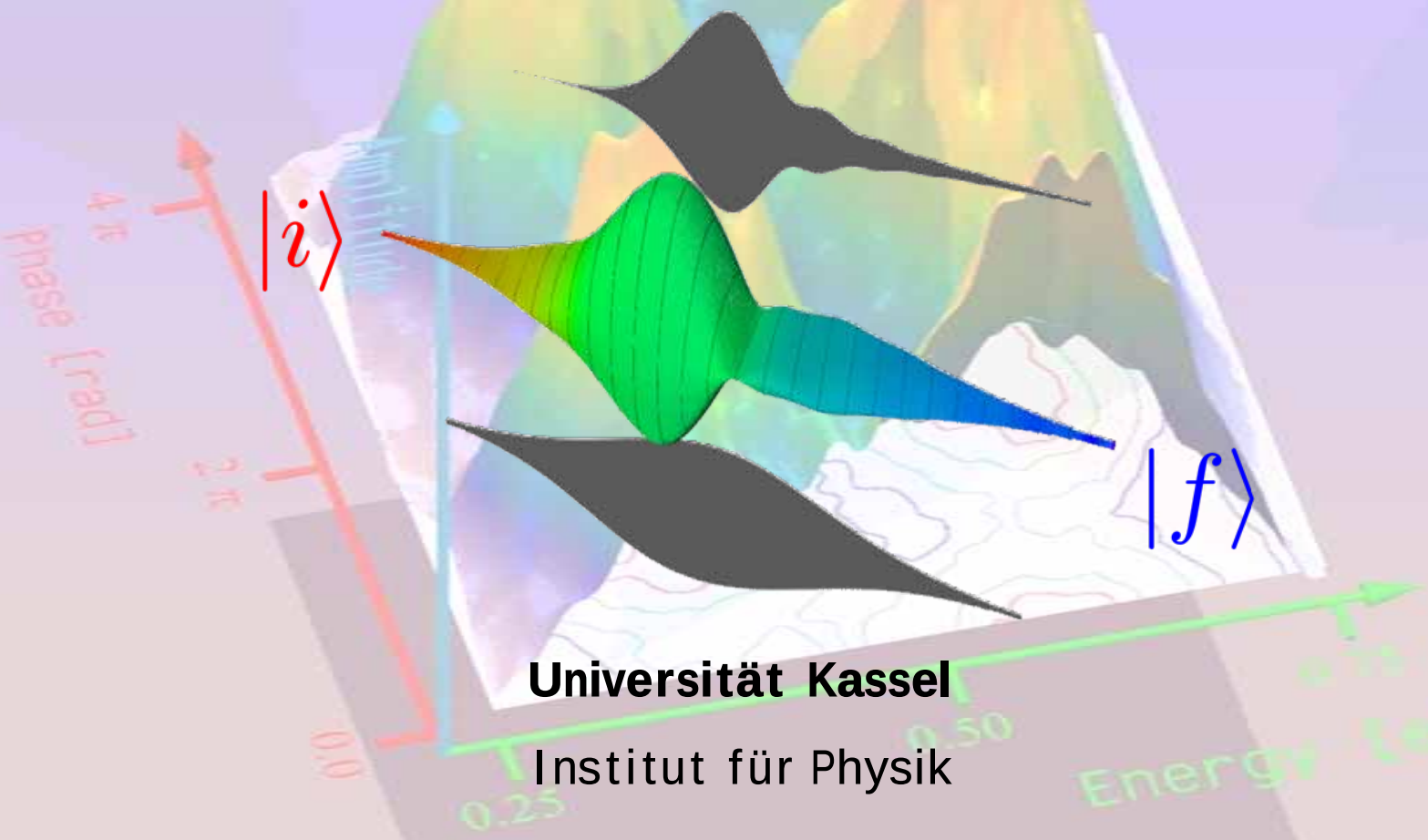
Robust Photon Locking

M. Wollenhaupt, T. Bayer and T. Baumert



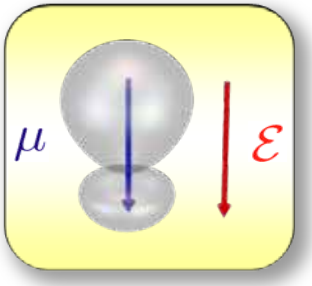
Universität Kassel

Institut für Physik

Outline

Photon Locking

- Photon locking for quantum control
- The physical mechanism of photon locking
- Experiments on ultrafast photon locking

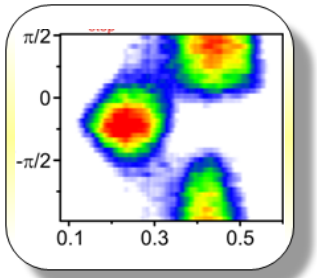


Strong-field control

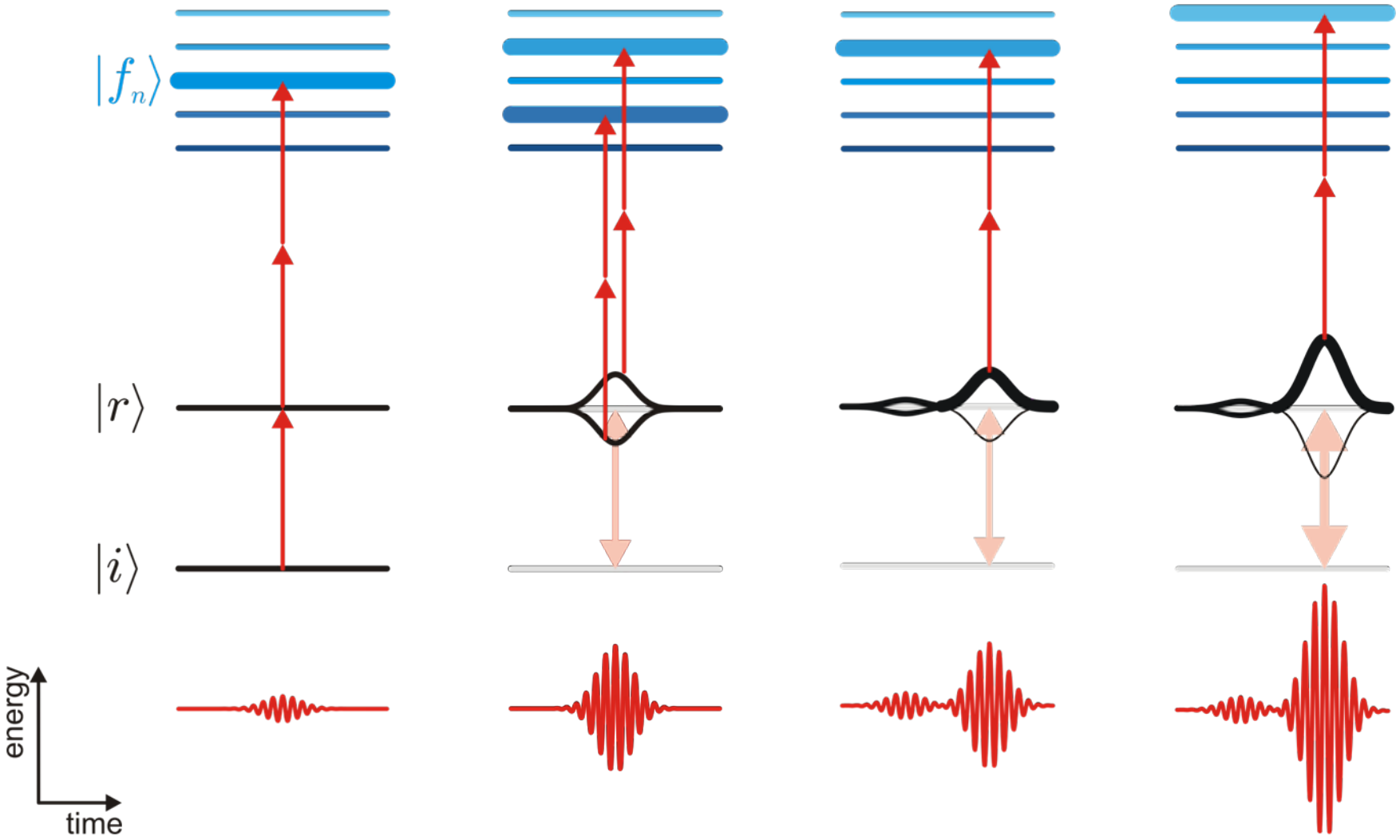
- The trouble with strong – field control
- Robust adiabatic techniques

Robust photon locking

- Shaped pulses for robust photon locking
- An ultrafast toggle switch
- Robustness via adiabatic state preparation



