Charge transfer as a diagnostic of excitation dynamics in a MOT

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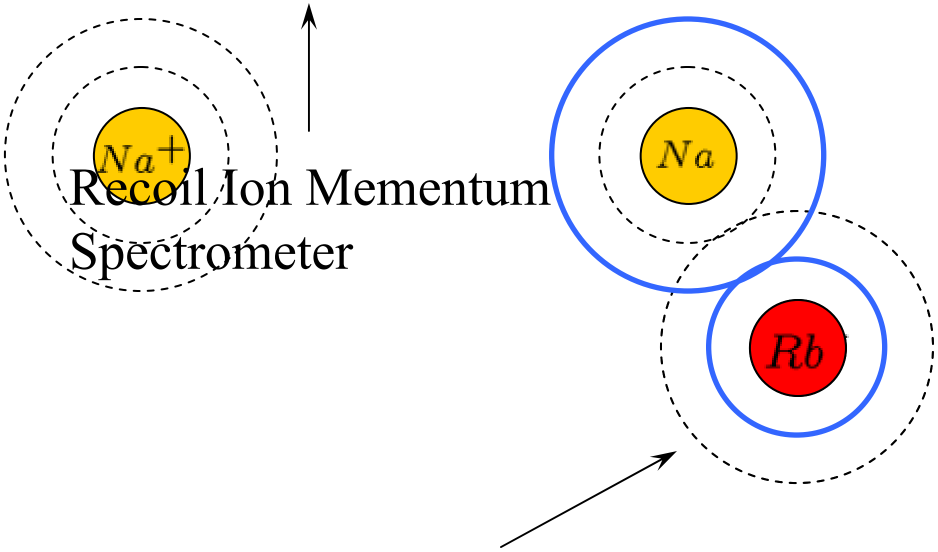
Charge Transfer with MOTRIMS

$$Q = E_i - E_f$$

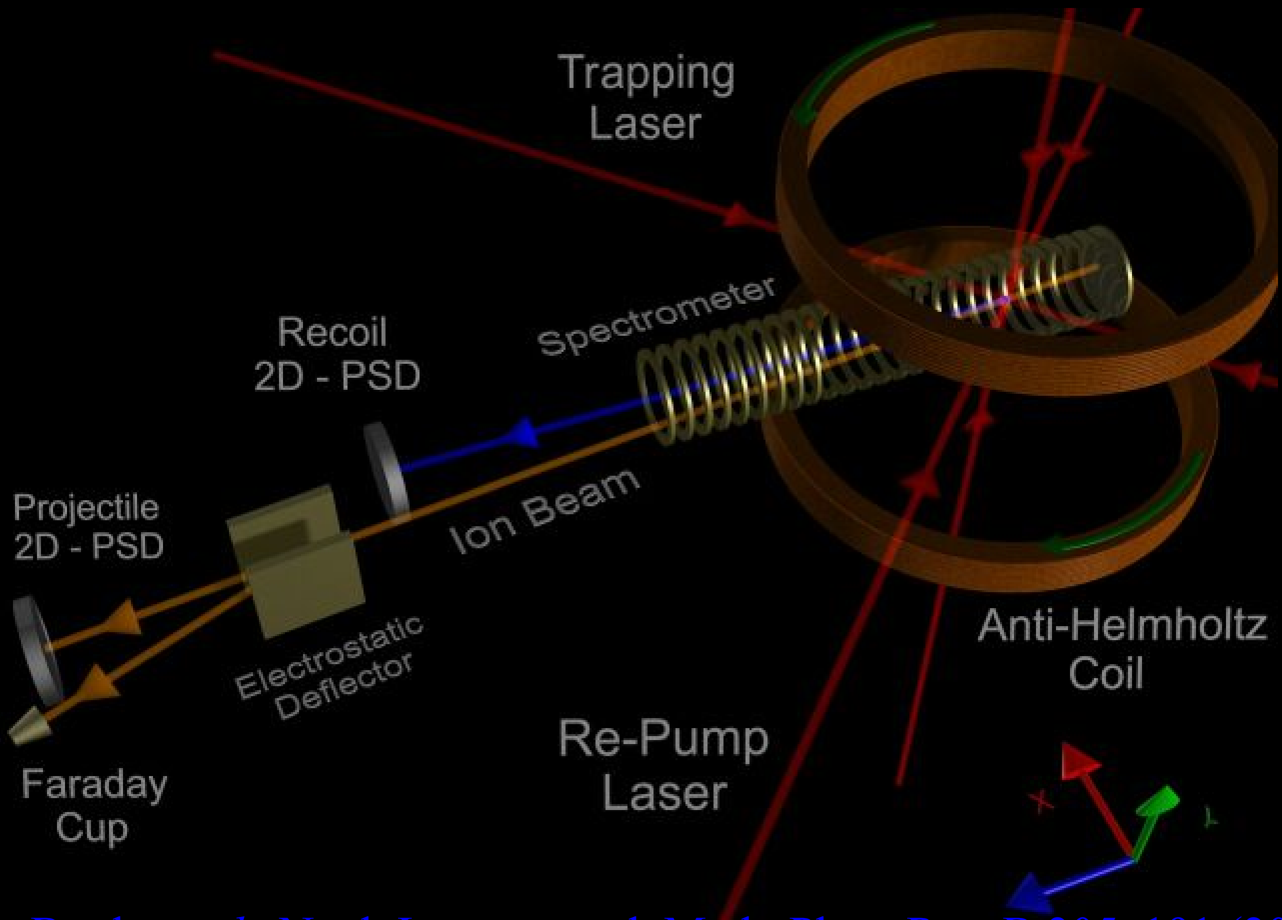
$$= -V_p \boxed{P_{||}} - \frac{1}{2} m_e V_p^2$$



