



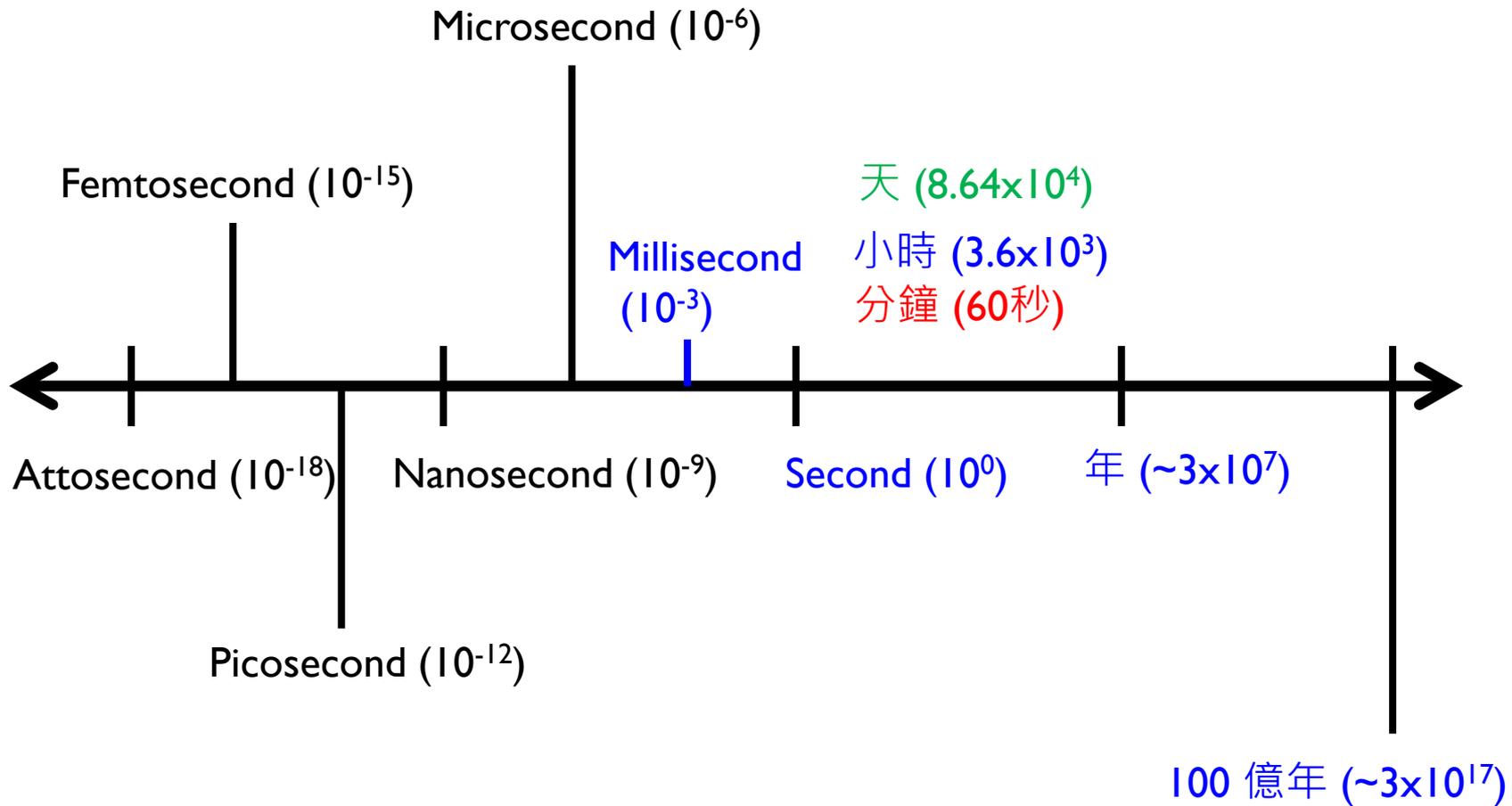
# 用雷射窺探物質的超快世界

林宮玄

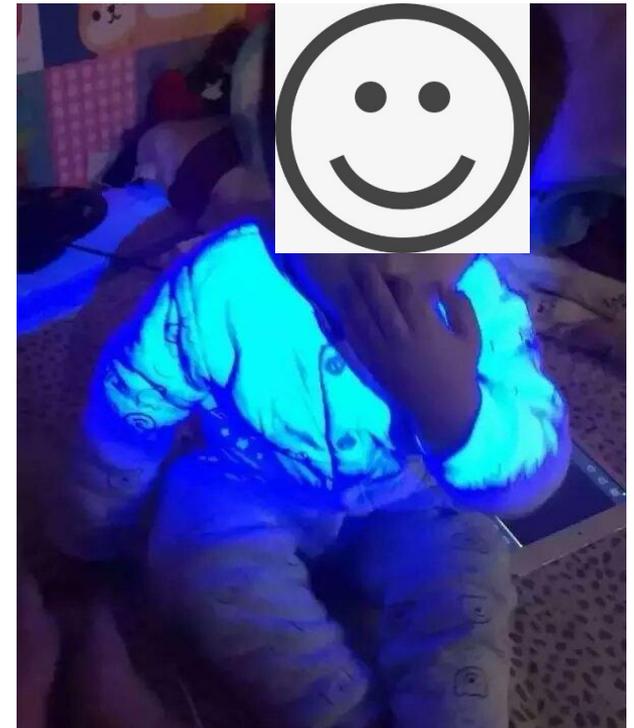
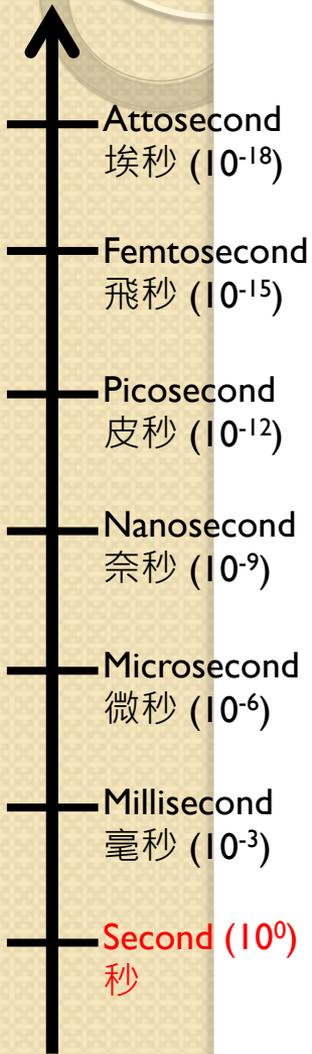
中央研究院物理研究所

2018.10.27 中研院開放日

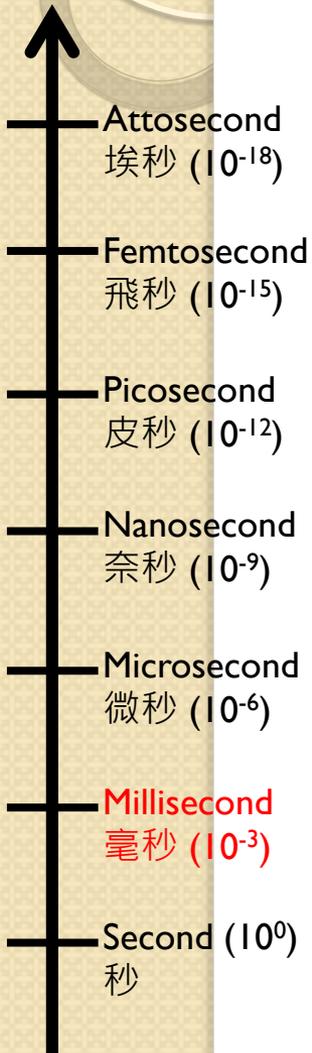
# 物理關心的時間尺度



# 螢光與磷光(夜光) – 人眼觀察



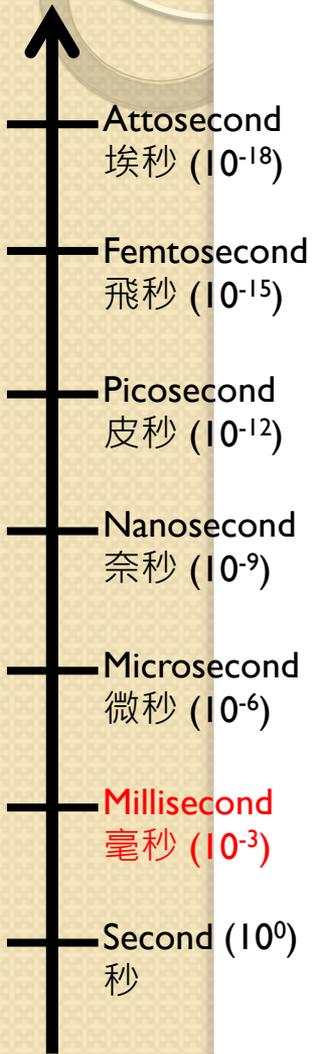
# 動畫－人眼觀察



<https://www.youtube.com/watch?v=fjtO6NYgfYU>

黃亮昕：進階動畫原理小作業

# 影片 - 機器記錄



iPhone X  拍攝廣色域的照片與原況照片 顯示器 Face ID A12 仿生 相機 唯有 iPhone 技術規格 [購買](#)