Strong-field control: the general picture

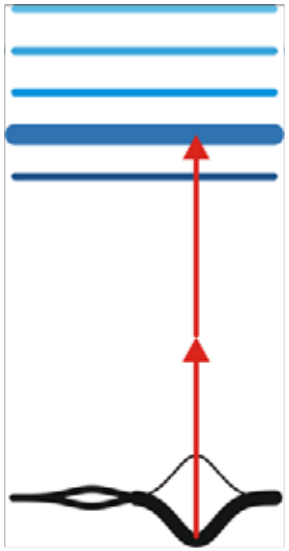


Selectivity and tunability

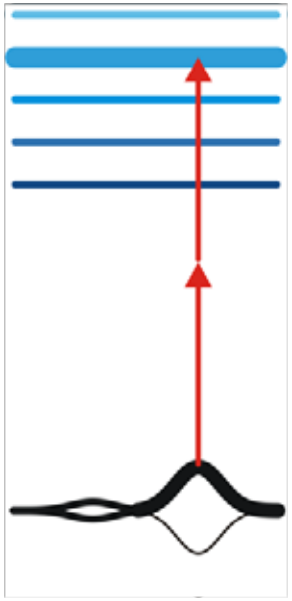
➢ Target state control is achieved by control of

❶ dressed state ***populations***

❷ dressed state ***energies***



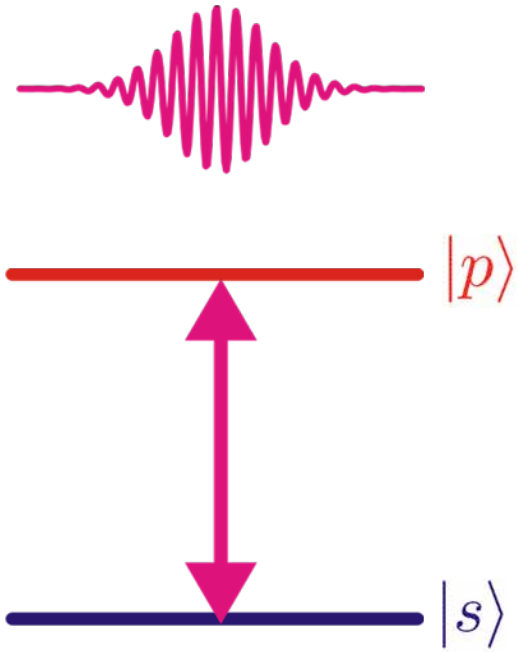
Selectivity



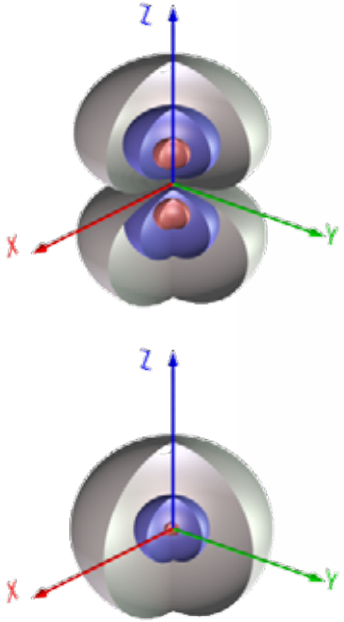
Tunability

What is photon locking?

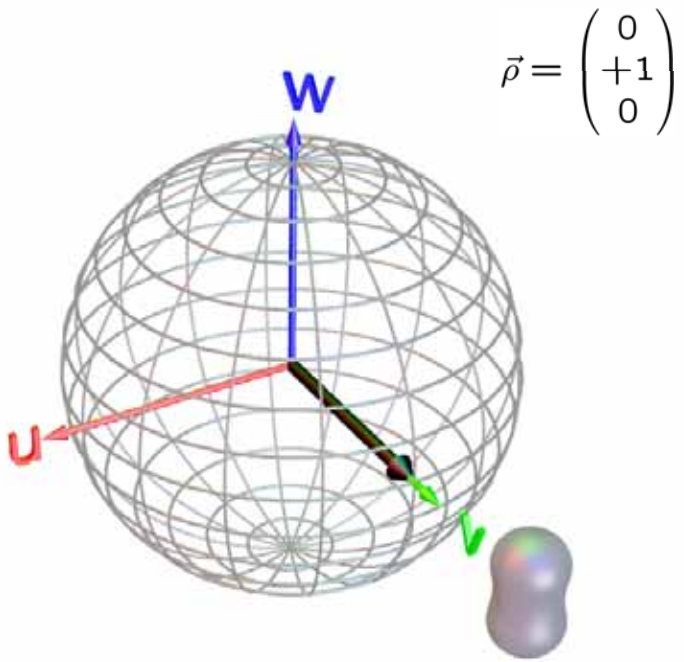
Bare states



Spatio-temporal



Bloch-vector



J. Phys. B., ***41***, *074007*, (2008), Special Issue on Quantum Control

Yet another picture: dressed states

$$\mathcal{H}_{bare} = \begin{pmatrix} E_a & -\hbar\Omega(t) \\ -\hbar\Omega^*(t) & E_b \end{pmatrix}$$

$$\mathcal{H}_{dressed} = \mathcal{A}\,\mathcal{H}_{bare}\,\mathcal{A}^\dagger$$

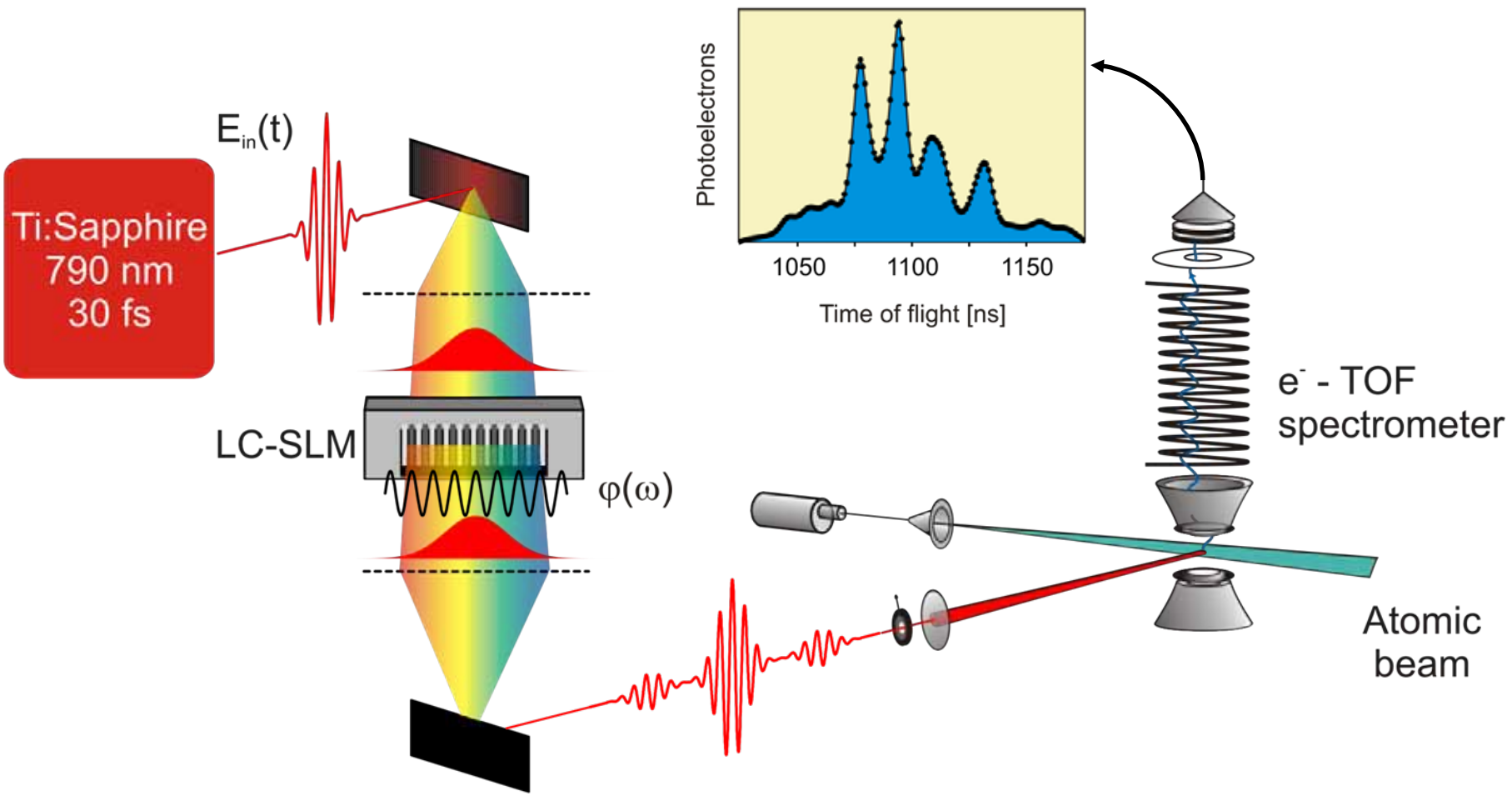
$$\mathcal{H}_{dressed} = \begin{pmatrix} \varepsilon_{low}(t) & 0 \\ 0 & \varepsilon_{up}(t) \end{pmatrix}$$

$$\Delta\varepsilon(t) = \varepsilon_{up}(t) - \varepsilon_{low}(t) = \hbar\Omega_g(t) \qquad \Omega_g(t) = \sqrt{|\Omega(t)|^2 + \delta^2}$$

$$\begin{pmatrix} d_{low}(t) \\ d_{up}(t) \end{pmatrix} = \mathcal{A} \begin{pmatrix} c_a(t) \\ c_b(t) \end{pmatrix}$$

