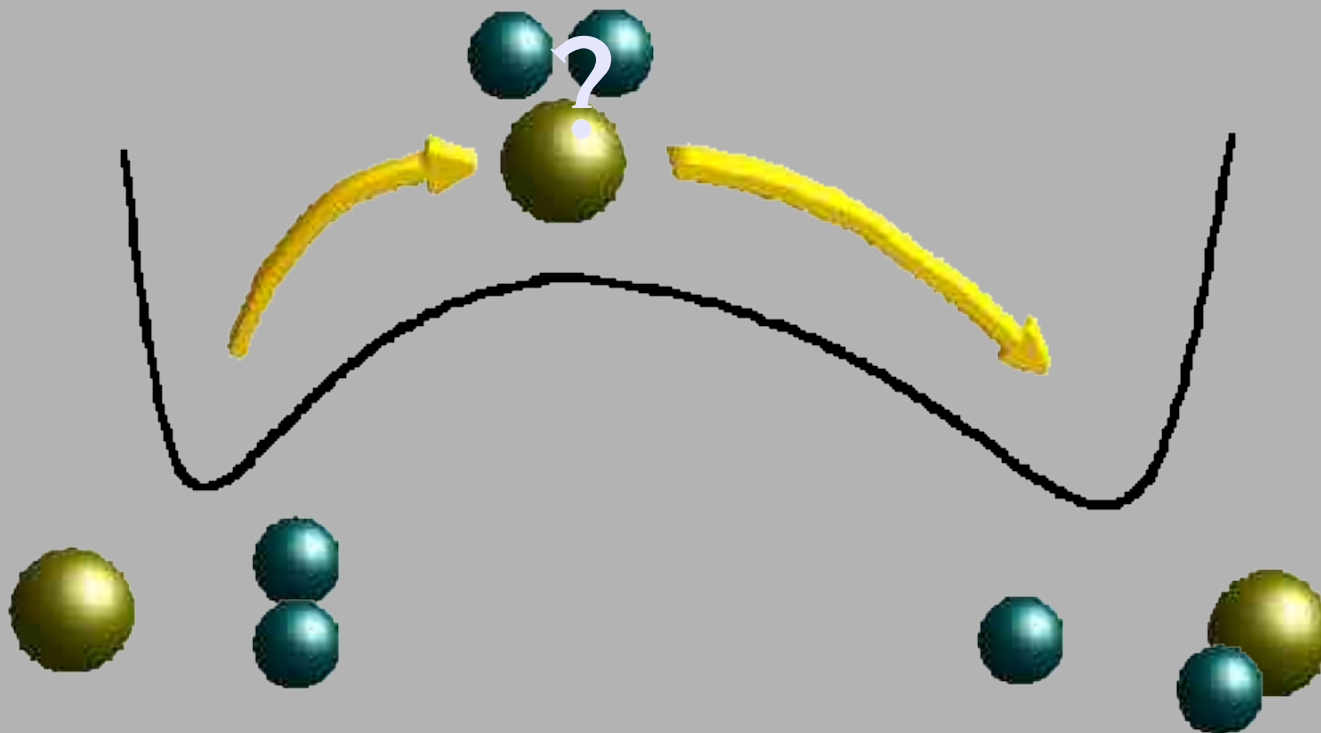


# Trends in Ultrafast Spectroscopy in the Molecular Sciences

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Tony Hansson

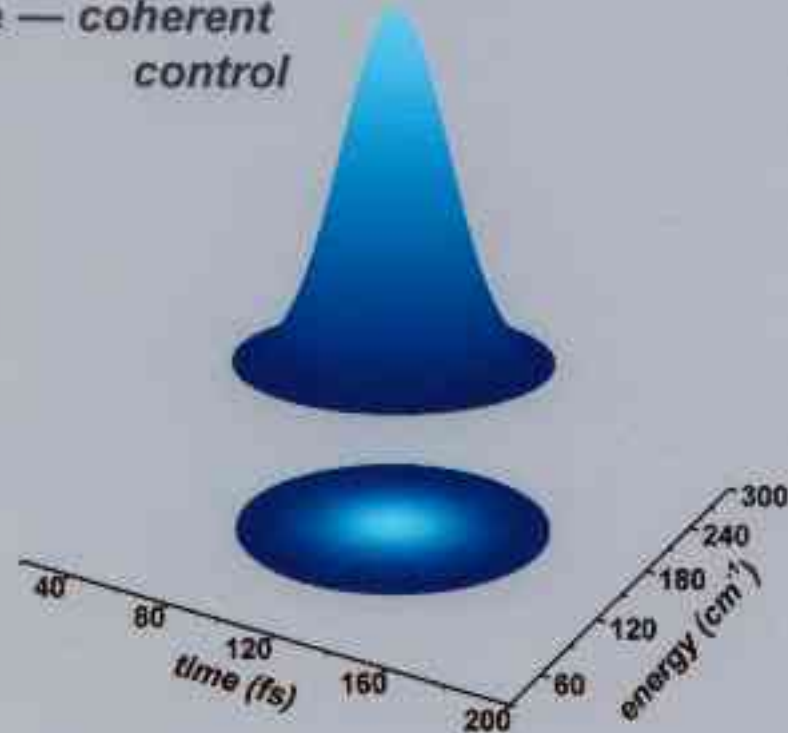
Molecular Physics, Stockholm University



# ultrafast pulses

- *what are they good for?*

- short — *time resolution*
- intense — *non-linear processes*
- shapeable — *coherent control*



# ultrafast molecular spectroscopy

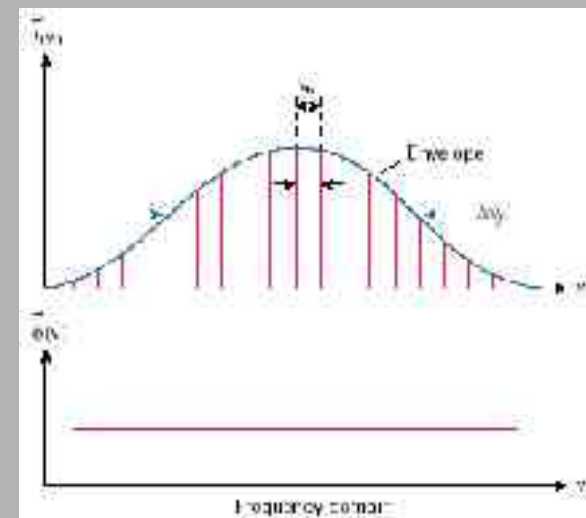
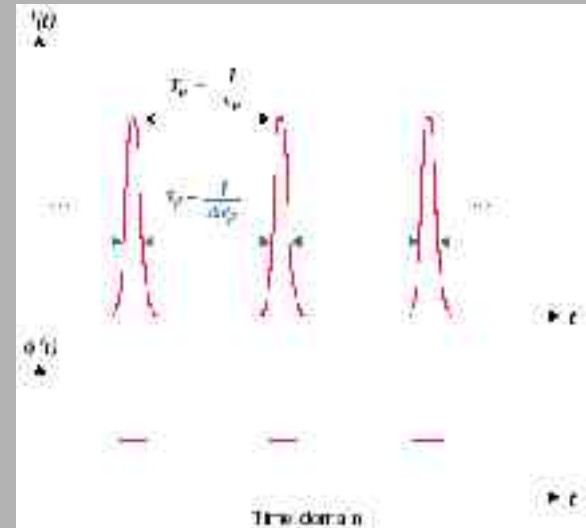
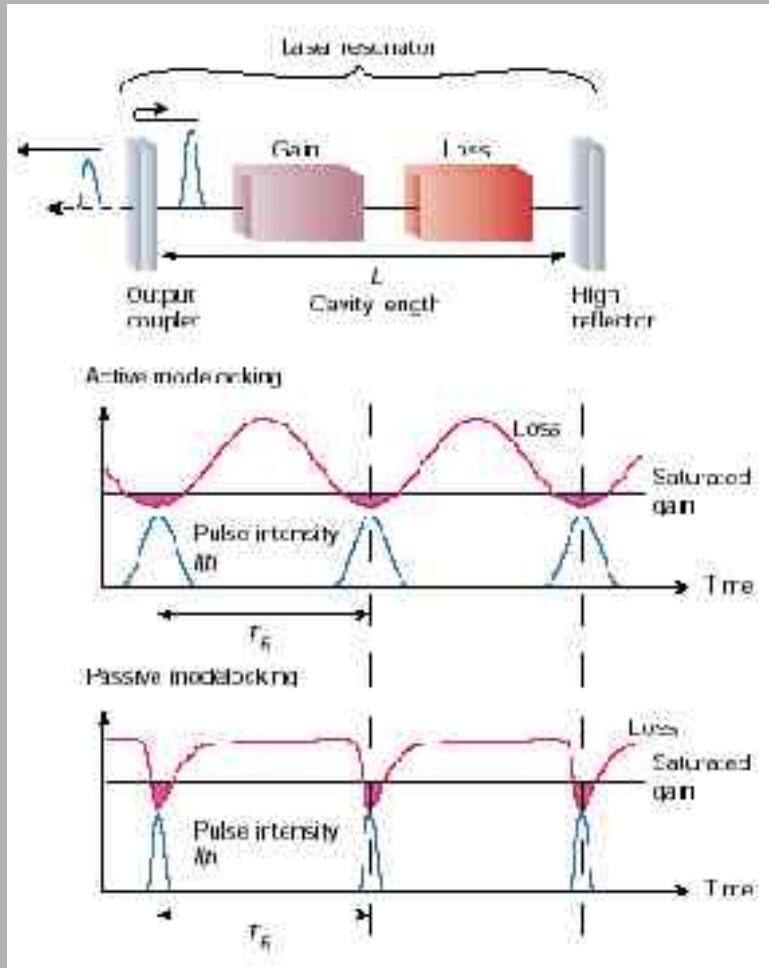
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## - *current trends*

