- 色散关系 $n \sim \lambda \rightarrow dn/d\lambda \sim \lambda$

$$\frac{e}{m} = -\left(\frac{c}{D}\right) \Delta U \frac{d\theta}{dU} \left(\frac{1}{\lambda B}\right) \frac{d\lambda}{dn}$$

- 拟合(与插值法)不确定度: $\frac{d\theta}{dU}$, λ , B , $\frac{d\lambda}{dn} \sim 2\%$
- 测量不确定度: $B \sim 1\%$

误差分析

$$dn/d\lambda \sim \lambda$$

- 插值法 (Method: Spline)
- 拟合?

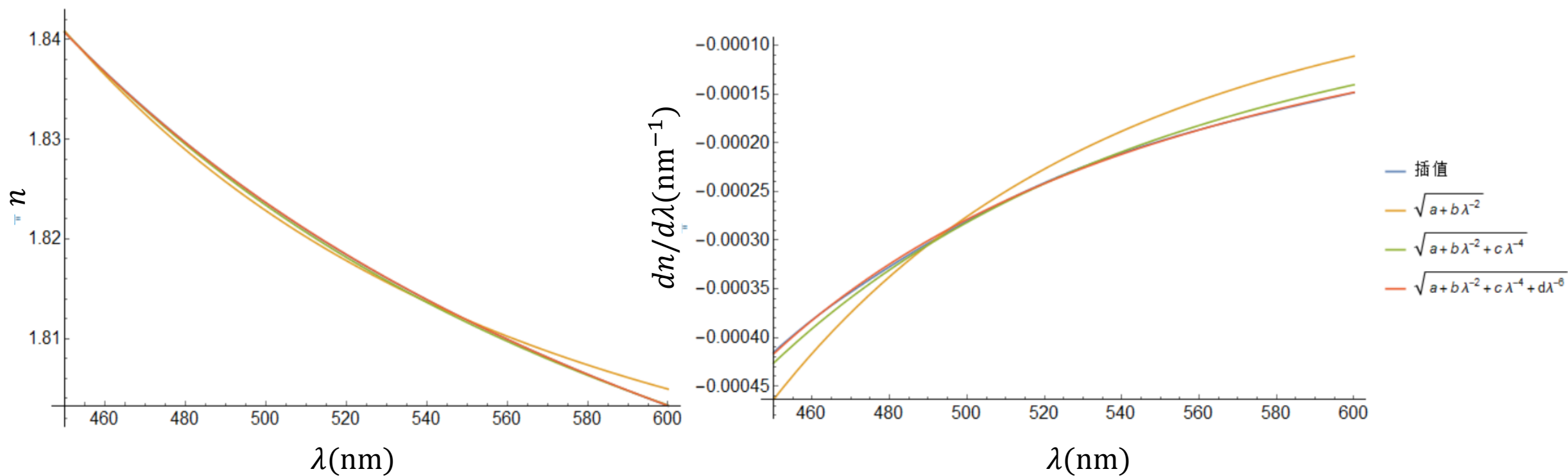
Cauchy经验公式

$$n = a + b\lambda^2 + c\lambda^{-2}$$

$$n = \sqrt{(a + b\lambda^{-2} + c\lambda^{-4})}$$

$$n = \sqrt{(a + b\lambda^{-2} + c\lambda^{-4} + d\lambda^{-6})}$$

误差分析



结论

- 检验偏振偏转 $\Delta\varphi \propto B$
- 检验定量常数 $\frac{e}{m^*} = (1.415 \pm 0.003) \times 10^{11} \text{ (C/kg)}$
- 误差分析：拟合、测量
($dn/d\lambda$) ~ λ 拟合方法

附录