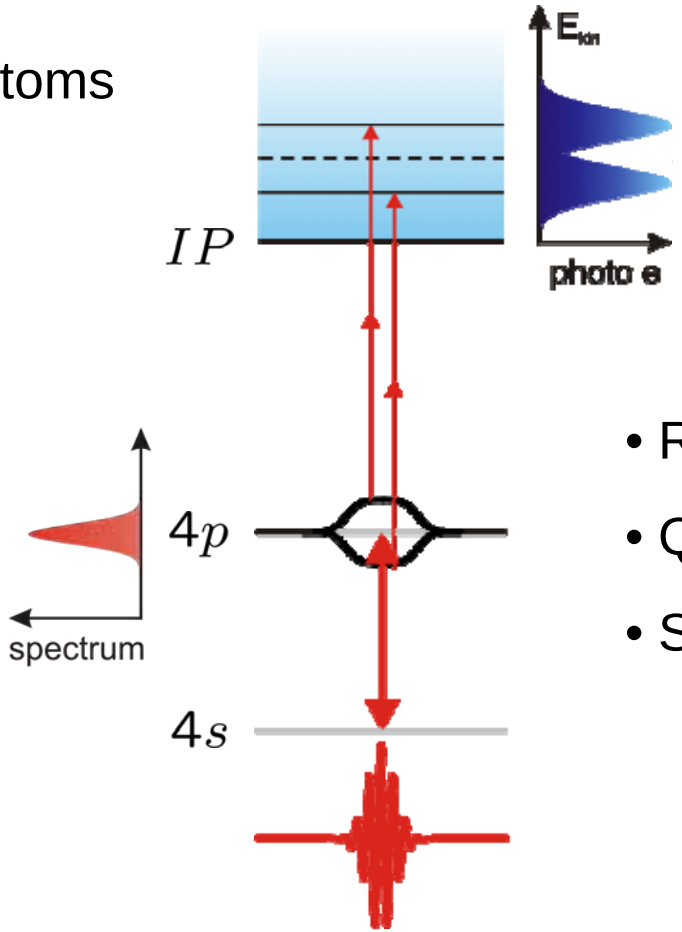
$|d_{low}(t)|^2$, $|d_{up}(t)|^2$ describe Population Of Dressed States (PODS)

Experimental setup



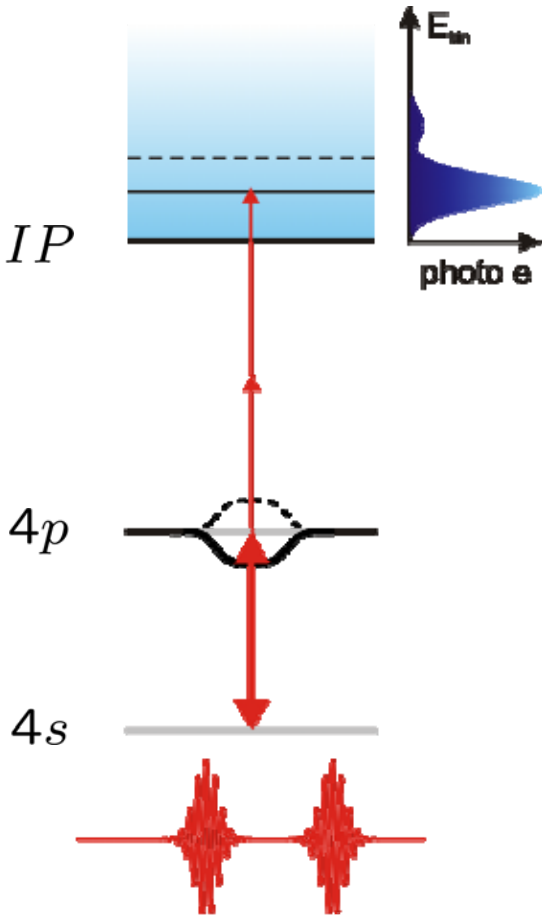
A model system for strong field control: REMPI on K atoms

K atoms

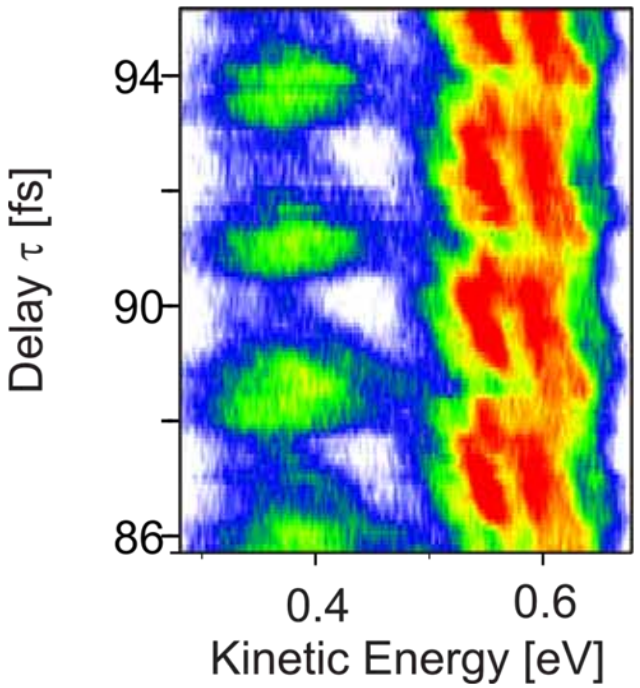


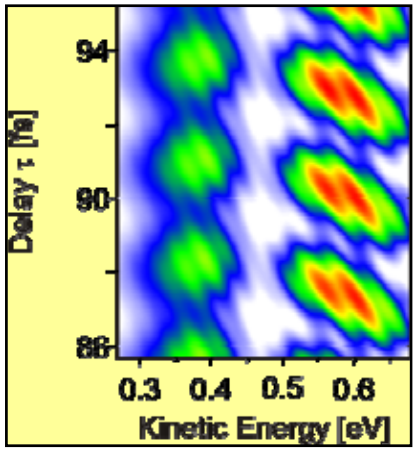
- REMPI: non-linear and resonant
- Quasi two-state system
- Strong fields: non-perturbative interaction

Photon locking with double pulse sequence



Photoelectron spectra





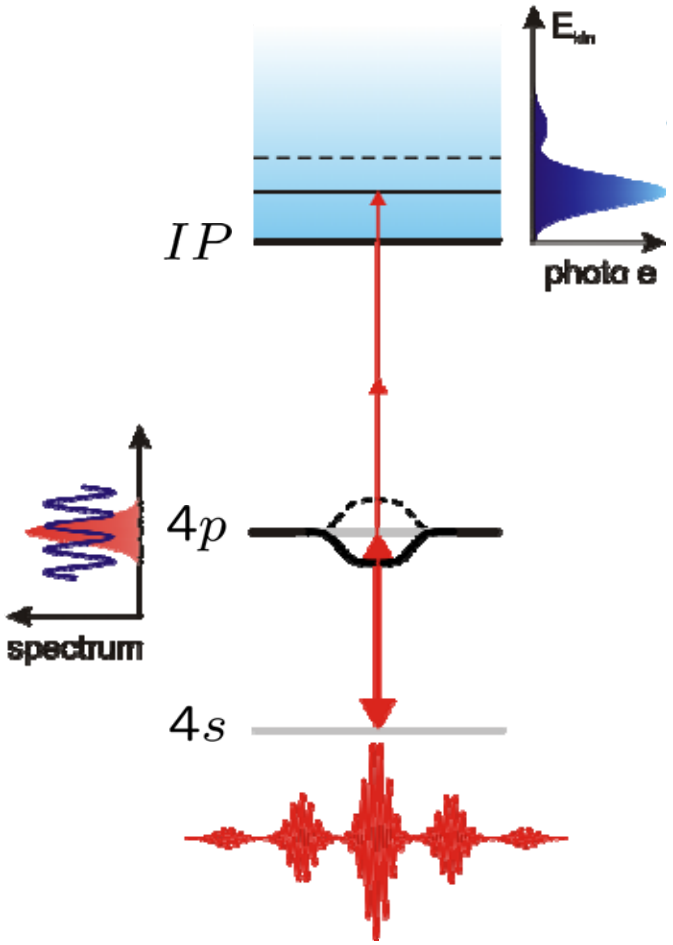
$$\dot{\vec{\rho}} = \vec{\Omega} \times \vec{\rho}$$