- increased time resolution – attosecond physics
  - electron dynamics
- real-time diffraction
  - atomic motion in space
- coherent control
  - chemical reaction control, quantum computing
- infrared pulses
  - intramolecular energy redistribution, structure
- product momentum imaging
  - chemical dynamics
- ultrahigh intensity @  $I > 10^{18}$  W/cm<sup>2</sup>
  - "new" physics, assisted nuclear fusion

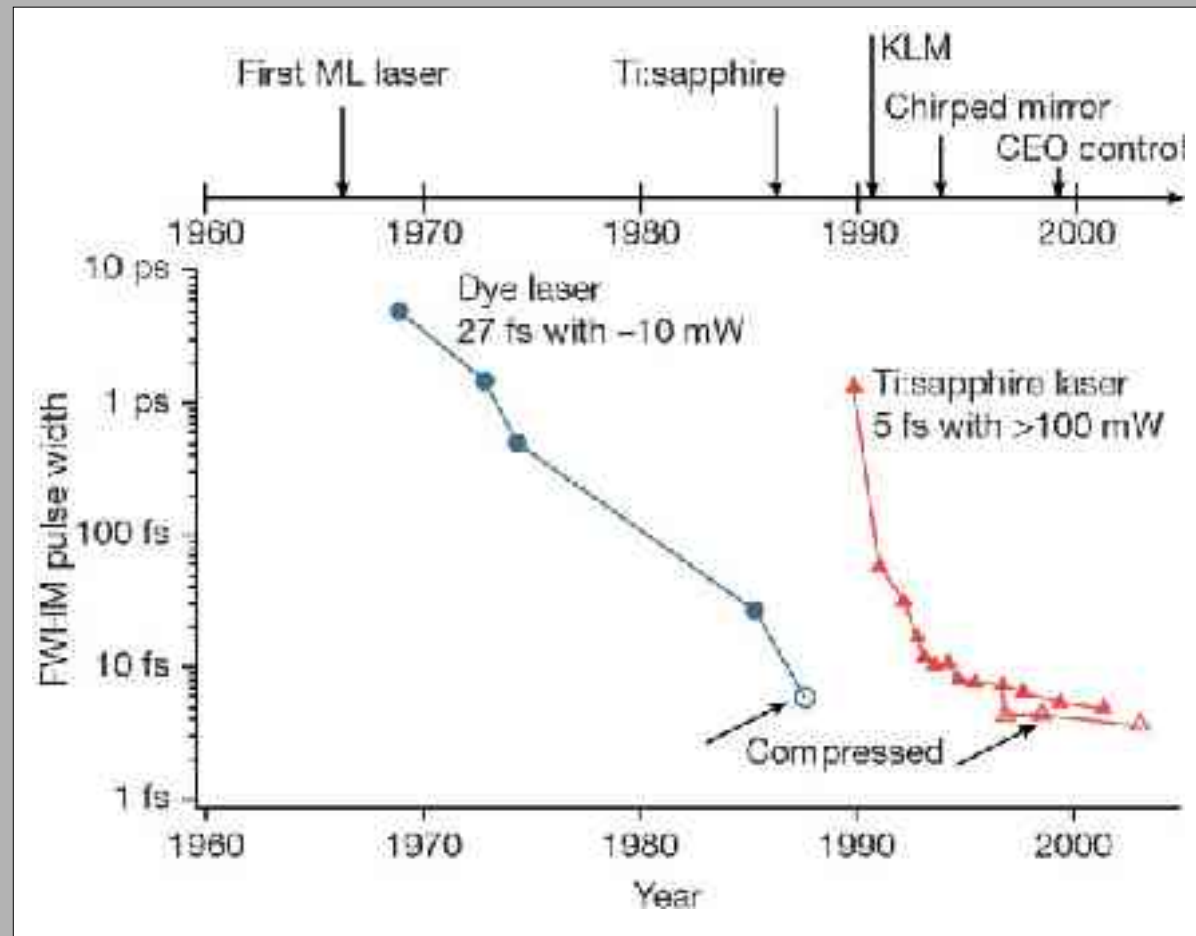
# ultrafast pulses

## - generation by mode-locking



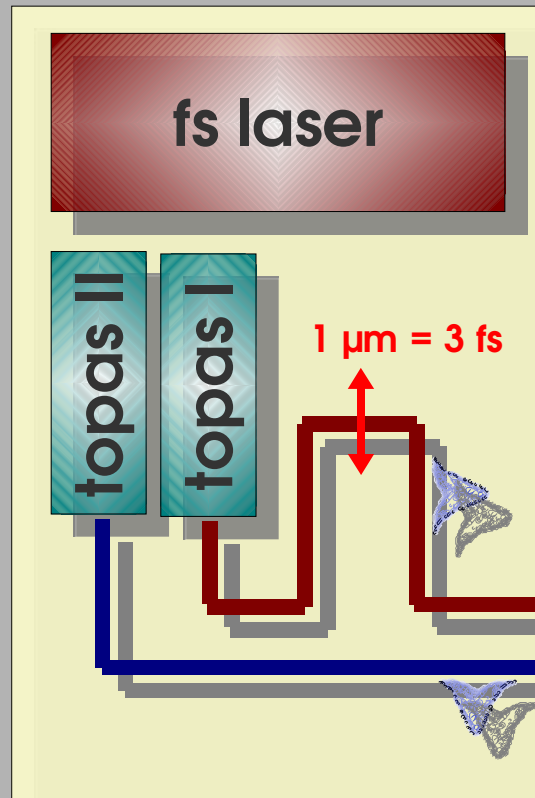
# ultrafast lasers

- *reaching the ultimate visible limit*