局部色調對映功能  
先進的紅眼校正功能  
曝光控制  
自動影像穩定功能  
連拍模式  
計時模式  
照片地理位置標記  
影像拍攝格式: HEIF 與 JPEG

**影片拍攝**

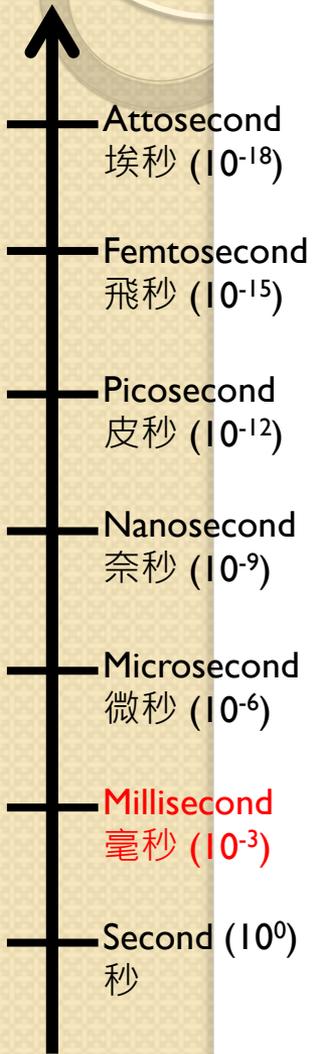
4K 影片拍攝, 24 fps、30 fps 或 60 fps  
1080p HD 影片拍攝, 30 fps 或 60 fps  
720p HD 影片拍攝, 30 fps

延伸動態範圍影片拍攝, 高達 30 fps  
適用於影片拍攝的光學影像穩定功能  
2 倍光學變焦; 高達 6 倍數位變焦  
4-LED 原彩閃光燈  
支援 1080p (120 fps 或 240 fps) 的慢動作影片  
具備視訊穩定功能的縮時攝影  
電影級視訊穩定功能 (1080p 與 720p)  
連續自動對焦錄影  
錄製 4K 影片時可拍攝 800 萬像素靜照  
縮放播放

# 機器拍攝影像 - 光源強度

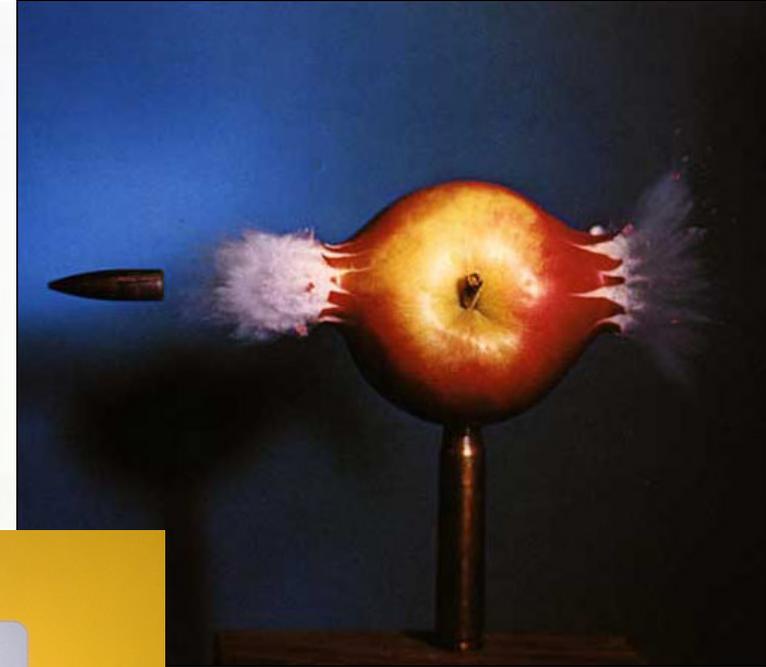


# 閃光 - 短曝光、強光源



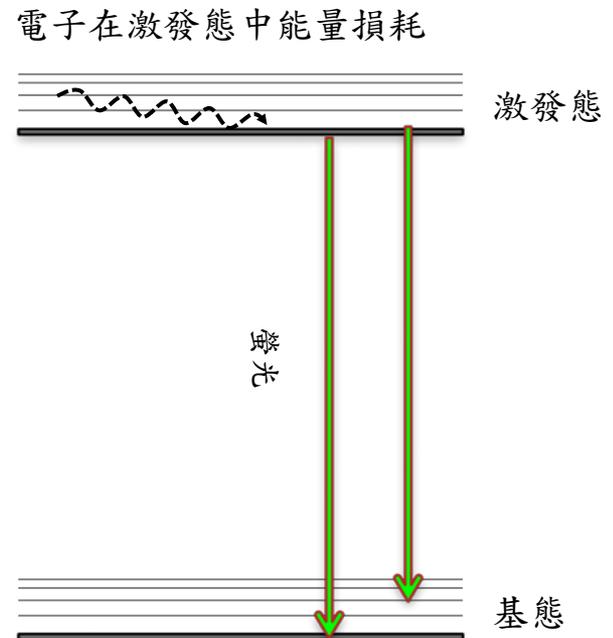
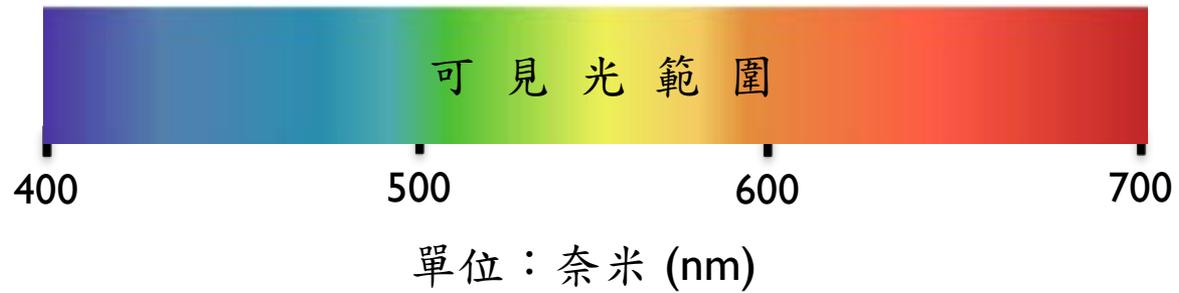
# 高速閃光攝影—凝結瞬間影像

- ↑
- Attosecond  
埃秒 ( $10^{-18}$ )
- Femtosecond  
飛秒 ( $10^{-15}$ )
- Picosecond  
皮秒 ( $10^{-12}$ )
- Nanosecond  
奈秒 ( $10^{-9}$ )
- Microsecond**  
**微秒 ( $10^{-6}$ )**
- Millisecond  
毫秒 ( $10^{-3}$ )
- Second ( $10^0$ )  
秒

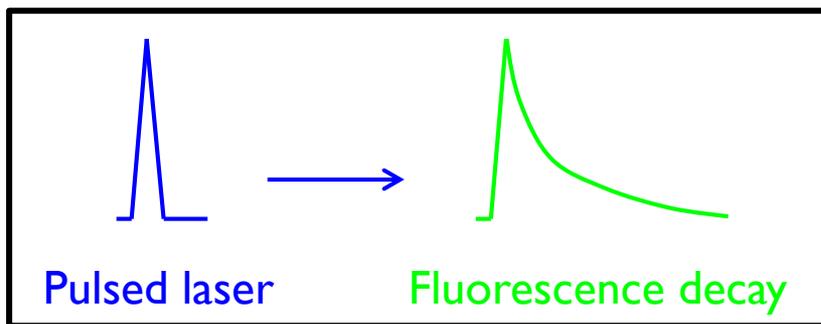
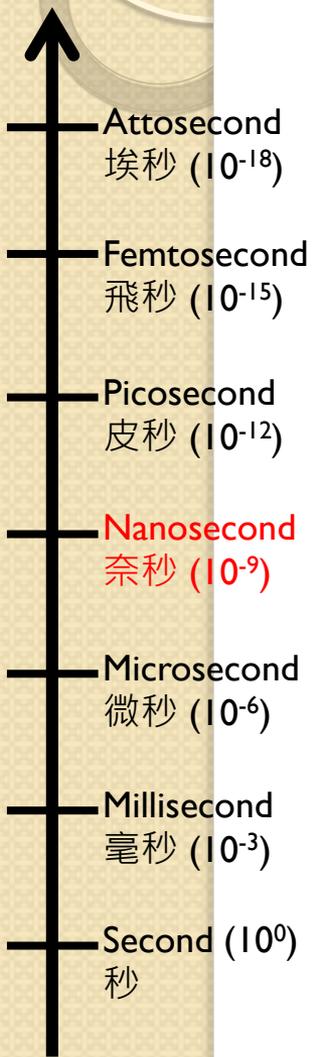