Phys. Rev. A, ***68***, *015401*, (2003)

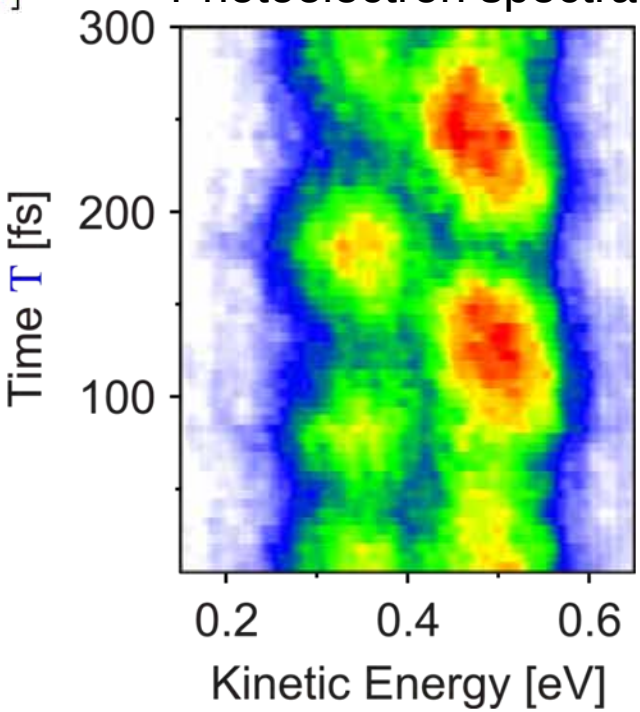
Annu. Rev. Phys. Chem, ***56***, *25*, (2005)

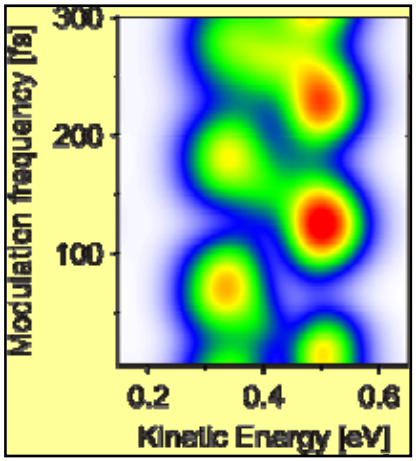
Photon Locking via shaped pulses

$$\varphi(\omega) = A \sin[(\omega - \omega_0) \cdot T + \phi]$$



Photoelectron spectra



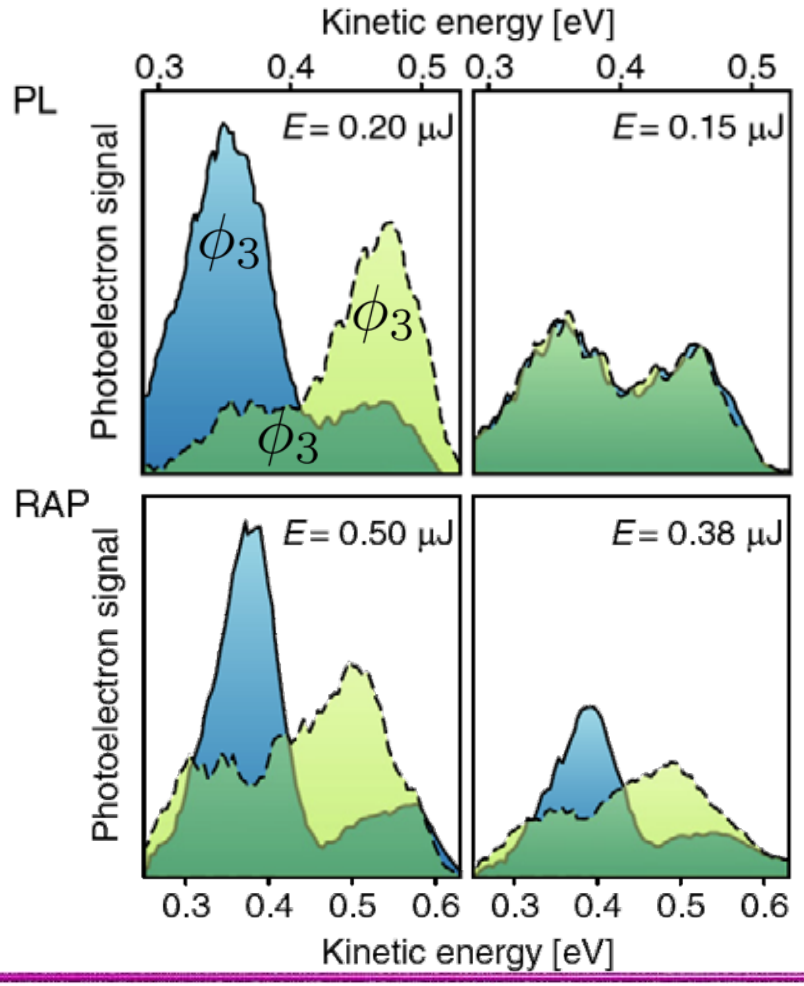


J. Mod. Opt., ***52***, *2187*, (2005)

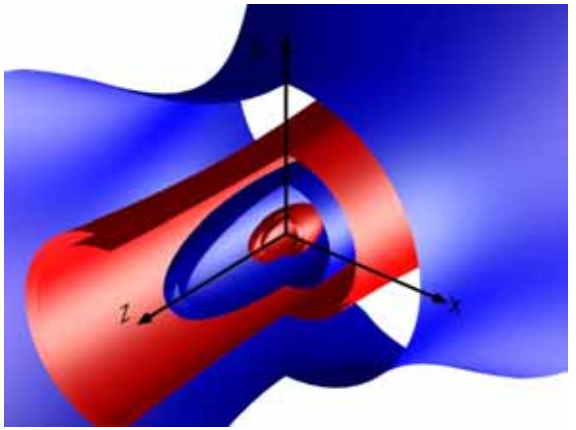
Phys. Rev. A, ***73***, *063409*, (2006)