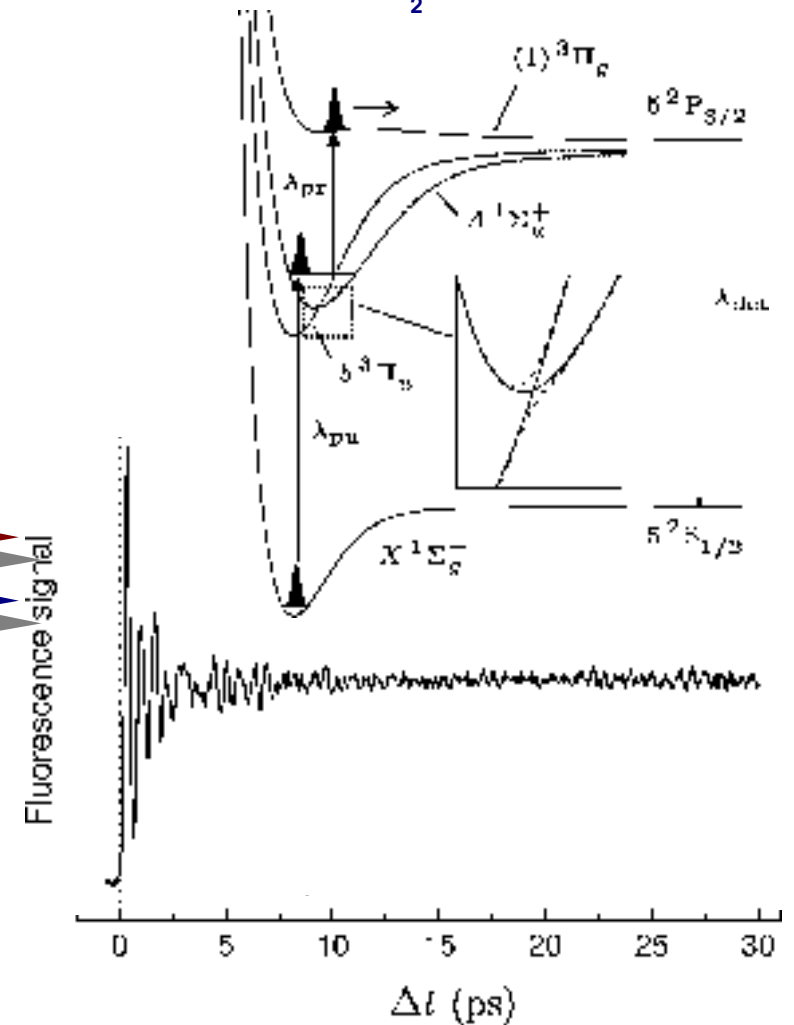


# laboratory for **ultrafast chemical physics**

- *ultrafast pump-probe spectroscopy*



*example* – perturbed molecular dynamics  
in  $\text{Rb}_2$



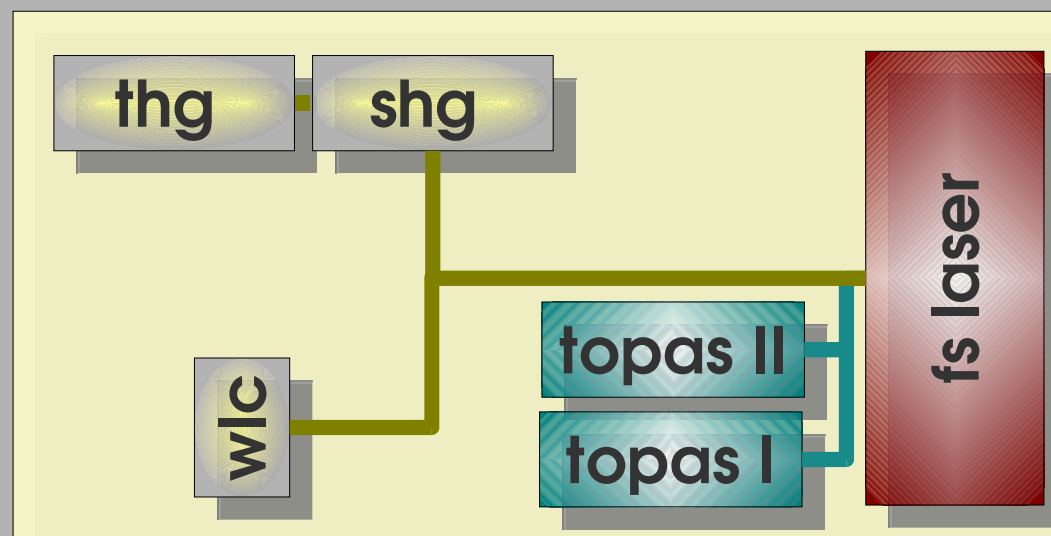
# laboratory for **ultrafast chemical physics**

## - *light characteristics*

**third harmonic**  
-----  
260 nm, 160 fs, 100μJ  
1 kHz

**second harmonic**  
-----  
390 nm, 160 fs, 250μJ  
1 kHz

**Clark-MXR  
CPA2001**  
-----  
780 nm  
160 fs  
800 μJ  
1 kHz

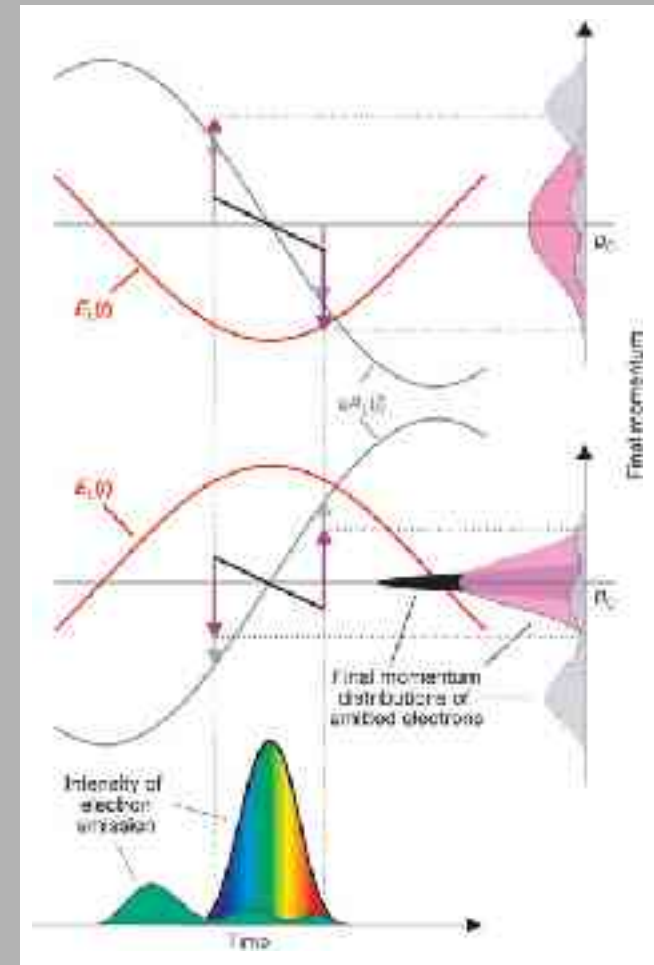
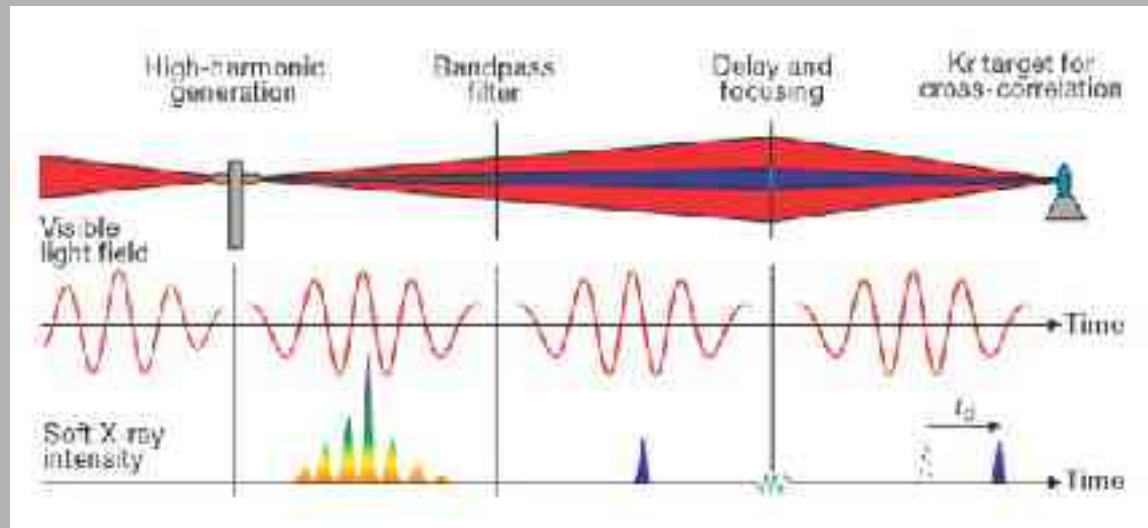