# 電子放出螢光的時間

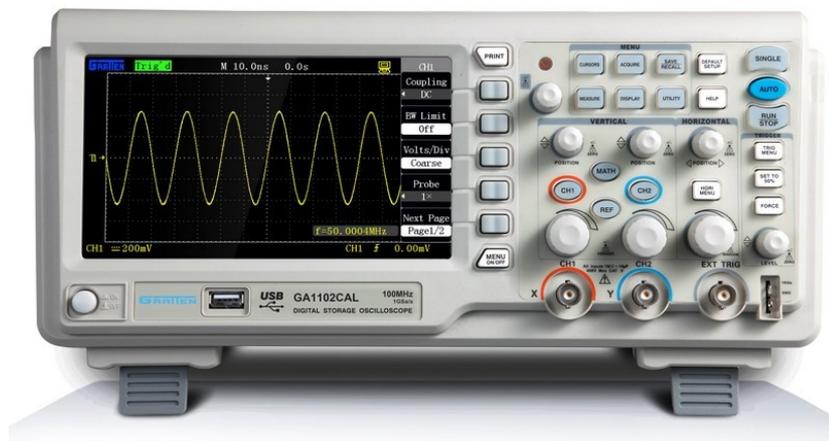
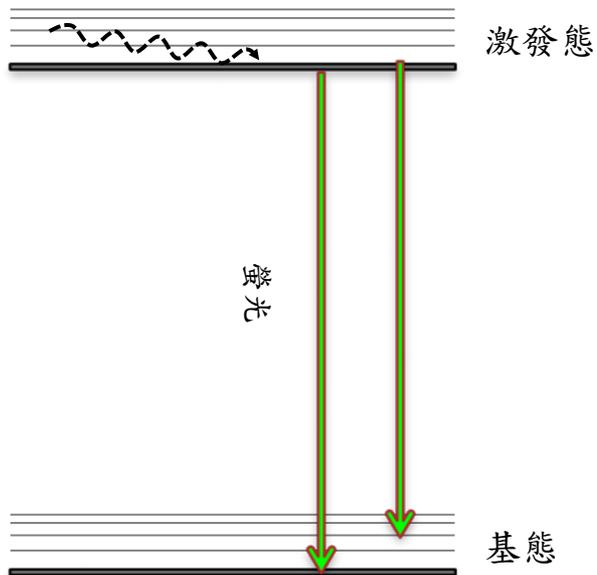
$$c \text{ (波速m/s)} = f \text{ (頻率Hz)} \times \lambda \text{ (波長 m)}$$



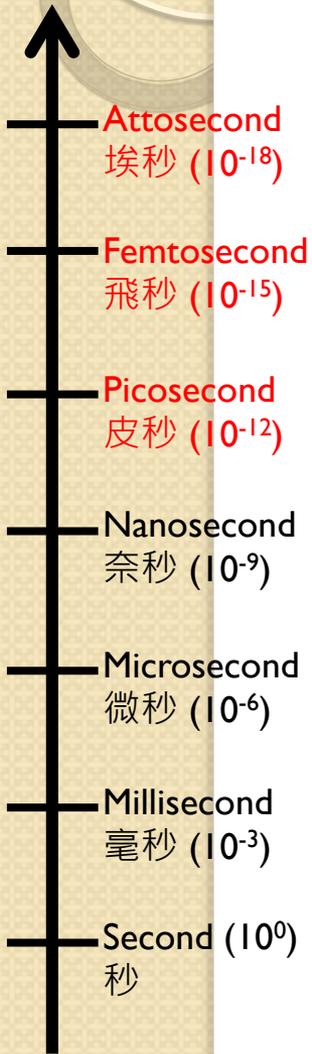
# 光致螢光的時間量測



電子在激發態中能量損耗



# 電子儀器能夠觀察的極限



attosecond (埃秒)	$10^{-18}$ s	科學家所能量到的最短時間
femtosecond (飛秒)	$10^{-15}$ s	世上最快的可見光雷射脈衝
picosecond (皮秒)	$10^{-12}$ s	世上轉換速度最快的電晶體
nanosecond (奈秒)	$10^{-9}$ s	螢光分子放光的時間尺度
microsecond (微秒)	$10^{-6}$ s	相機用閃光的最短脈衝時間
millisecond (毫秒)	0.001 s	蒼蠅飛行翅膀振動的週期

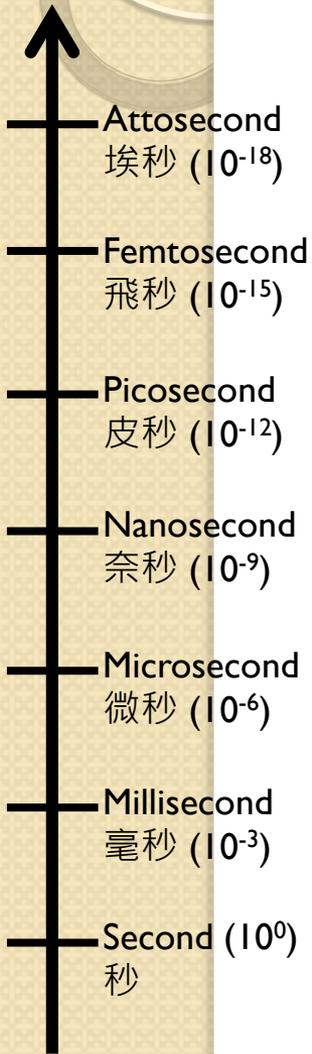
皮秒除斑??

飛秒近視手術??

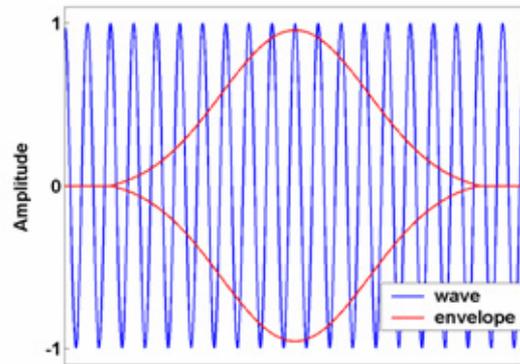
**超快脈衝雷射**

# 雷射

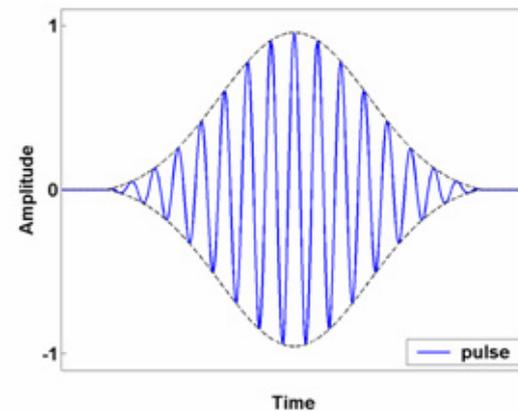
- 雷射特性：單波長特性、指向性高(好導光)