Recoil Ion Mementum Spectrometer

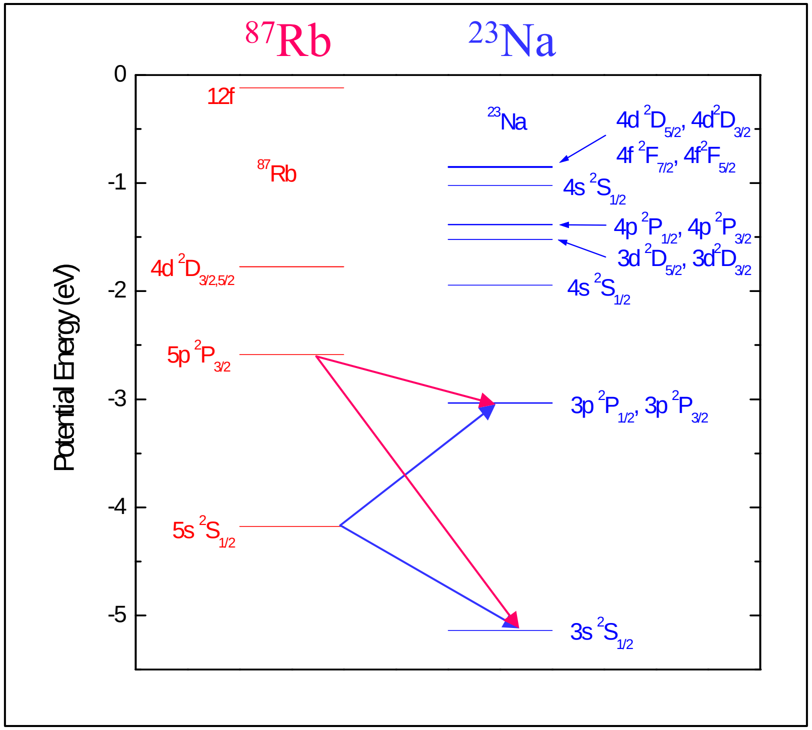
Rubidium MOT

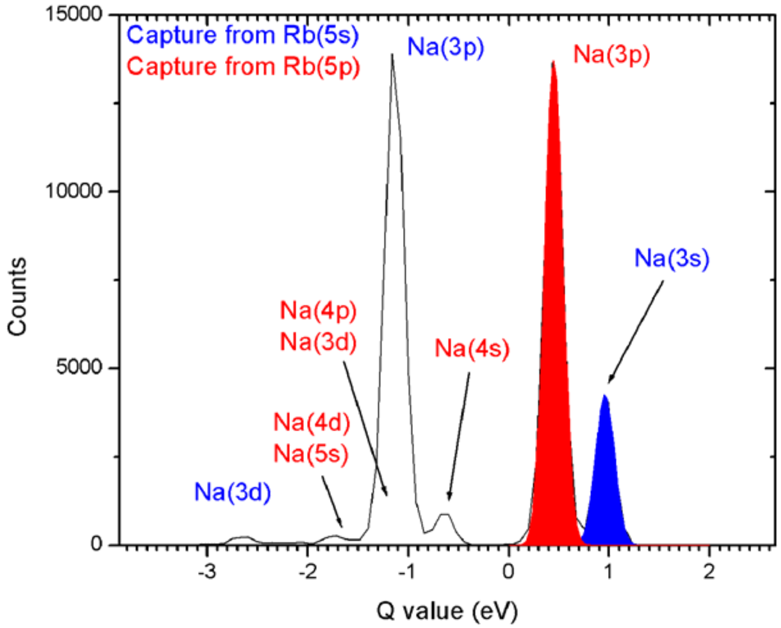
Apparatus



Ref: R. Bredy *et al.*, Nucl. Instrum. and Meth. Phys. Res. B 205, 191 (2003)