**white-light continuum**  
-----  
330 nm-NIR, 160 fs  
< 1μJ, 1 kHz

**Light Conversion, TOPAS**  
-----  
240-2300 nm, 110 fs  
1-50 μJ, 1 kHz

# increased time resolution

## - attosecond pulse generation



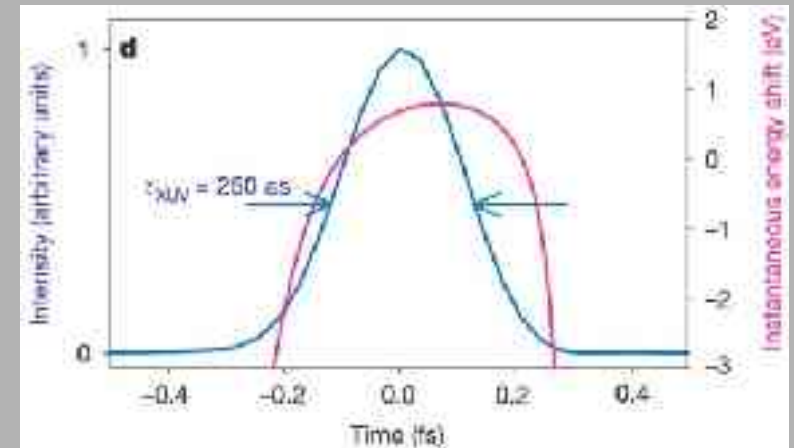
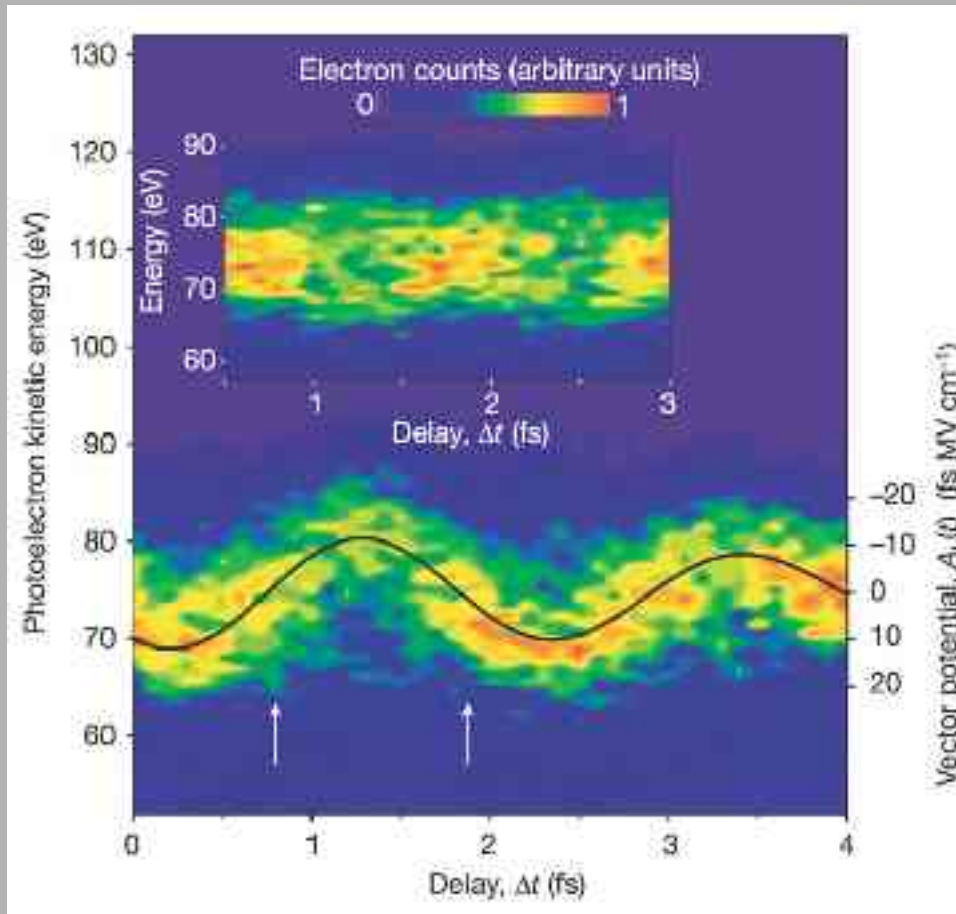
R. Hienberger<sup>1</sup>, E. Goulielmakis<sup>2</sup>, M. Uiberacker<sup>3</sup>, A. Baltuska<sup>1</sup>,  
V. Yakovlev<sup>1</sup>, F. Bammer<sup>4</sup>, A. Senf<sup>1</sup>, Th. Wornatzenbach<sup>1</sup>,  
U. Kleineberg<sup>1</sup>, U. Heinzmann<sup>1</sup>, M. Drescher<sup>1</sup> & F. Krausz<sup>1</sup>

SCIENCE 305 (42) (26 FEBRUARY 2004)