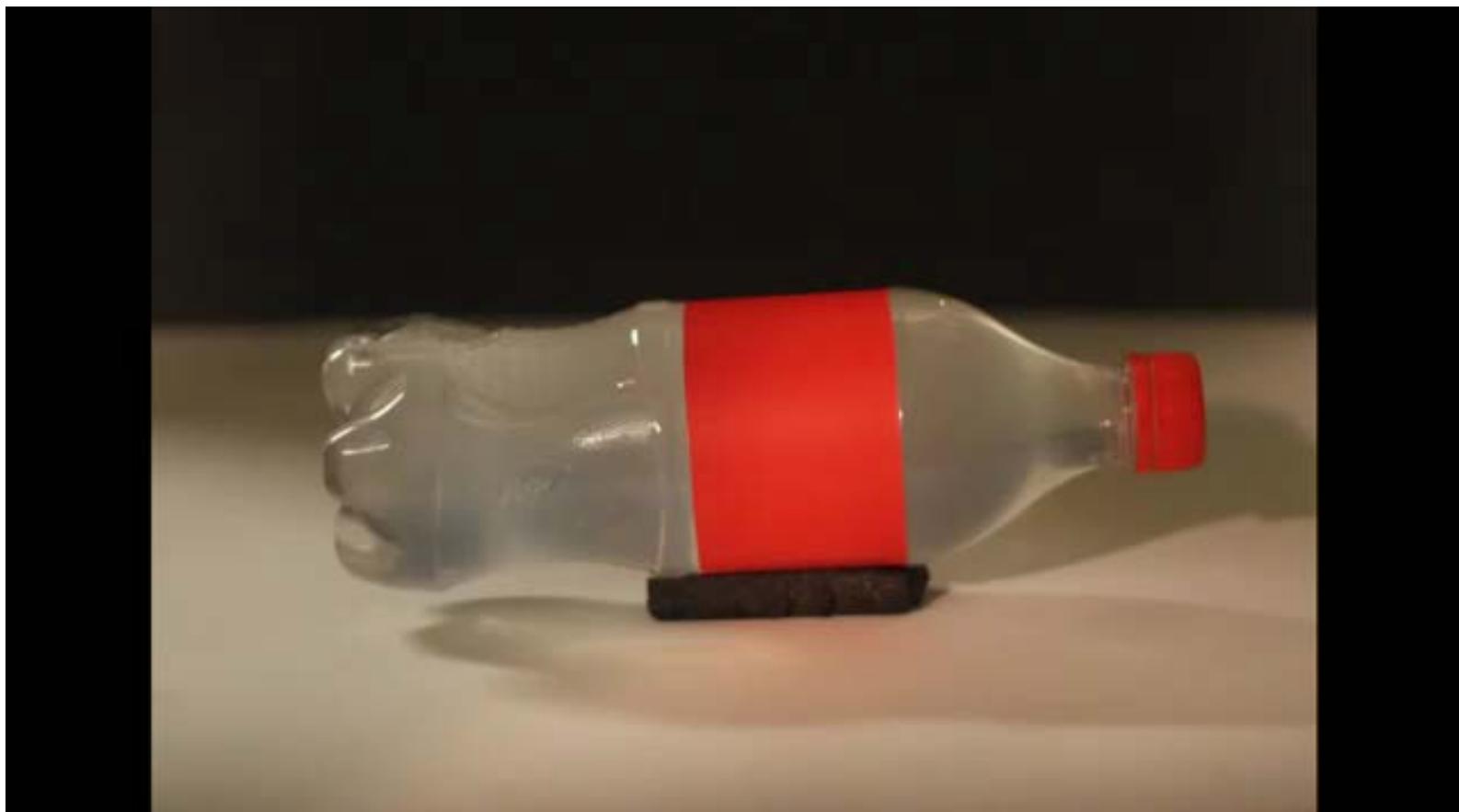
## 連續波雷射



## 脈衝光雷射

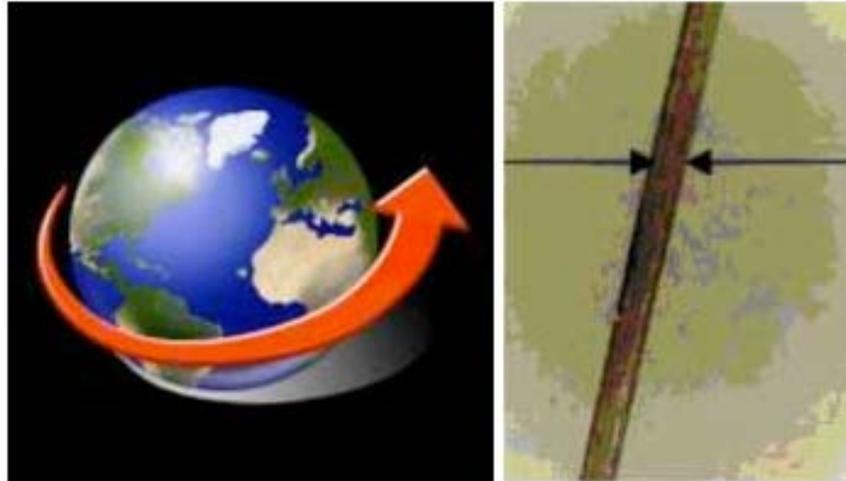
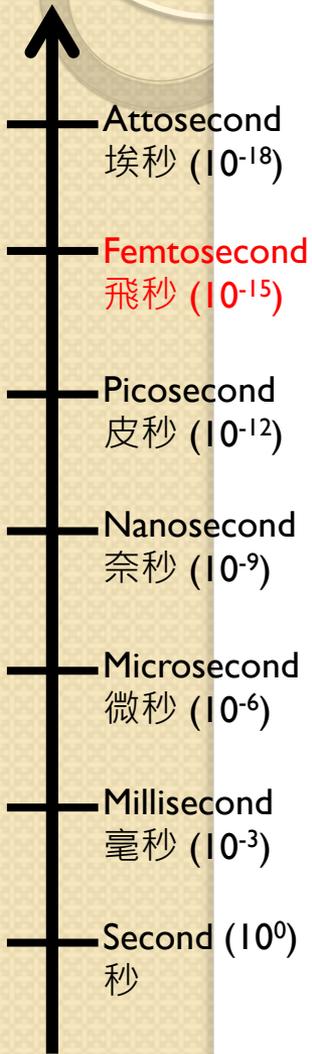


# 脈衝雷射光行進 -- 慢動作重播



<http://youtu.be/-fSqFWcb4rE>

# 100 飛秒有多快？

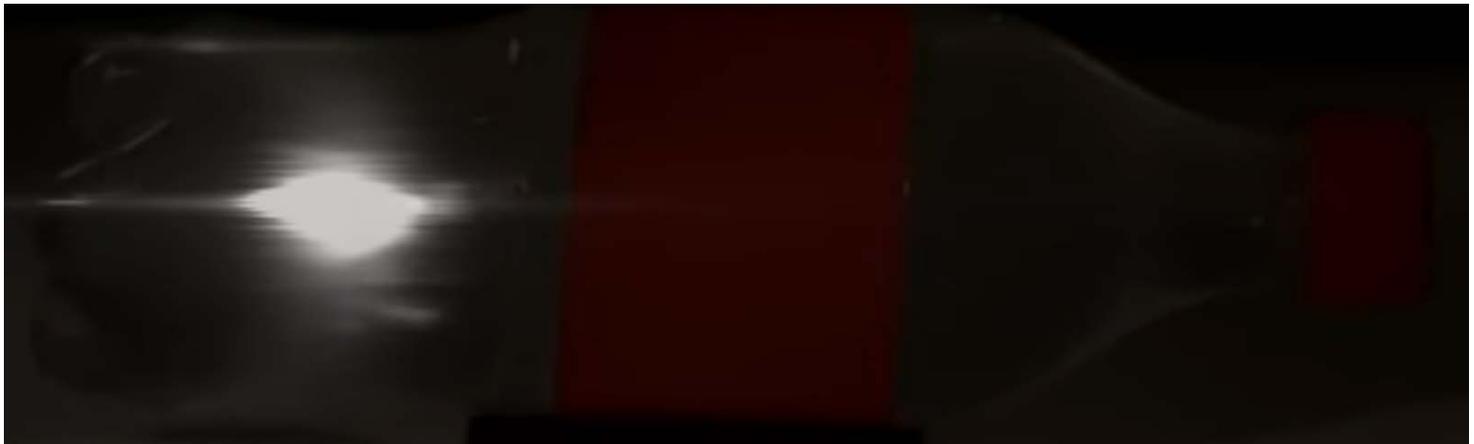


光1秒走 30,000 公里

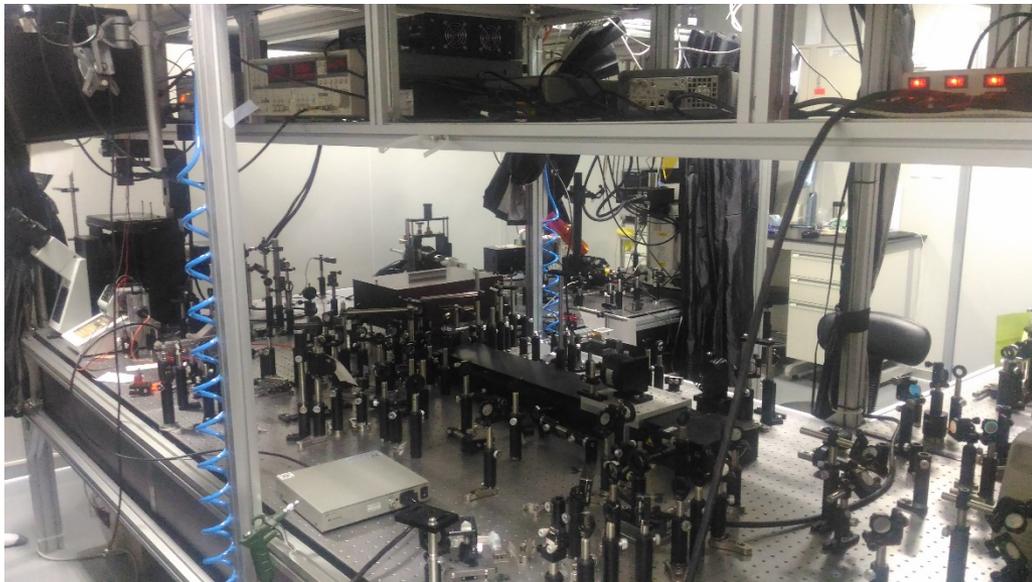
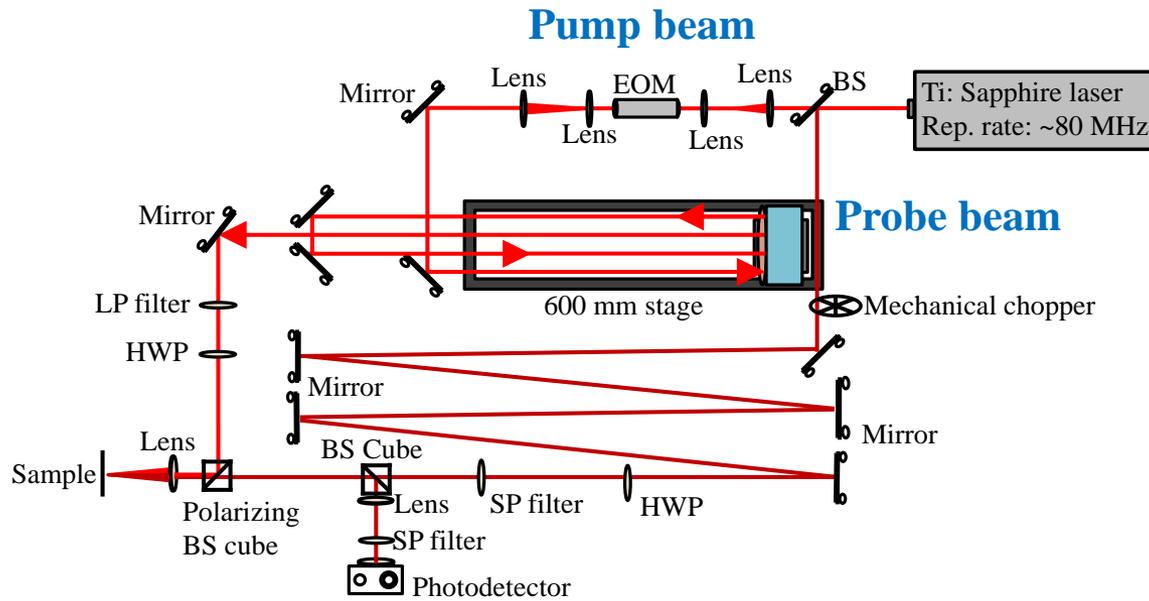
光100飛秒走 0.03 公釐