The trouble with strong-field excitation

Highly sensitivity to intensity



Averaging over focal intensity distribution

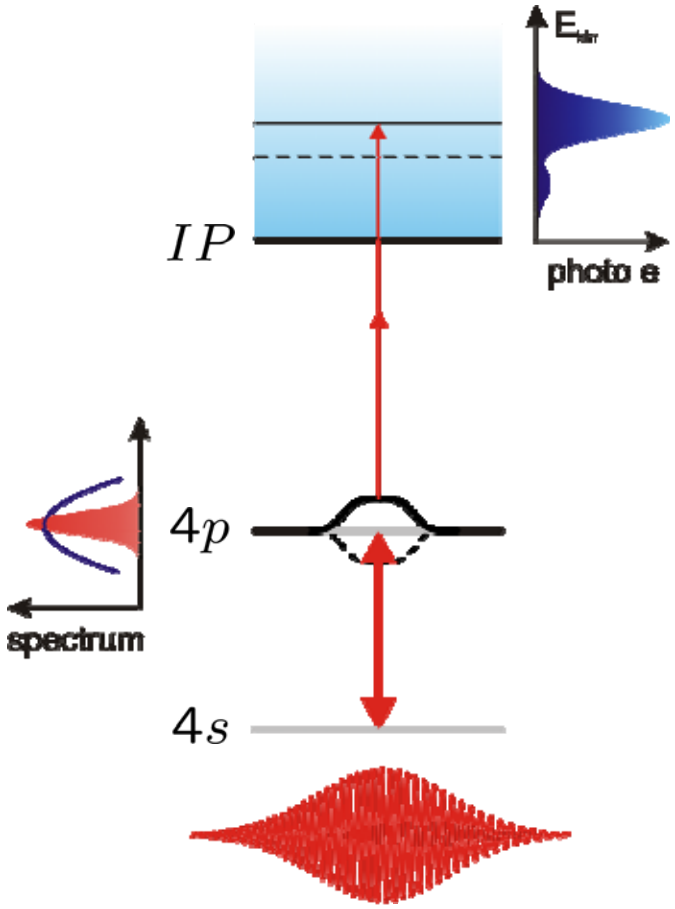


J. Phys. B., ***41***, *074007*, (2008),

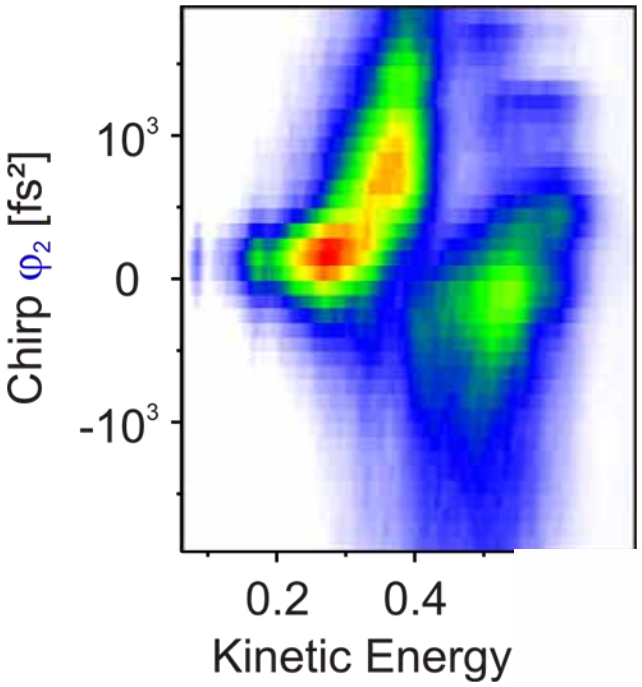
Special Issue on Quantum Control

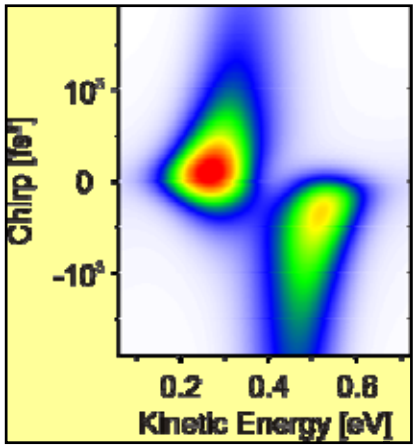
Adiabatic excitation: RAP

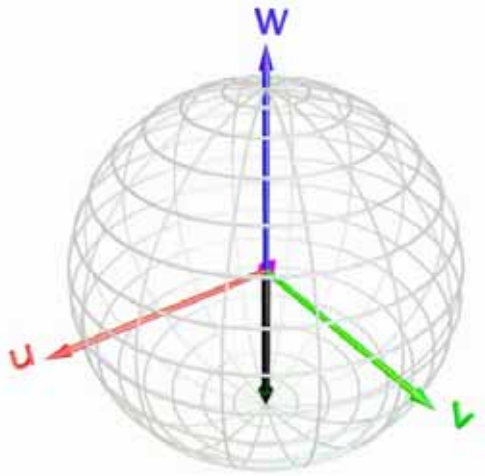
$$\varphi(\omega) = \varphi_2 \, (\omega - \omega_0)^2$$



Photoelectron spectra

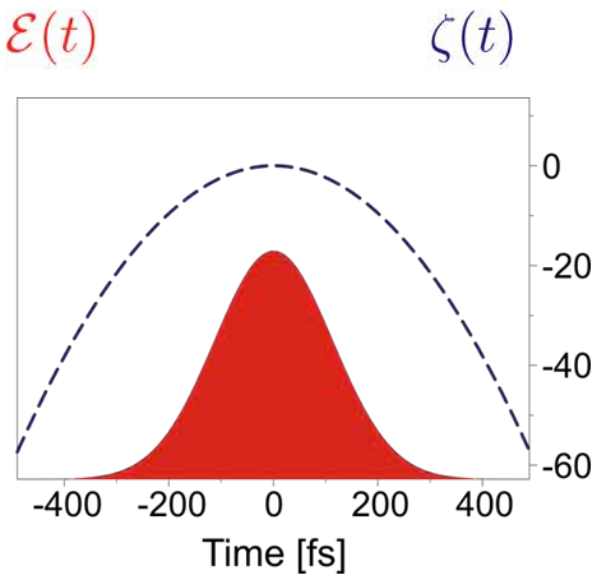




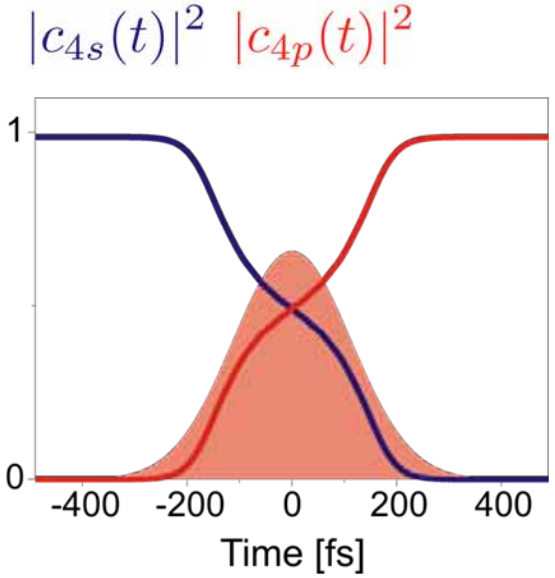


RAP (Rapid adiabatc passage)