# increased time resolution

## - attosecond pulse generation

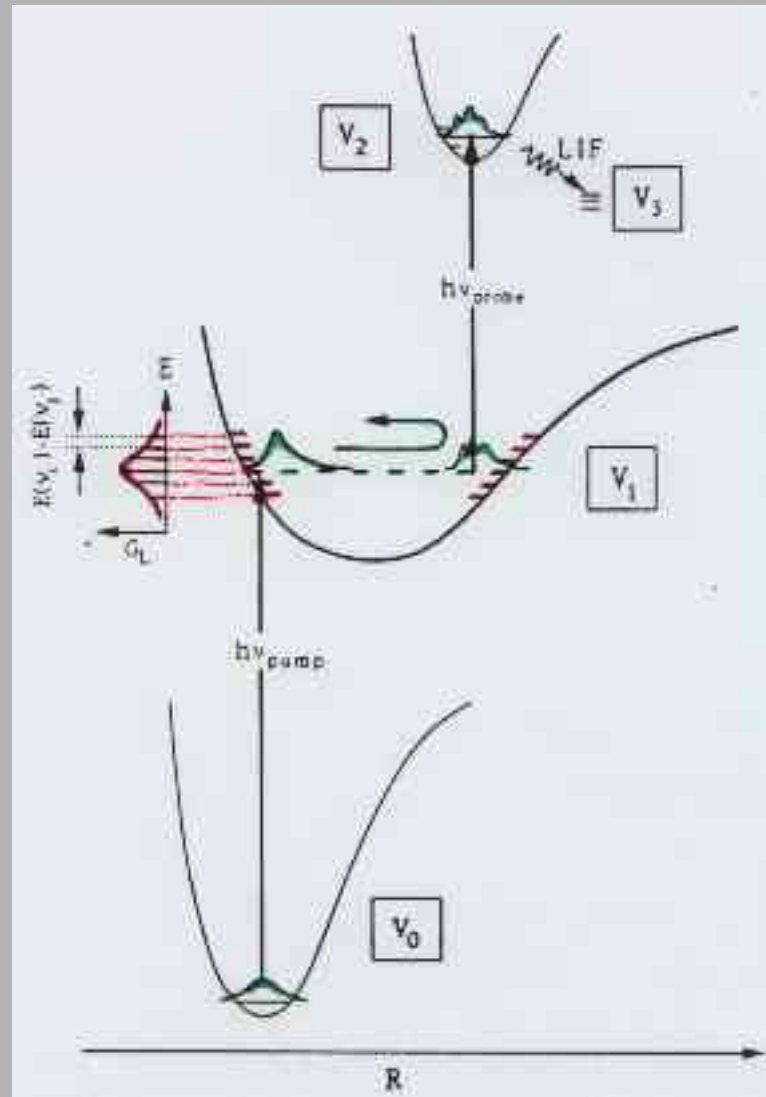


R. Miesberger<sup>1</sup>, E. Goulielmakis<sup>1</sup>, M. Uiberacker<sup>1</sup>, A. Baltuska<sup>1</sup>,  
V. Yakovlev<sup>1</sup>, F. Bammer<sup>1</sup>, A. Saratz<sup>1</sup>, Th. Wornatzenbock<sup>1</sup>,  
U. Kleineberg<sup>1</sup>, U. Heinzmann<sup>1</sup>, M. Drescher<sup>1</sup> & F. Krausz<sup>1</sup>

NATURE VOL 431 | 24 FEBRUARY 2004

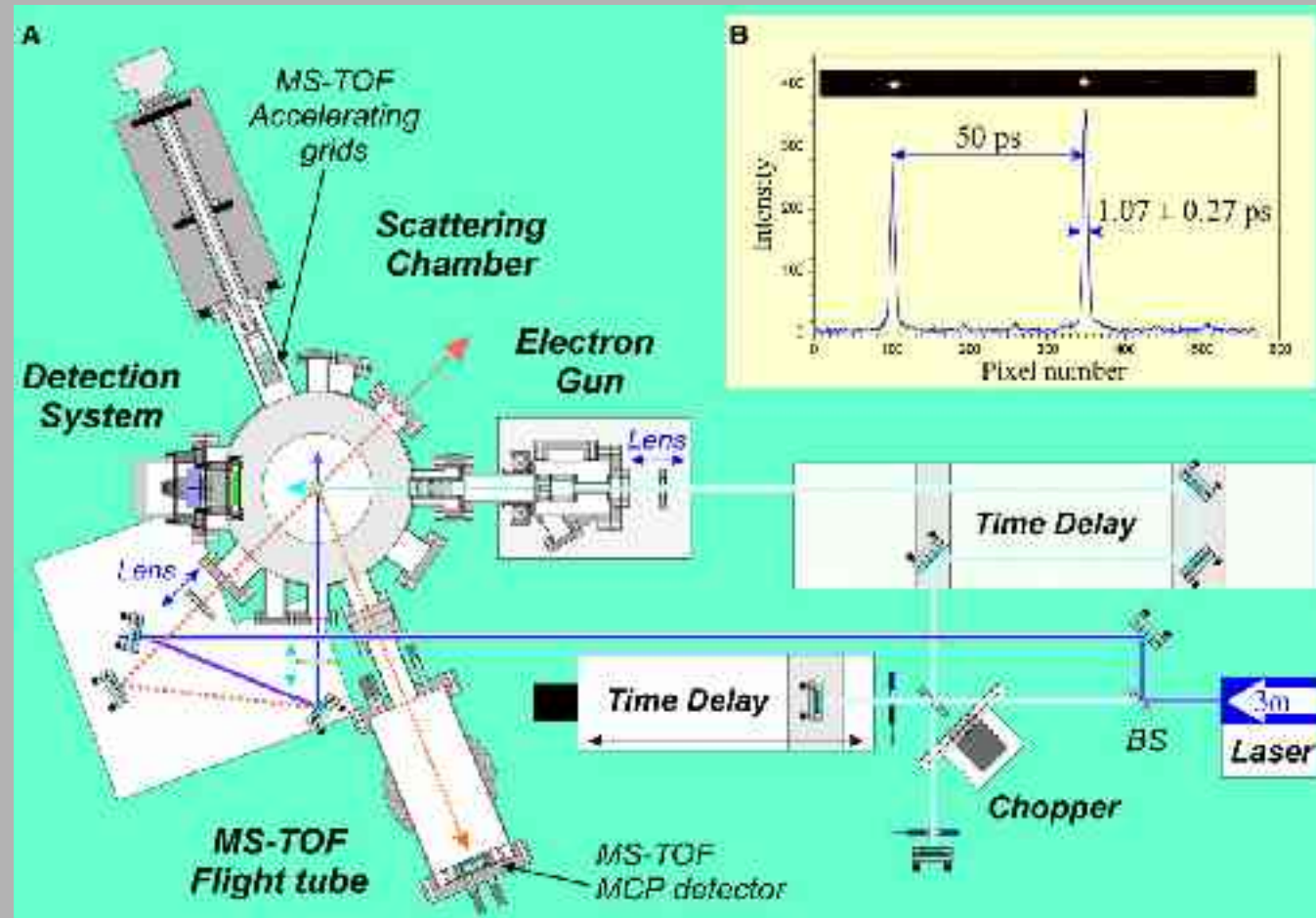
# real-time diffraction

- absorption yields position indirectly



# real-time diffraction

## - electron diffraction

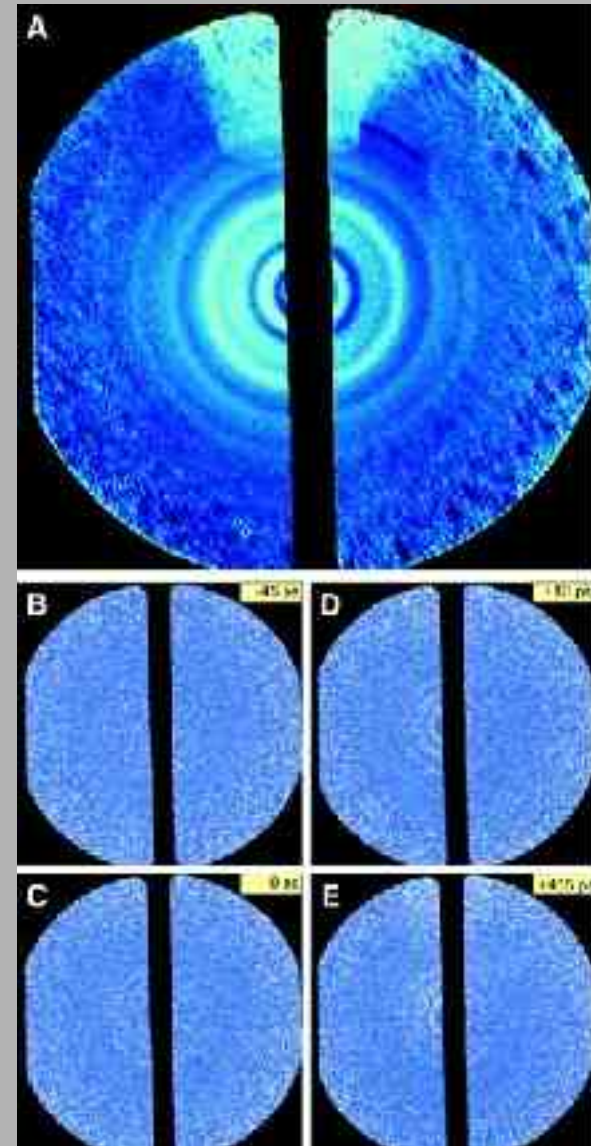
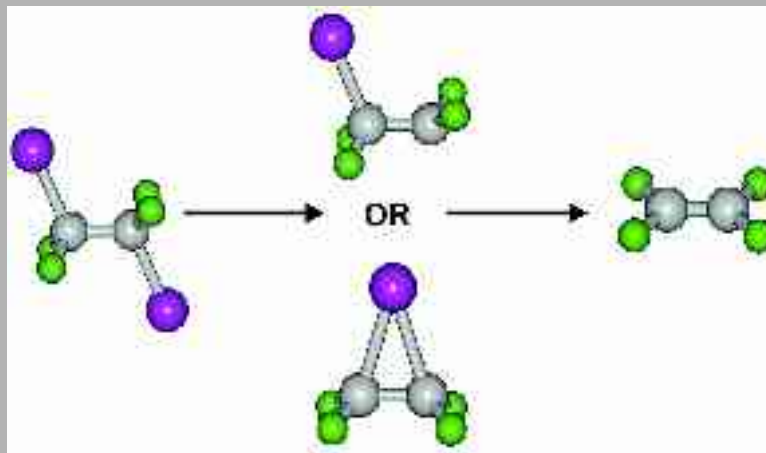