# 如何拍超快相片與動畫

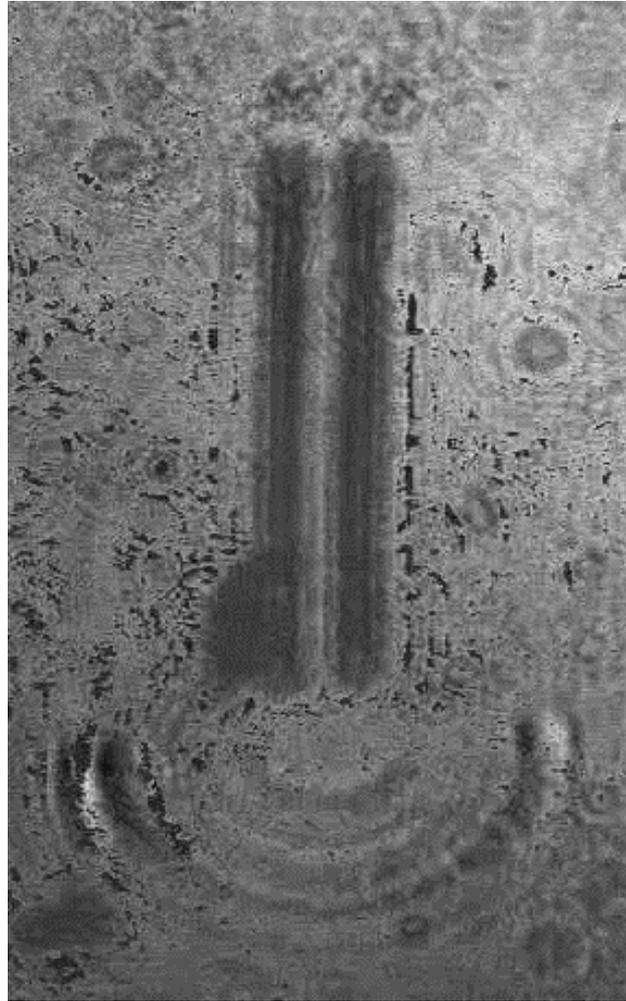
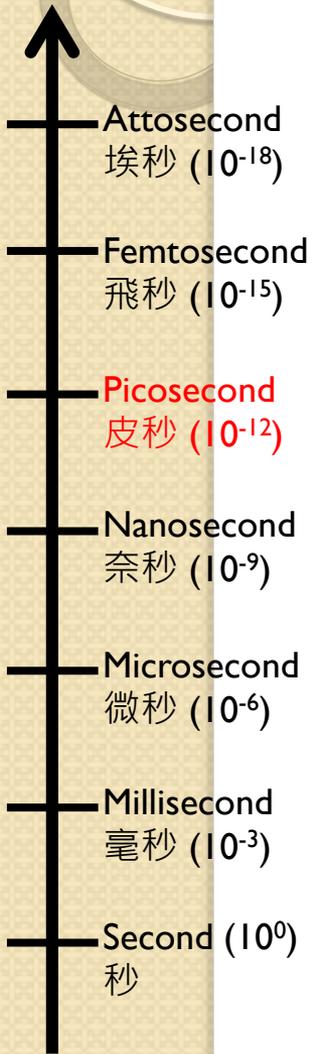
- 超短脈衝光
- 同步訊號
- 光偵測元件(相機或光偵測器)