Charge Transfer with MOTRIMS





$$Q = E_i - E_f$$

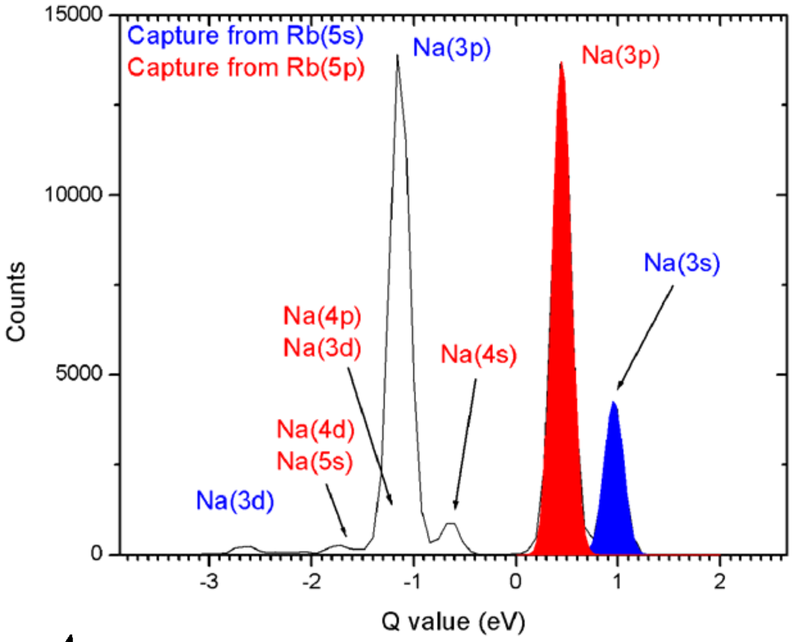
$$A_i = c n_i \sigma_i$$

A_i = area under the peak

n_i = number of atoms in the i-th state

σ_i = Charge transfer cross section

Diagnostics with Charge Transfer



$$f = \frac{n_p}{n_p + n_s}$$

$$= \frac{A_p}{A_p + A_s \frac{\sigma_p}{\sigma_s}}$$

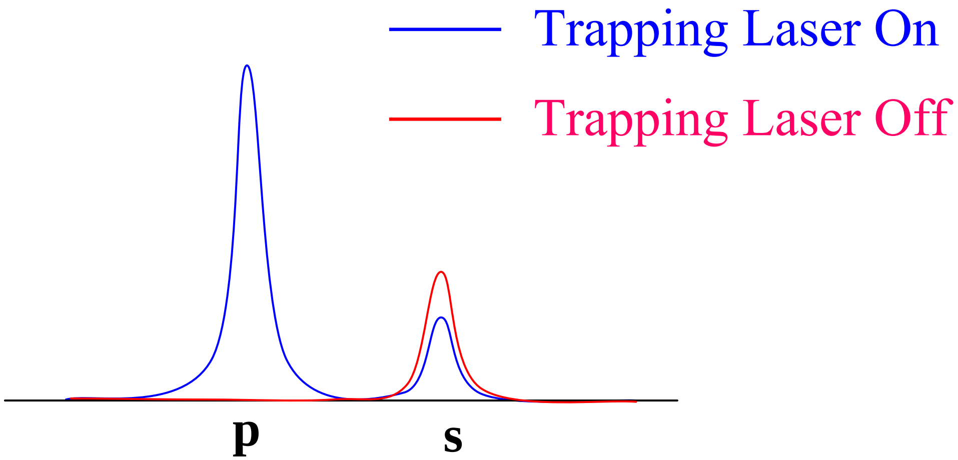
$$\frac{\sigma_p}{\sigma_s} = 11.29 \pm 0.66$$

$$A_s = c n_s \sigma_s$$

$$A_p = c n_p \sigma_p$$

Ref: X. Flechard *et al.*, PRL 91, 243005 (2003)

Diagnostics with Charge Transfer



Trapping Laser is off
only for a short time, so that

$$n_{tot} = Const$$