Huyecherl Ihae, Vladimir A. Lobastov, Udo M. Gomes,  
Royd M. Candon, Ramesh Srinivasan, Chong-Yu Fan  
Ahmed H. Zewail\*

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# real-time electron diffraction

- *molecular dynamics in space*



Huyecherl Ihse, Vladimir A. Lobastov, Udo M. Gomez,  
Reyd M. Candoss, Ramesh Srinivasan, Chong-Yu Fung,  
Ahmed H. Zewail\*

10.1038/35017011

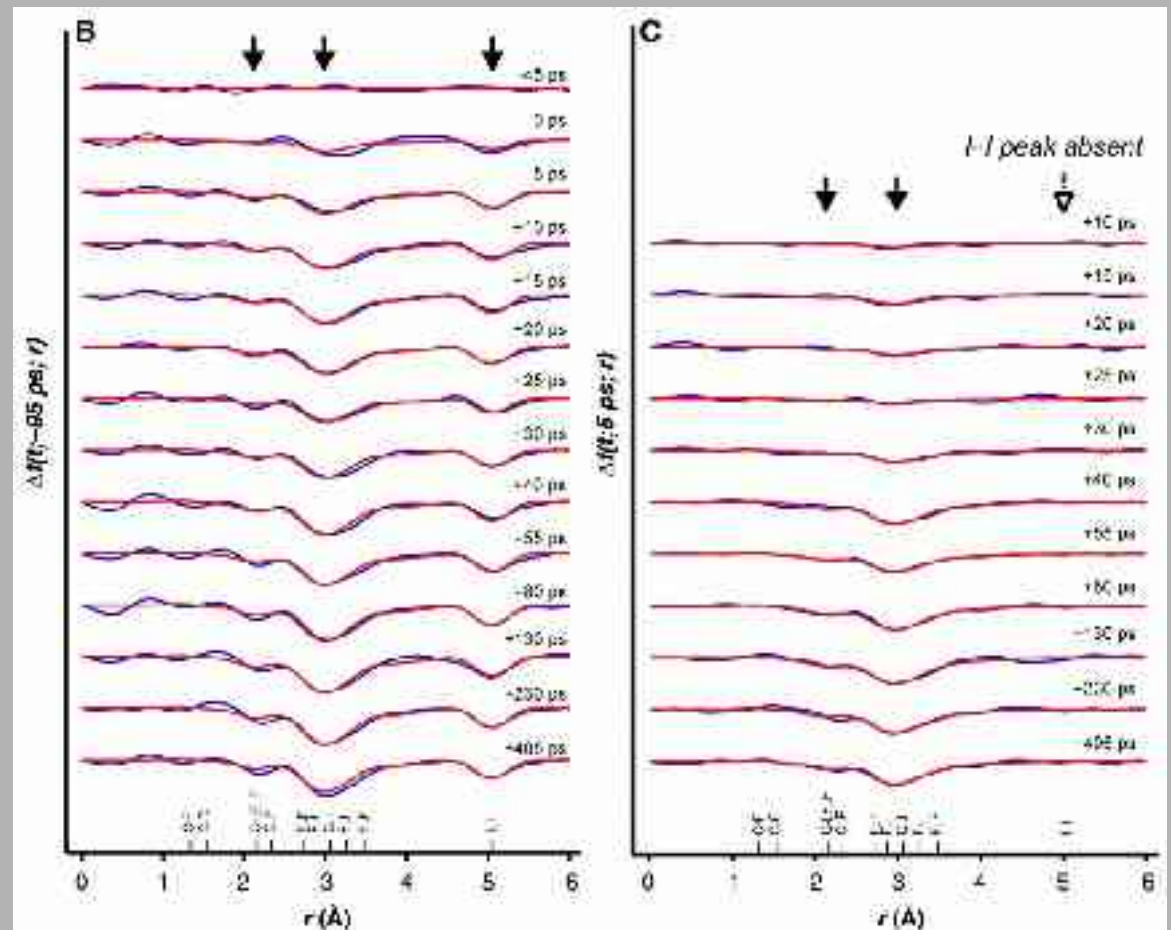
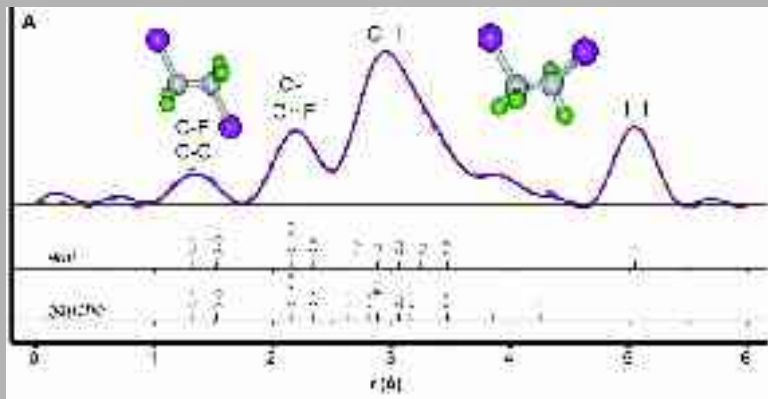