# 激發與探測 (Pump-Probe)

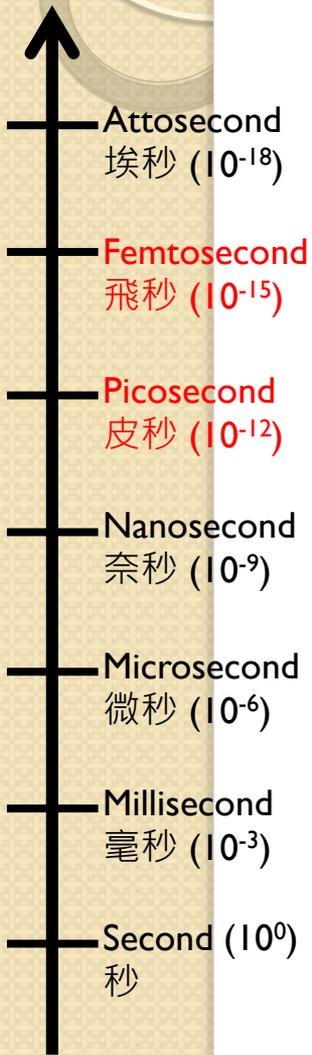


# 超快顯微動畫 – 兆赫電磁波傳播

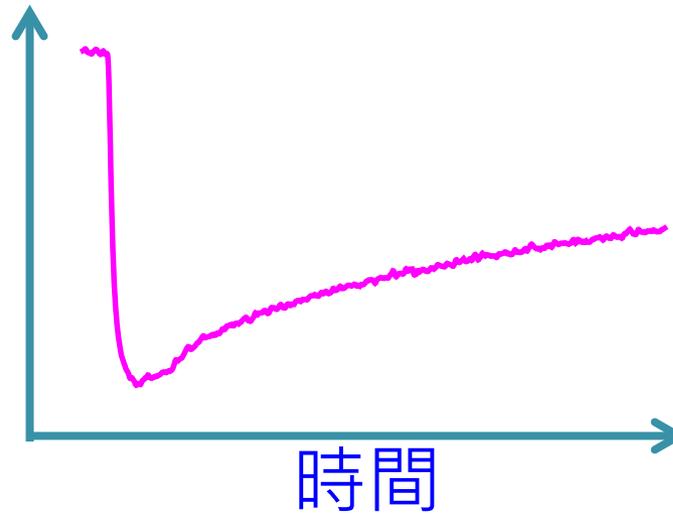


Keith Nelson Group, MIT

# 用雷射觀察物質的超快變化



光性質變化

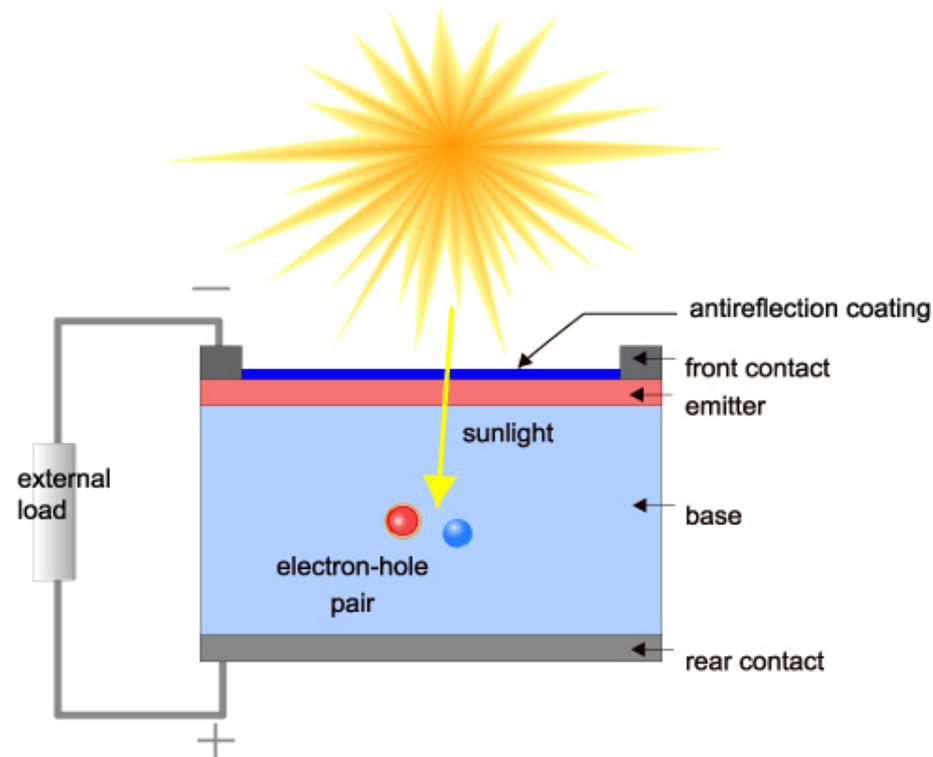


- 放光強度變化
- 光反射、穿透變化
- 光折射率變化
- 光偏振方向變化

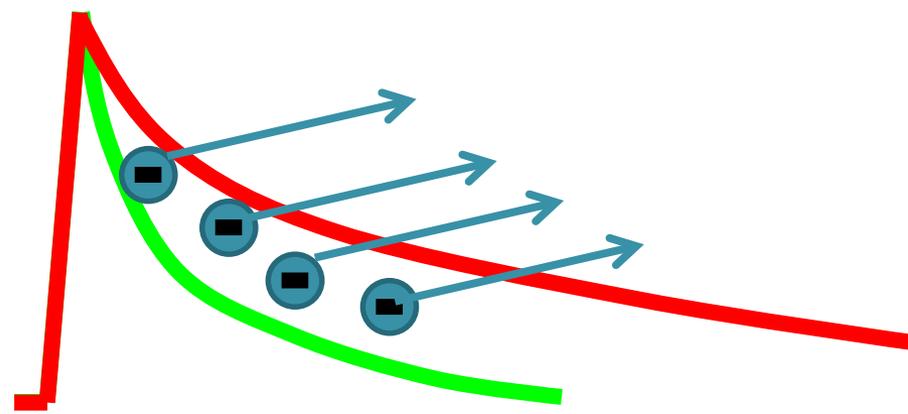
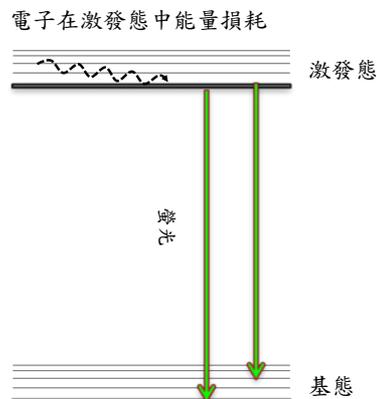
→ 研究物質中晶格結構、電子、磁、熱等物理特性

# 物質科學的動態行為

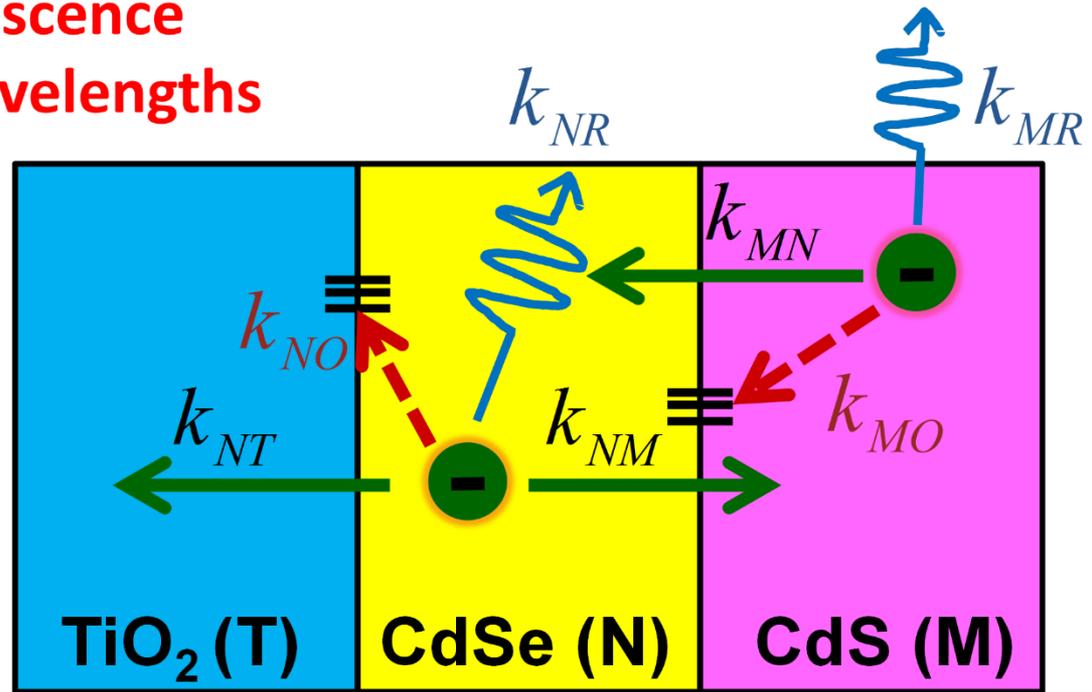
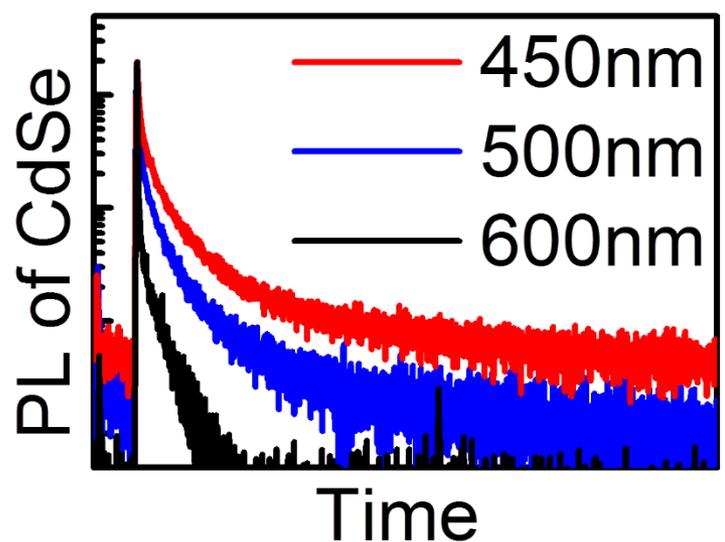
- 電子
- 原子、晶格 (熱)
- 光



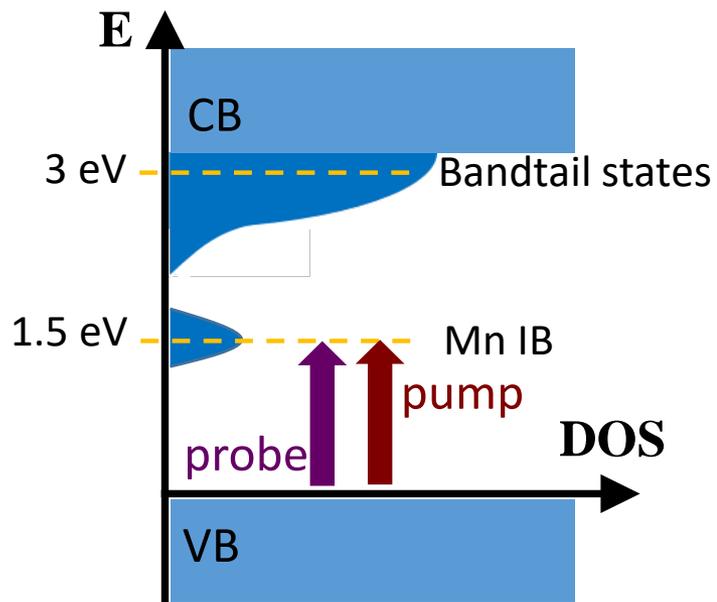
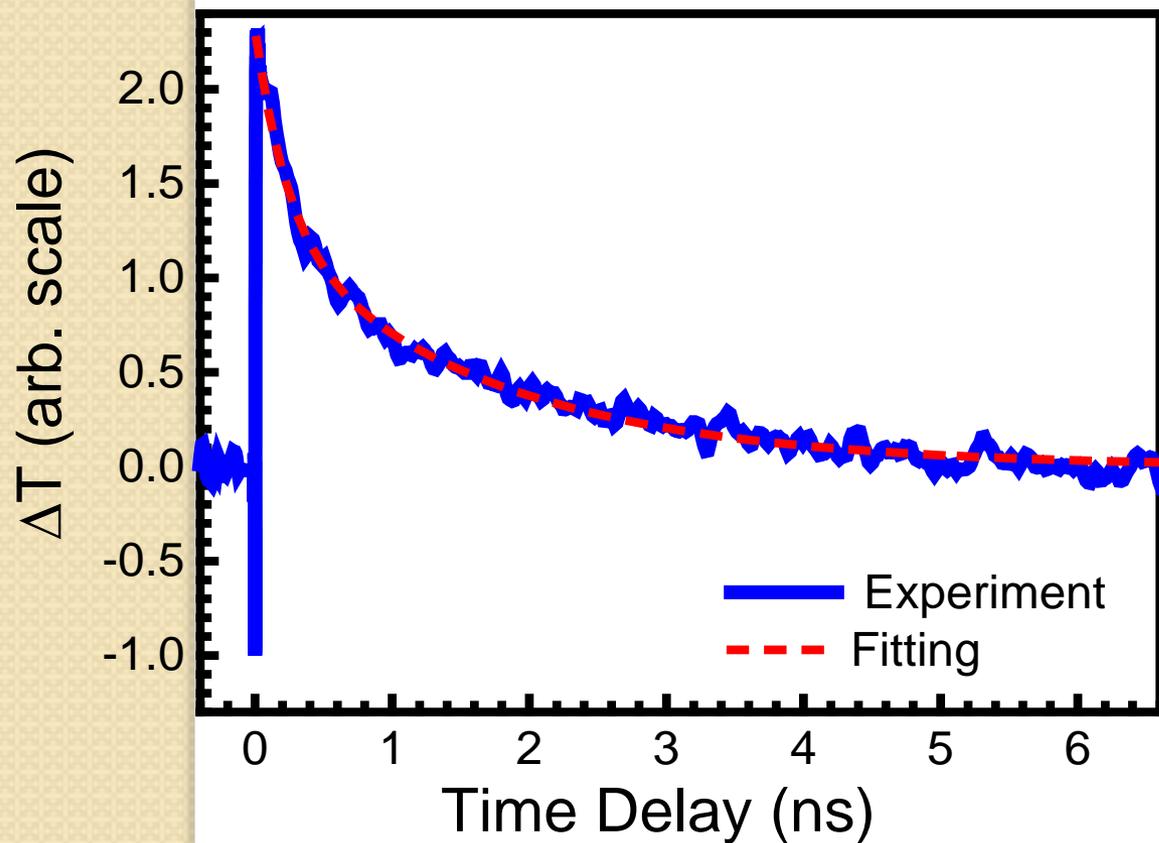
# 光敏太陽能電池材料電子動態