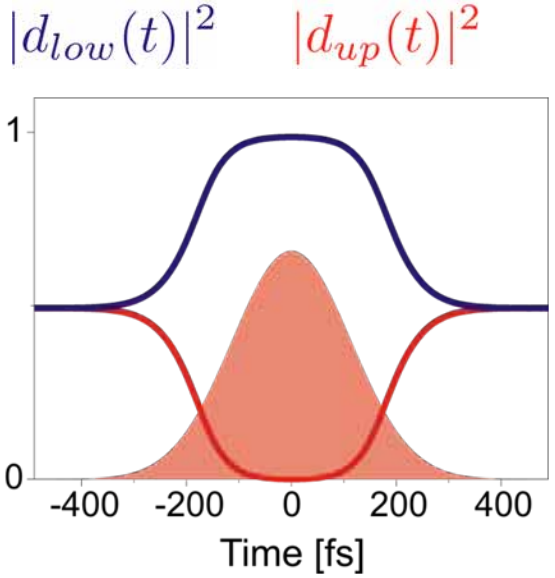
Shaped pulse



Bare state dynamics



Dressed state dynamics



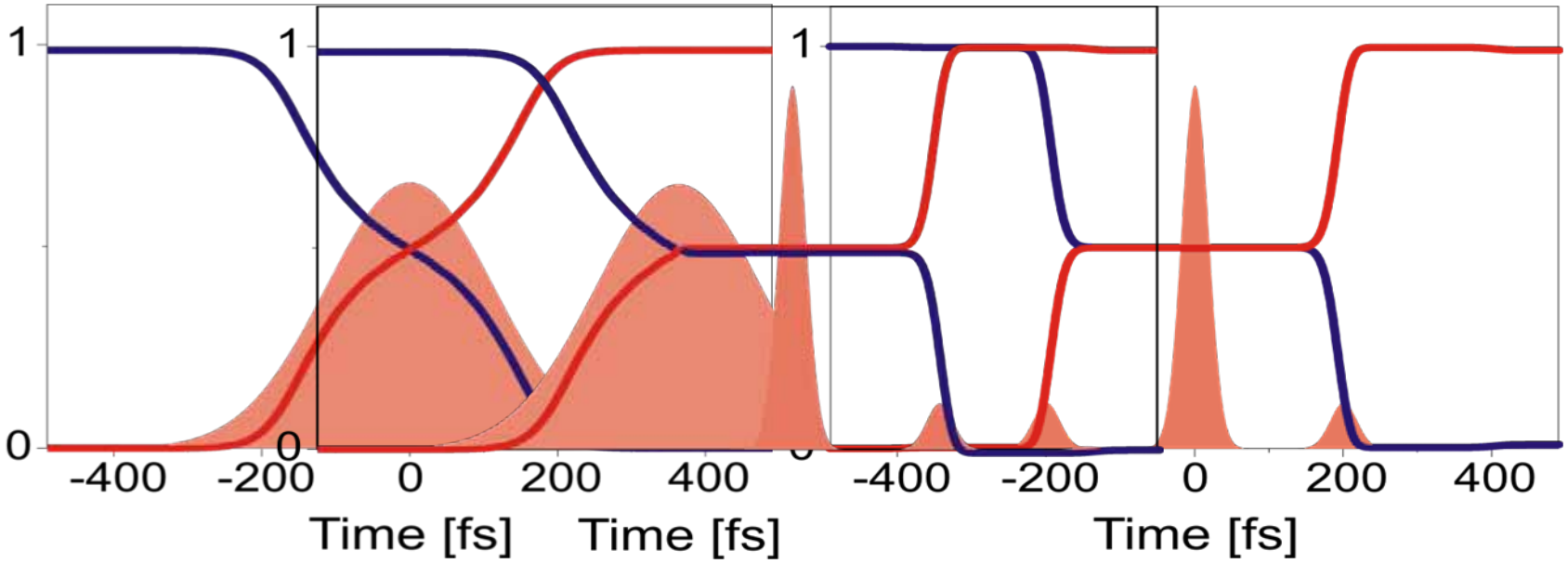
Robustness

Combine robustness and efficiency

$|c_{4s}(t)|^2$ $|c_{4p}(t)|^2$

RAP

Photon Locking

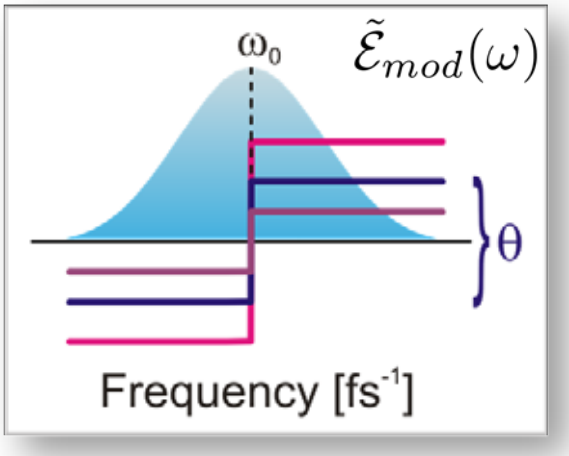


θ-step modulation in frequency domain

$$\tilde{\mathcal{M}}(\omega) = e^{-i\frac{\theta}{2}\sigma(\omega)}$$

$$= \cos\left[\frac{\theta}{2}\right] - i\sigma(\omega)\sin\left[\frac{\theta}{2}\right]$$

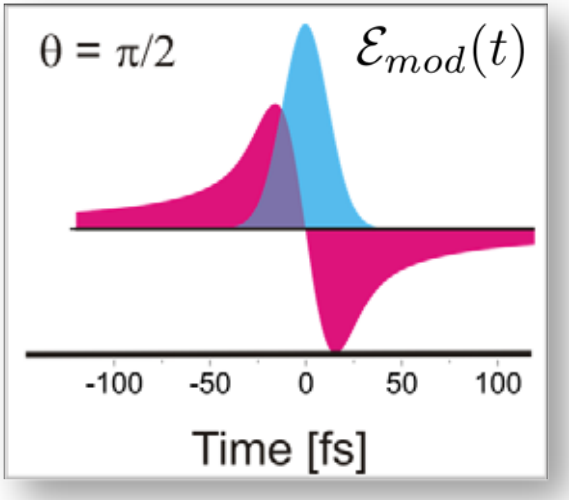
$$\mathcal{M}(t) = \delta(t)\cos\left[\frac{\theta}{2}\right] + \frac{1}{\pi t}\sin\left[\frac{\theta}{2}\right]$$



$$\mathcal{E}_{mod}(t) = \mathcal{E}(t) \otimes \mathcal{M}(t)$$

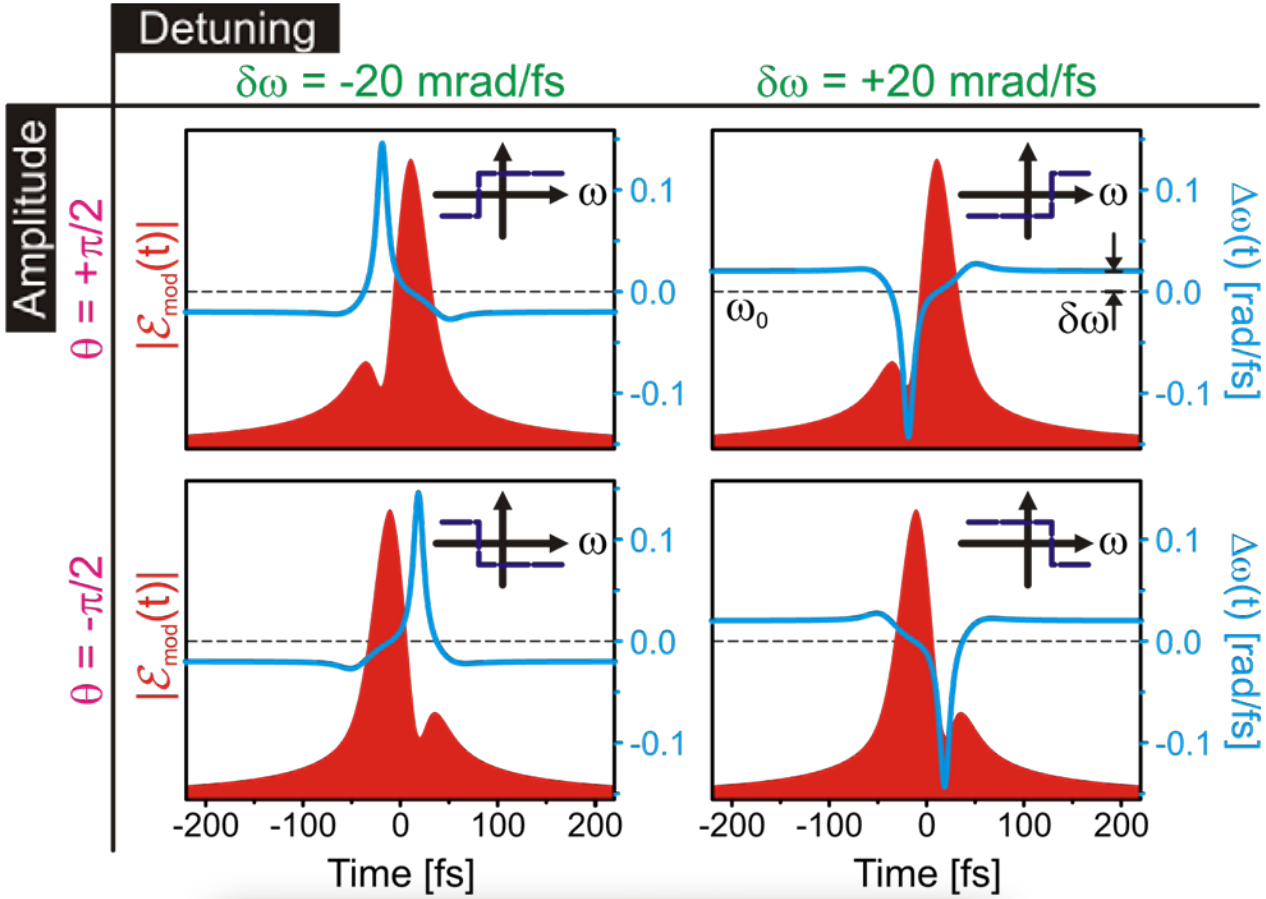
$$= \mathcal{E}(t) \otimes \left\{\delta(t)\cos\left[\frac{\theta}{2}\right] + \frac{1}{\pi t}\sin\left[\frac{\theta}{2}\right]\right\}$$

$$= \cos\left[\frac{\theta}{2}\right]\mathcal{E}(t) - \sin\left[\frac{\theta}{2}\right]\hat{\mathcal{E}}(t)$$



Pulse gallery for the generalized θ-step

$$\tilde{\mathcal{E}}_{mod}(\omega) = \tilde{\mathcal{E}}(\omega) e^{-i\frac{\theta}{2}\sigma(\omega-\delta\omega)}$$



$$\Delta\omega_{\pm\infty} = \delta\omega$$

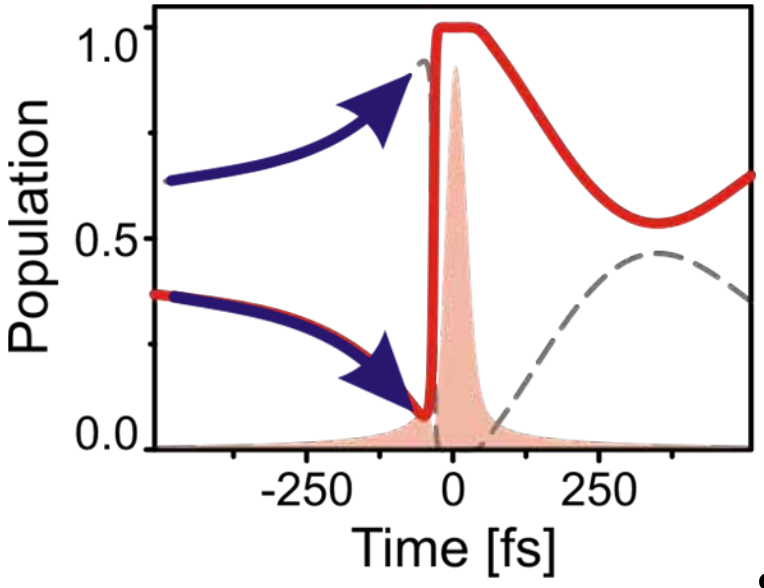
$$\theta > 0 \Rightarrow \text{peak @ t} > 0$$