FYSIKUM

# real-time electron diffraction

- *molecular dynamics in space*

$$f(r) = \int_0^{r_{\text{max}}} sM(s) \sin(sr) \exp(-ks^2) ds$$



Huyecherl Ihse, Vladimir A. Lobastov, Udo M. Gomez,  
Reyd M. Candoss, Ramesh Srinivasan, Chong-Yu Fan,  
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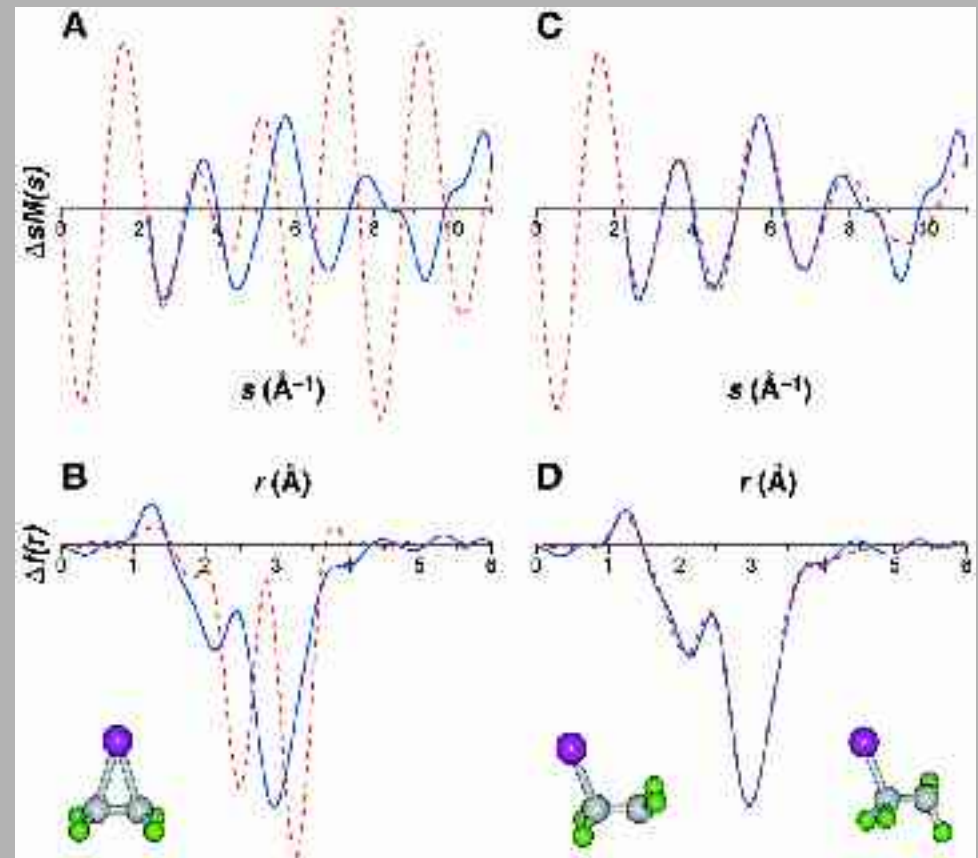
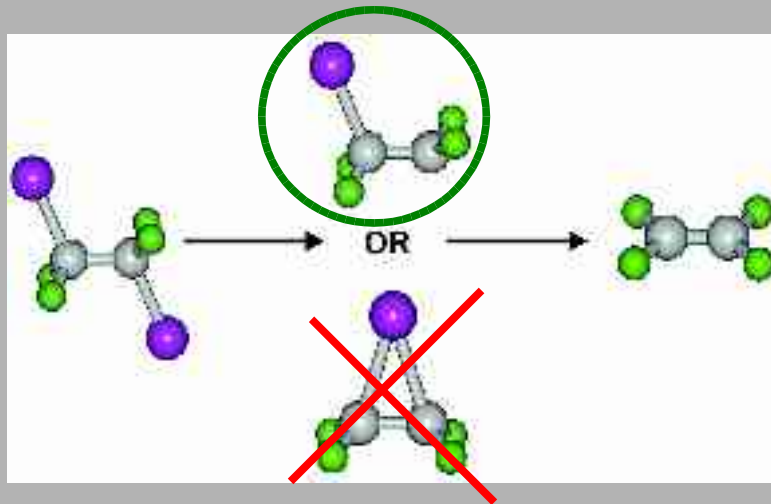
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FYSIKUM

# real-time electron diffraction

- *molecular dynamics in space*

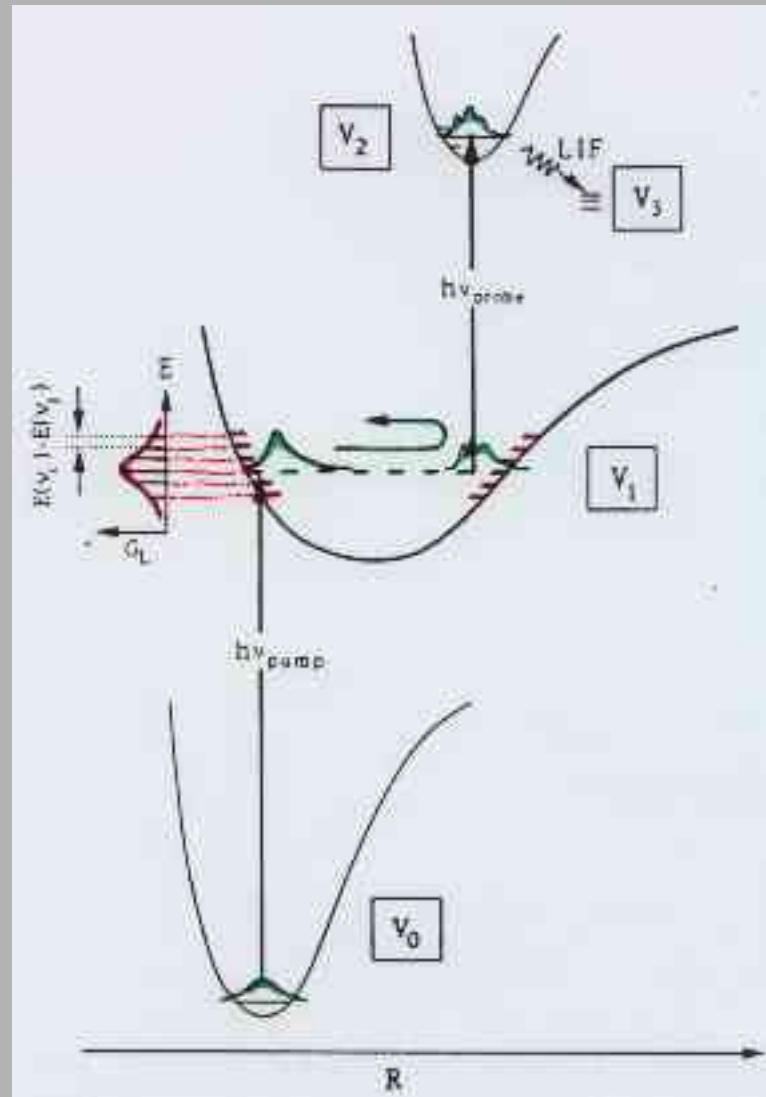


Huyecheri Ihae, Vladimir A. Lobastov, Udo M. Gomes,  
Royd M. Candon, Ramesh Srinivasan, Chong-Yu Fuan,  
Ahmed H. Zewail\*