$$\Delta n_p = -\Delta n_s$$

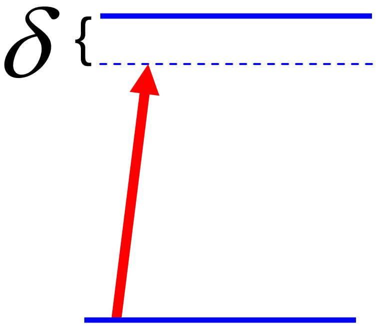
$$\Delta A_p / \sigma_p = -\Delta A_s / \sigma_s$$

$$\sigma_p / \sigma_s = -\Delta A_p / \Delta A_s$$

Ref: X. Flechard *et al.*, PRL 91, 243005 (2003)

Application Example: Excited State Fraction

$$f \equiv \frac{n_{ext}}{n_{tot}}$$



- *Two level system*
- *A single plain wave*
- *Linearly polarized*
- *Intensity is low*

$$f = \frac{I/I_s}{1+2I/I_s+(2\delta/\Gamma)^2}$$

$$I_s = \frac{2\pi hc\Gamma}{3\lambda^3}$$

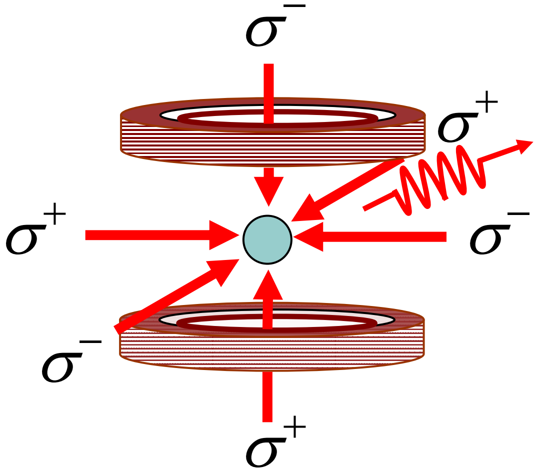
Ref: W. Demtröder, Laser Spectroscopy. (Springer, 2002)

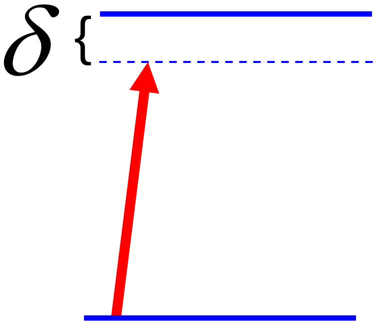
Application Example: Excited State Fraction