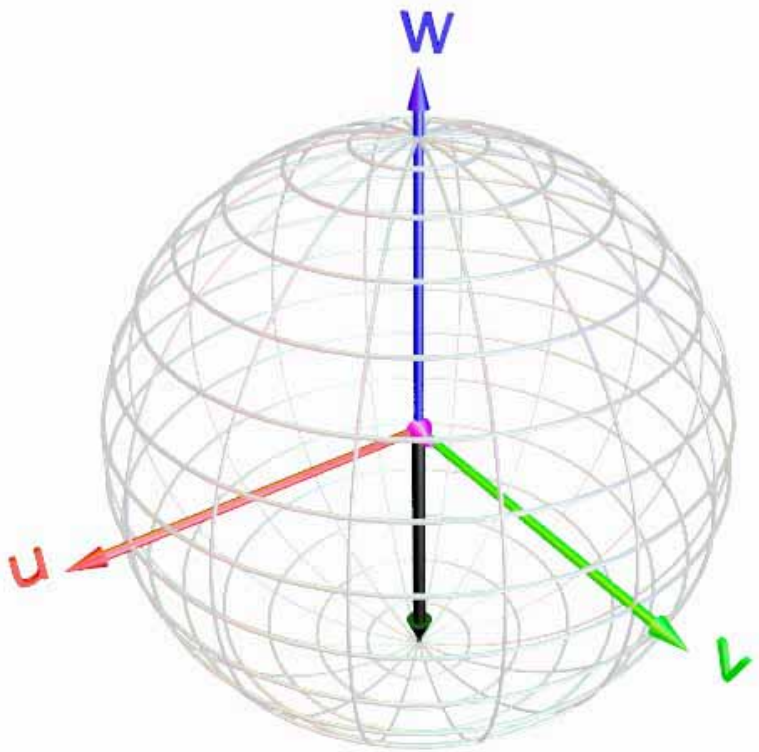
Robust Photon Locking

$$\theta > 0 \Rightarrow \text{peak @ t} > 0$$

$$\Delta\omega_{\pm\infty} = \delta\omega < 0$$

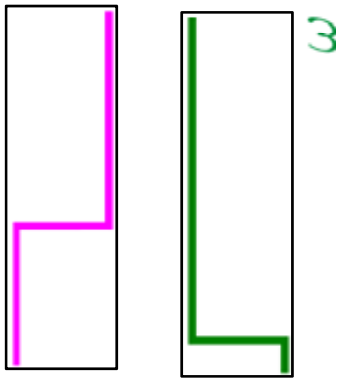
upper dressed state

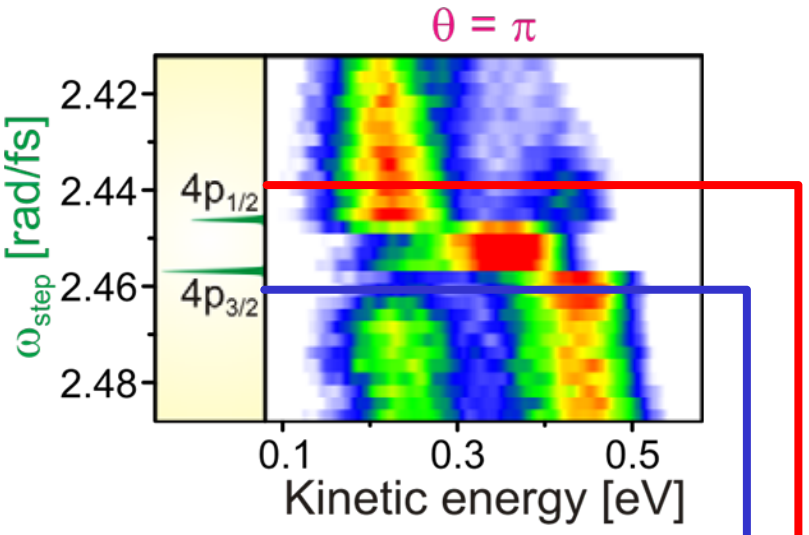


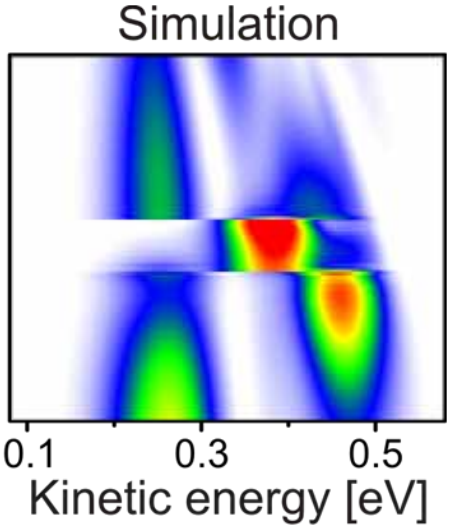


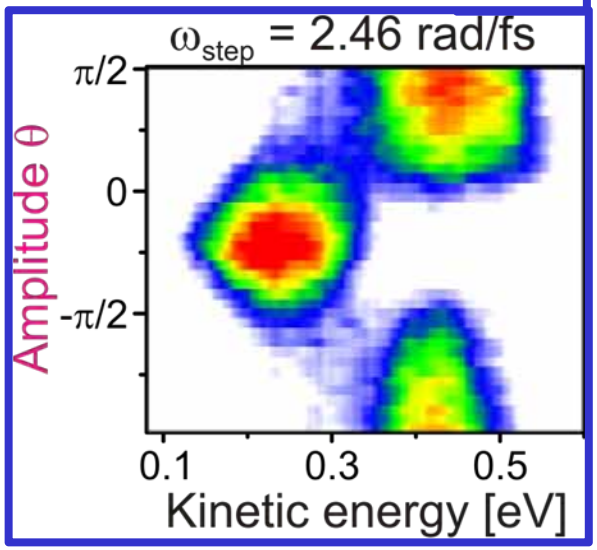
Selective population of the upper dressed state during strong-field interaction