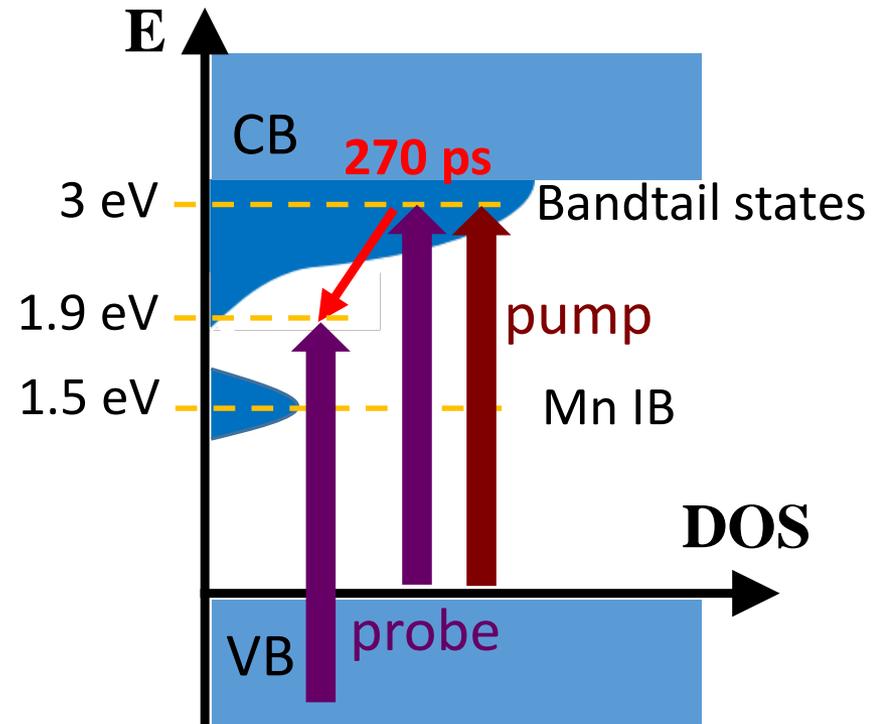
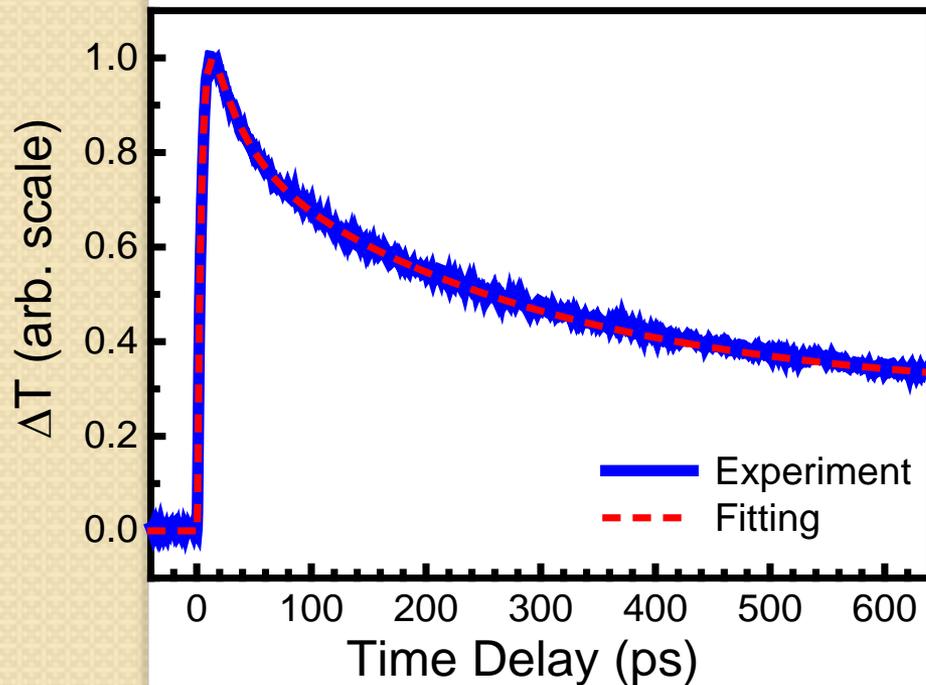
## Time-resolved photoluminescence with different excitation wavelengths



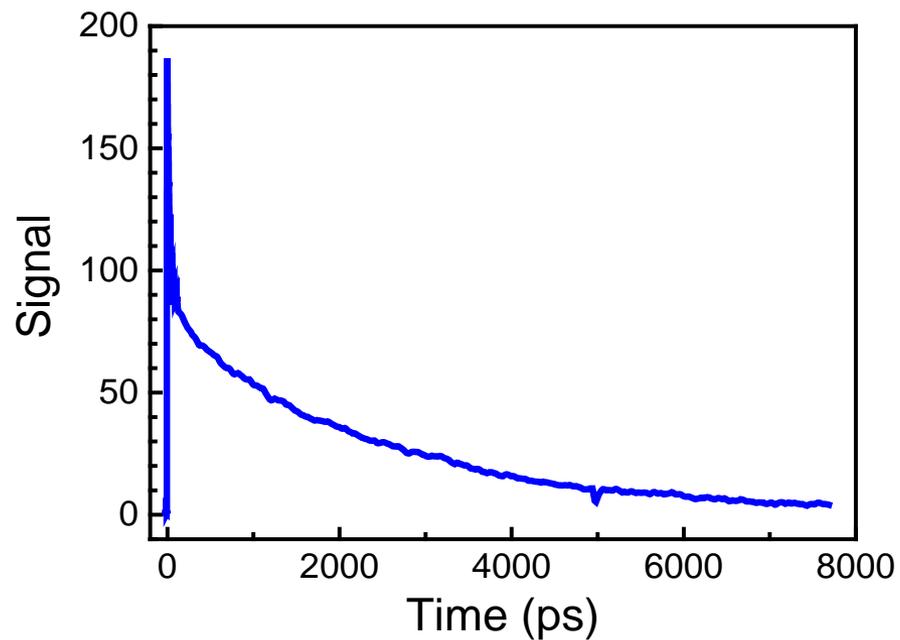
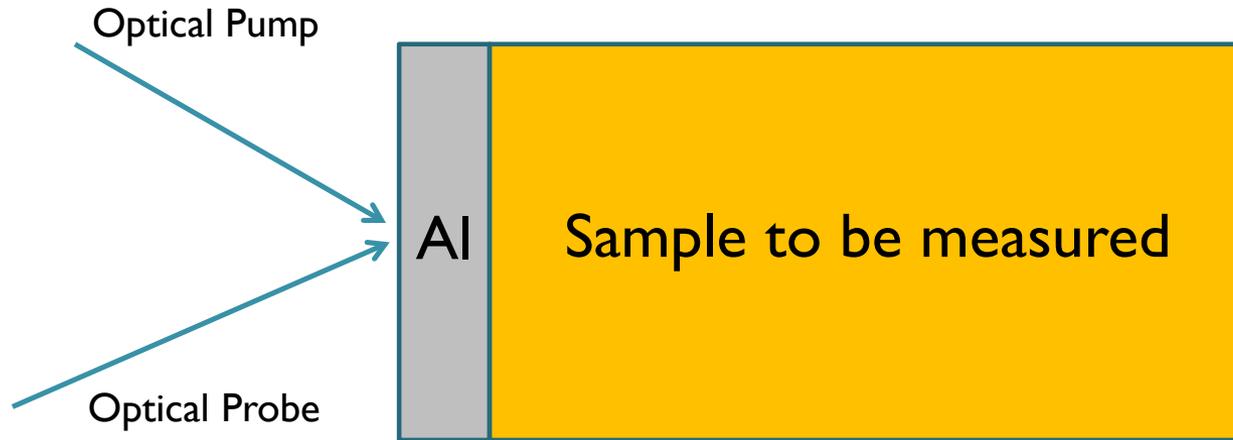
# 半導體太陽能材料電子動態