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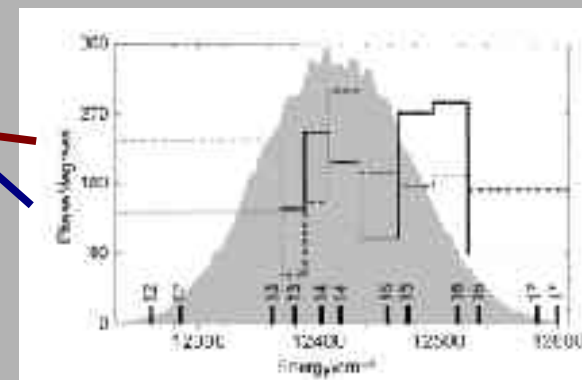
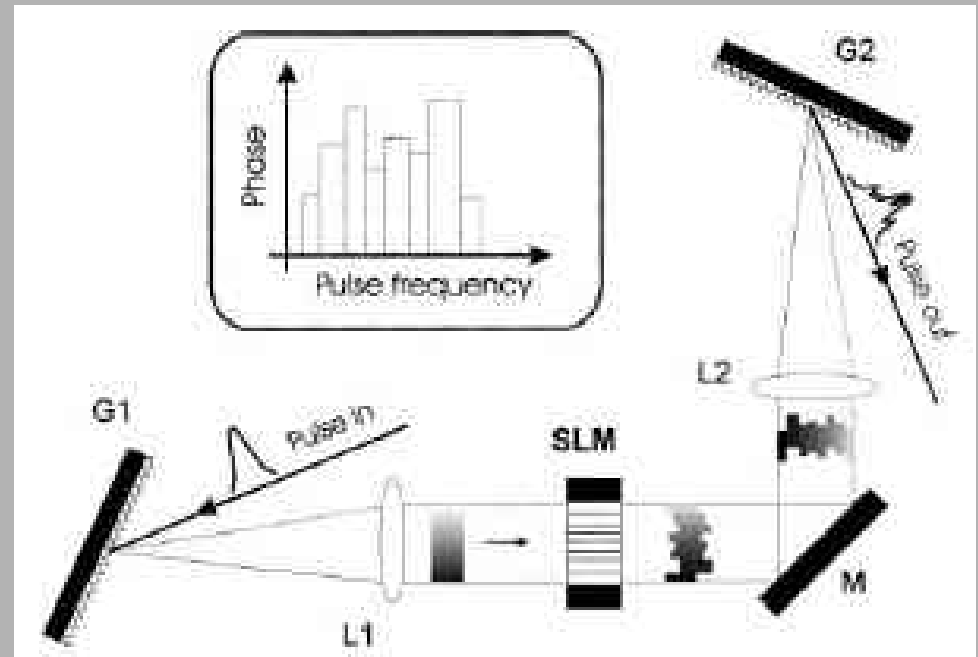
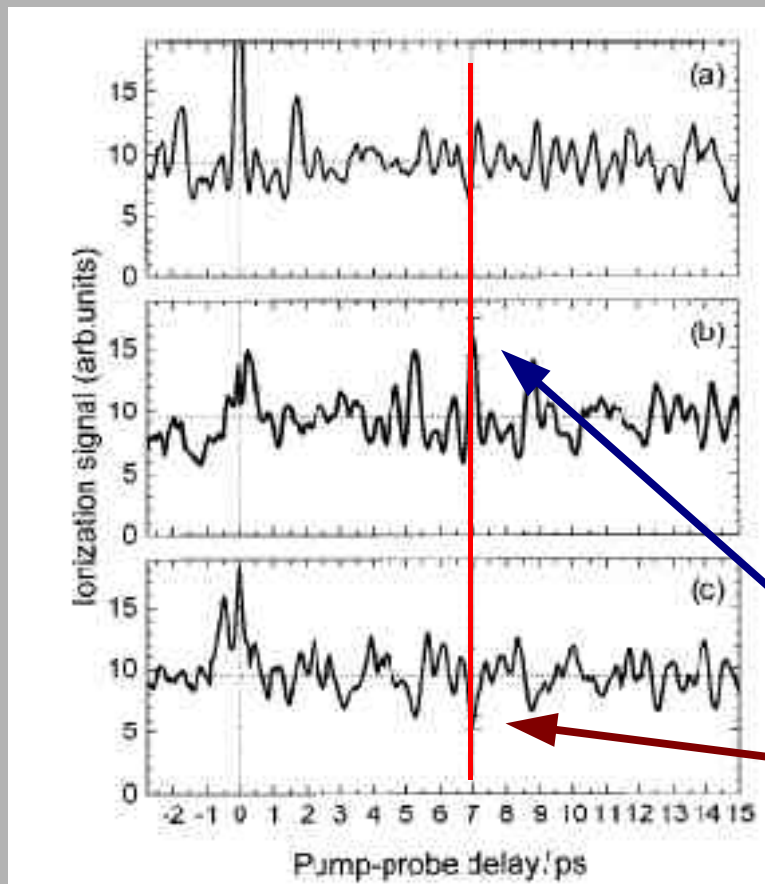
# coherent control

## - molecular quantum wavepackets



# coherent control

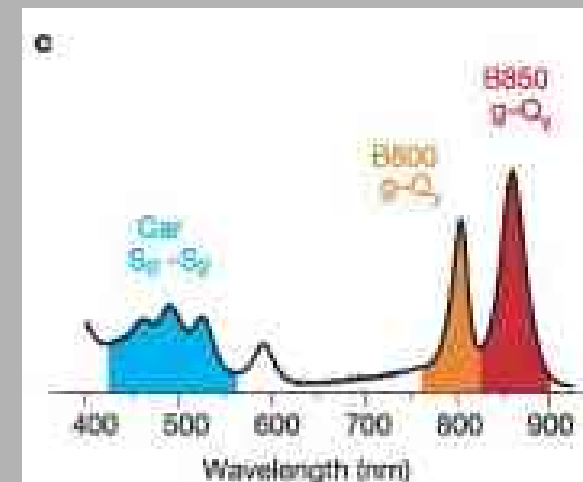
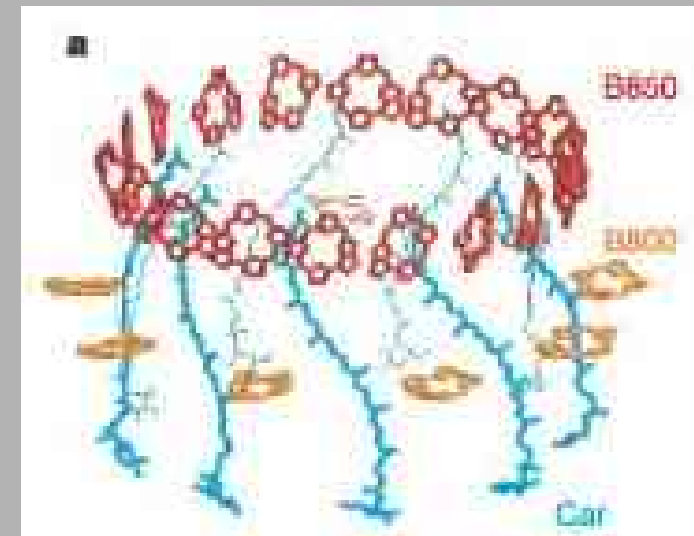
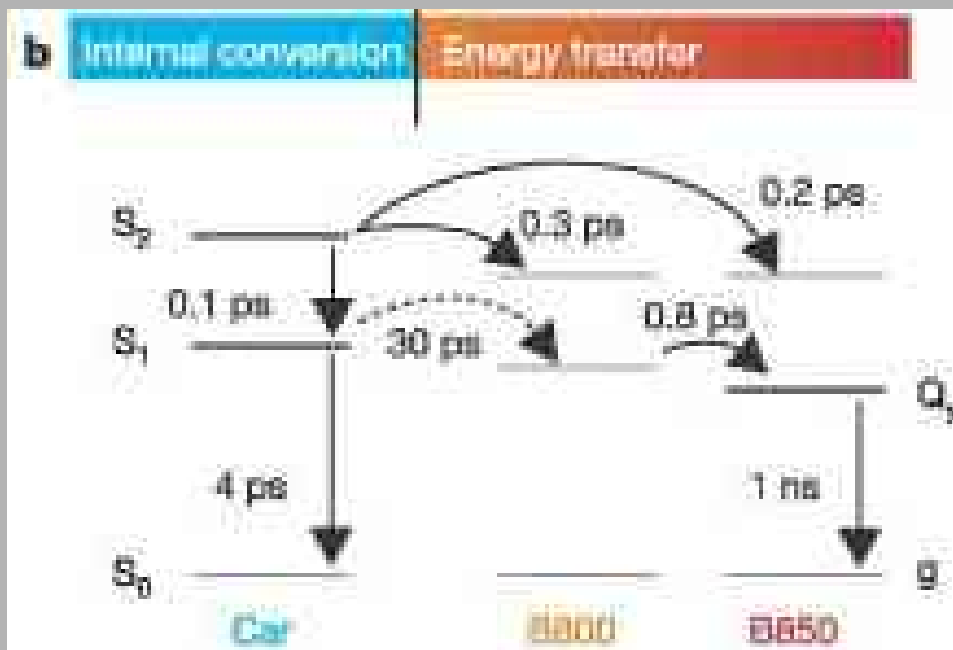
- *manipulating molecular quantum dynamics*





# coherent control

## - controlling biological light harvesting



Jennifer L. Horek<sup>1</sup>, Wael Wehbe<sup>2</sup>, Richard J. Cogdell<sup>3</sup>,  
Dirk Zaidler<sup>1</sup> & Marcus Motzkus

NATURE PHOTONICS | 10 MAY 2012 | www.nature.com