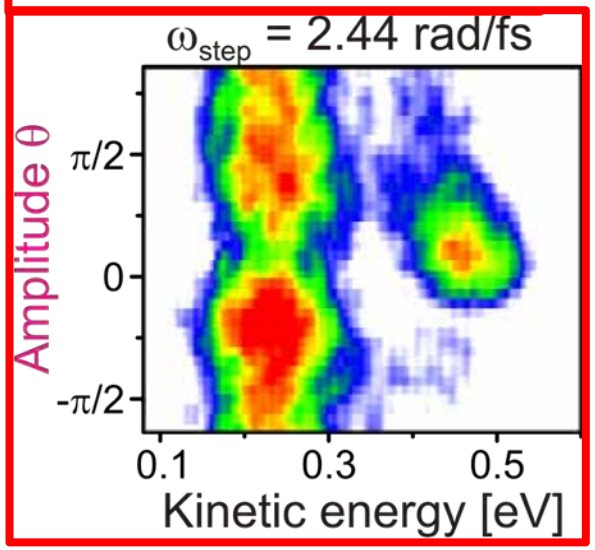
Switching by θ and $\delta\omega$



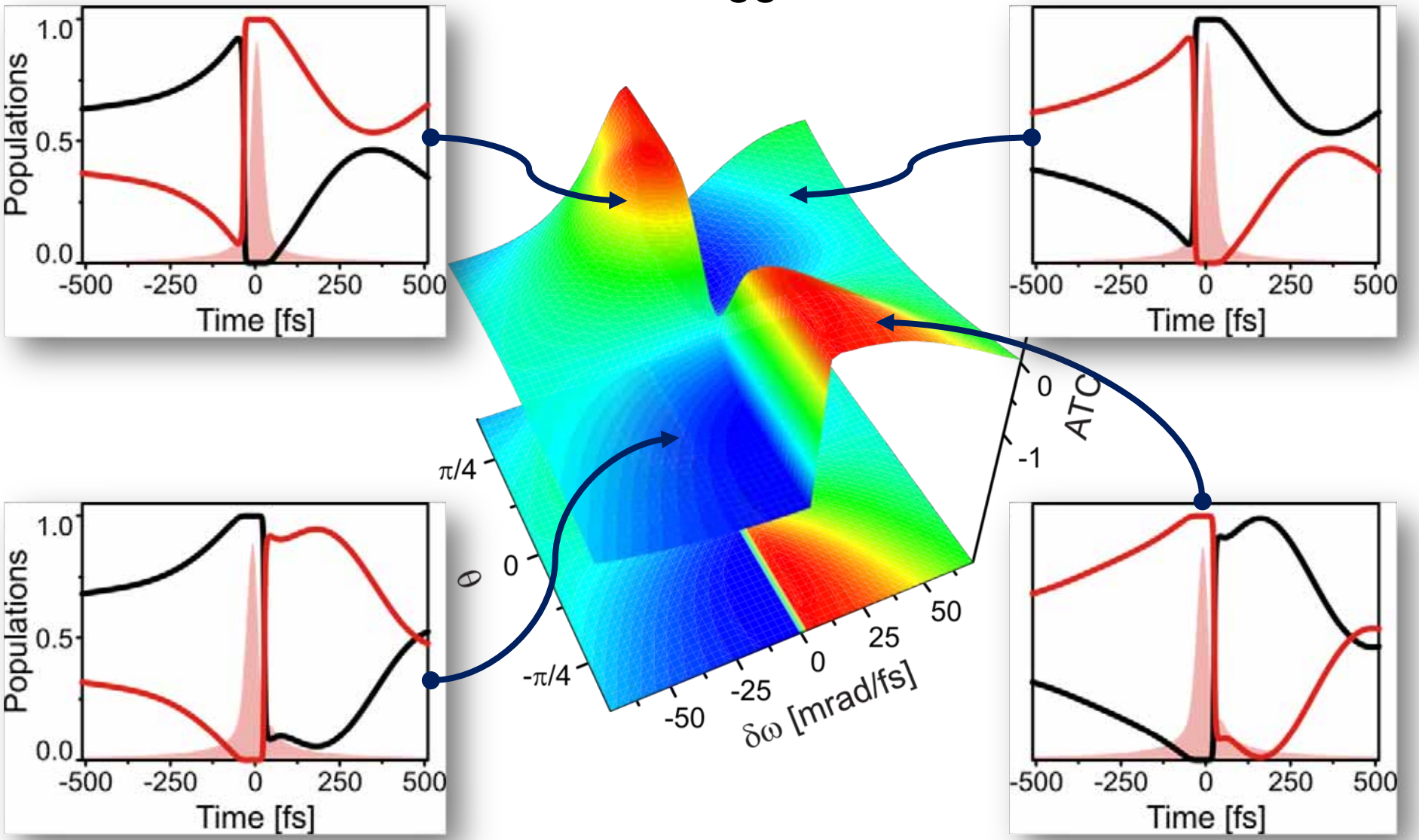






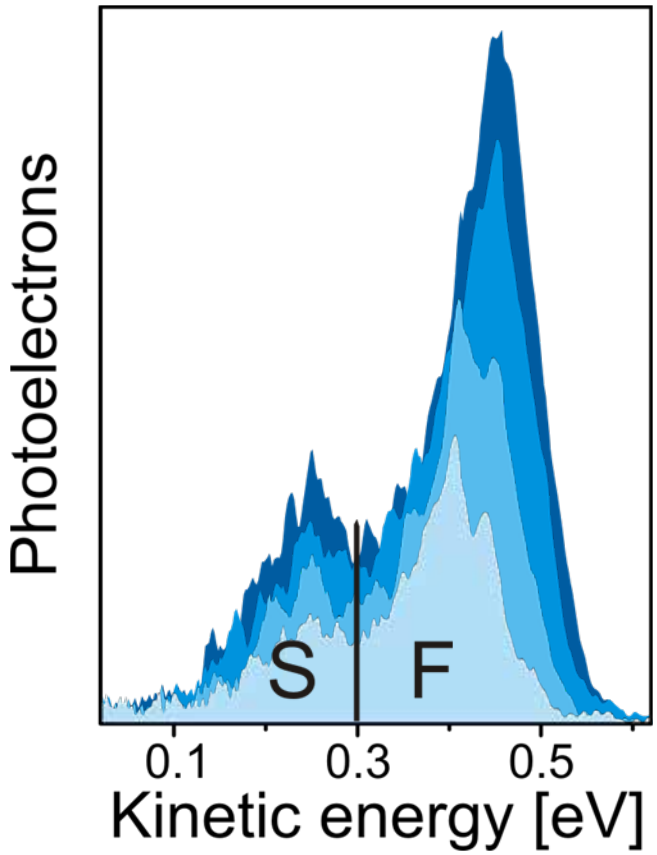


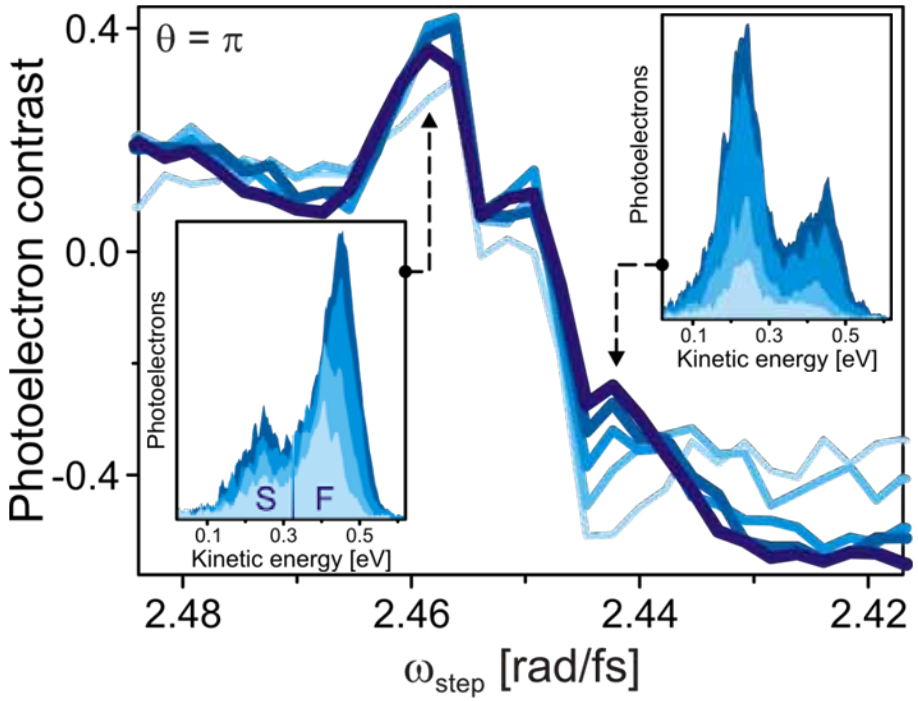
An ultrafast toggle switch



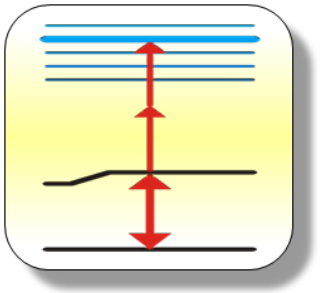
Experimental results: robustness

$$C = \frac{F - S}{F + S}$$

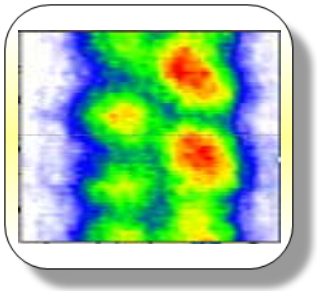




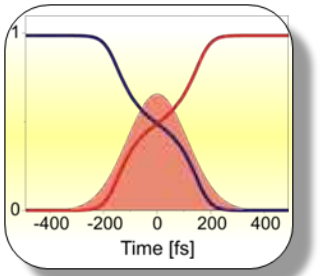
Conclusion



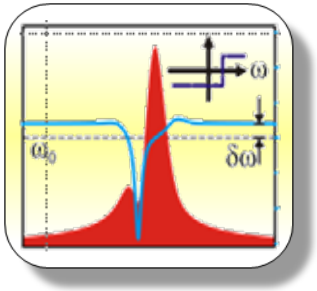
- *Photon locking for quantum control by Selective Population of Dresses States* (SPODS)



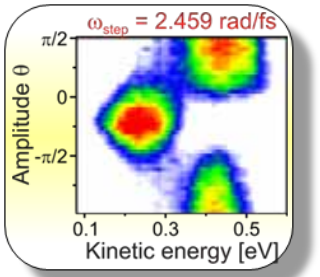
- *Experimental demonstration of efficient and ultrafast photon locking based on PL*



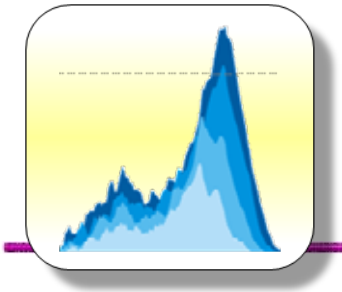
- *Robust adiabatic techniques based on RAP*



- *Shaped pulses for robust photon locking*



- *Ultrafast switching by photon locking*



- *Robustness by adiabatic preparation of maximum coherent states*

UNIKASSEL VERSITÄT

PHD positions available


Prof. Dr. T. Baumert


PD Dr. M. Wollenhaupt


T. Bayer


L. Englert


L. Haag


C. Horn


P. Kasper


A. Klumpp


M. Krug


U. Meier-Diedrich


J. Mildner


C. Sarpe


J. Schneider


M. Winter


PD Dr. A. Assion


R. Bäumner


Dr. D. Liese


Dr. A. Präkelt