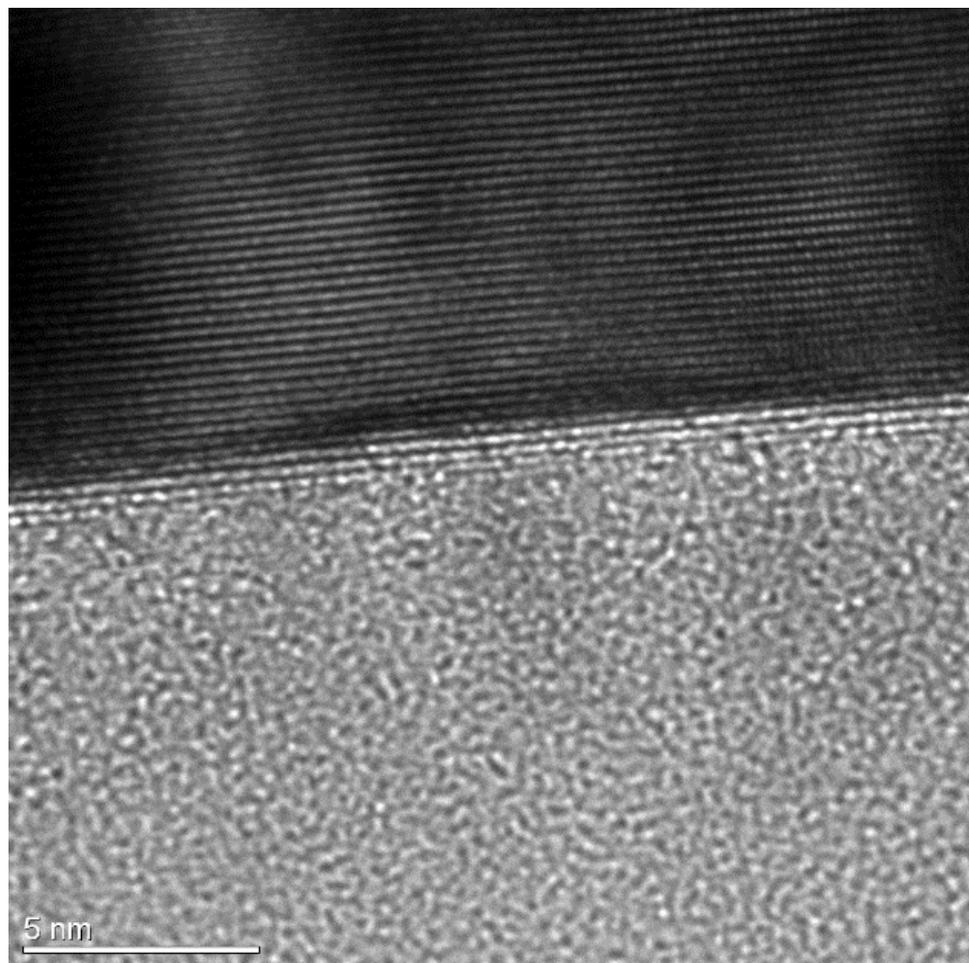
# 半導體太陽能材料電子動態



# 薄膜熱導率量測



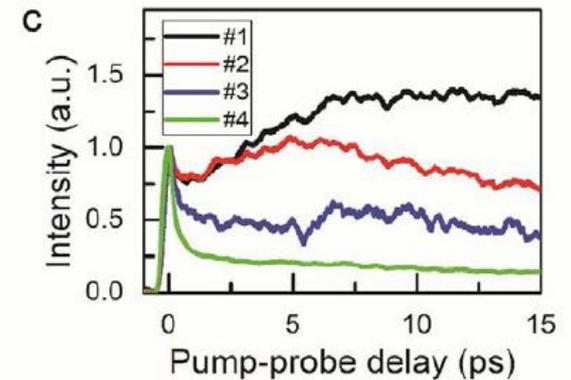
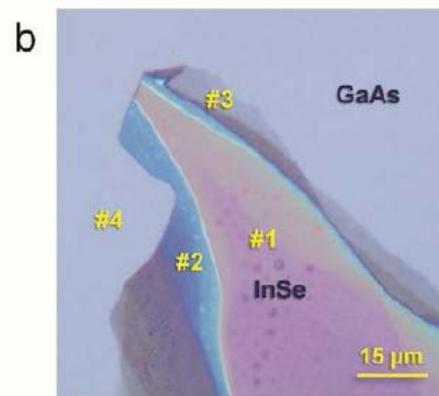
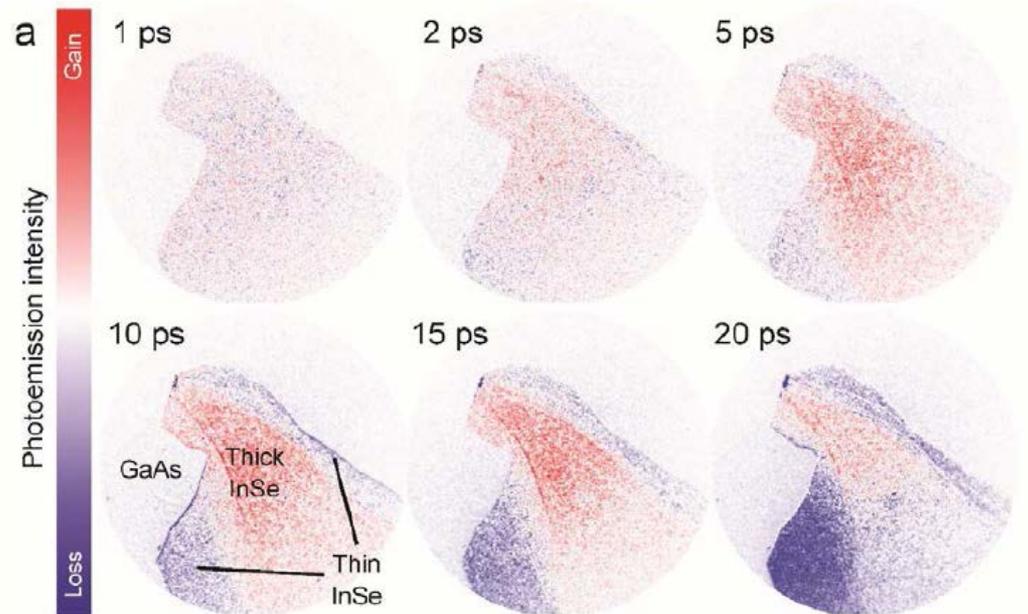
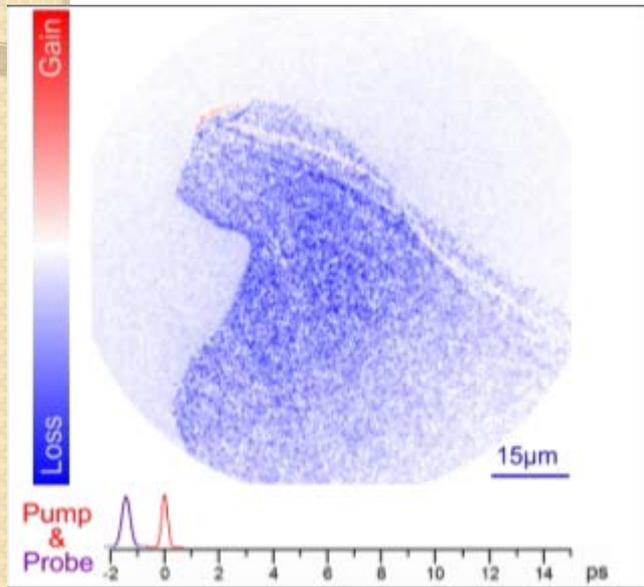
# 雷射與電子顯微影像結合



氮化鎵

二氧化矽

# 電子在半導體間動態影像



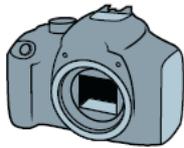
# 激發與探測 -- 飛秒光譜學

Stopwatch



1  
second

Fastest camera  
shutter



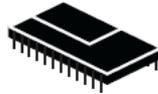
$10^{-3}$   
millisecond

Chemical  
reactions



$10^{-6}$   
microsecond

Fast  
electronics



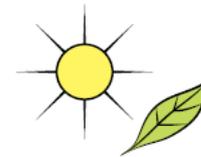
$10^{-9}$   
nanosecond

Molecular  
vibrations



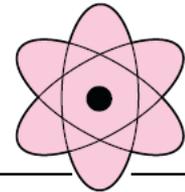
$10^{-12}$   
picosecond

Photosynthesis



$10^{-15}$   
femtosecond

Electron motion  
in atoms and  
molecules



$10^{-18}$   
attosecond

## The Nobel Prize in Chemistry 1999



Photo from the Nobel Foundation  
archive.

Ahmed H. Zewail

Prize share: 1/1

The Nobel Prize in Chemistry 1999 was awarded to Ahmed H. Zewail "for his studies of the transition states of chemical reactions using femtosecond spectroscopy."

# 物質的超快世界

利用超快雷射窺探電子與原子的動態