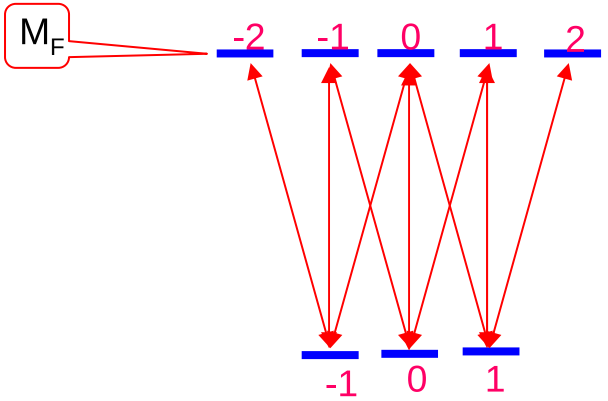
$$f \equiv \frac{n_{ext}}{n_{tot}}$$

- Absolute Photo-Ionization Cross Sections
- Cold Atoms Collisions Cross Sections
- Photo-Association Rates
- Total Number of Atoms in a MOT

The Problem





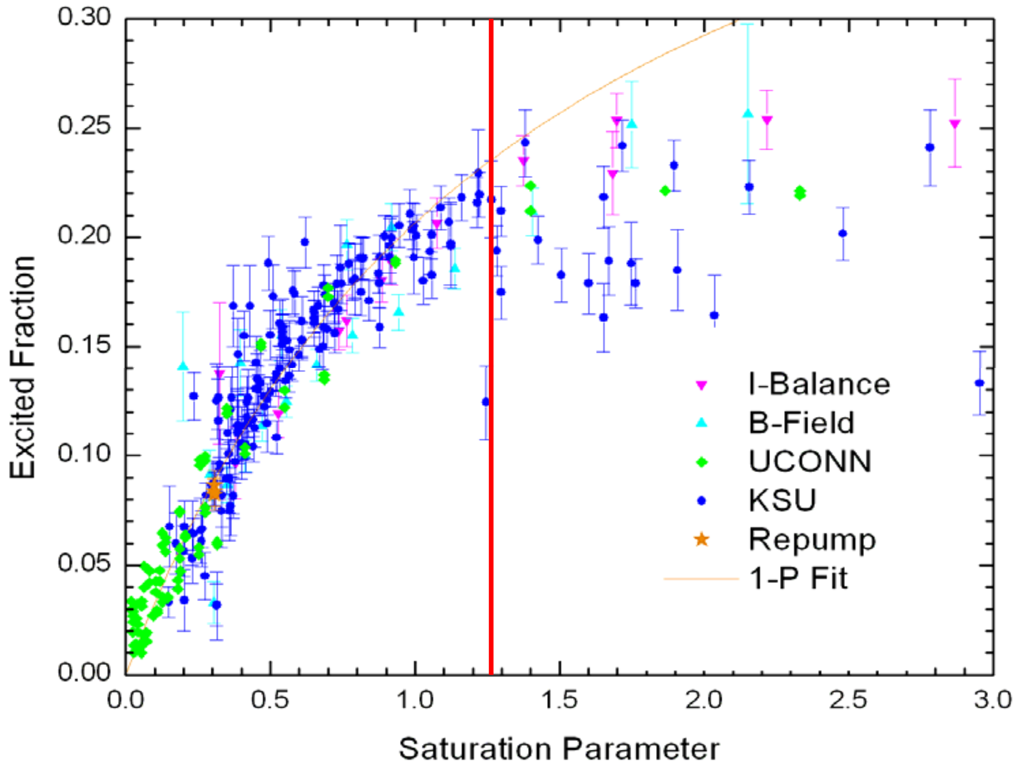


$$f \overset{?}{=} \frac{I/I_s}{1+2I/I_s+(2\delta/\Gamma)^2}$$

$$I_s \overset{?}{=} \frac{2\pi hc\Gamma}{3\lambda^3}$$

- *Multilevel system*
- *Six plain waves*
- *Circularly polarized*
- *Intensity is not low*

Results: Simple Model (1-Parameter) Fit



$$f = \frac{I/I_s}{1+2I/I_s+(2\delta/\Gamma)^2}$$

$$s = \frac{I/I_s}{1+(2\delta/\Gamma)^2}$$

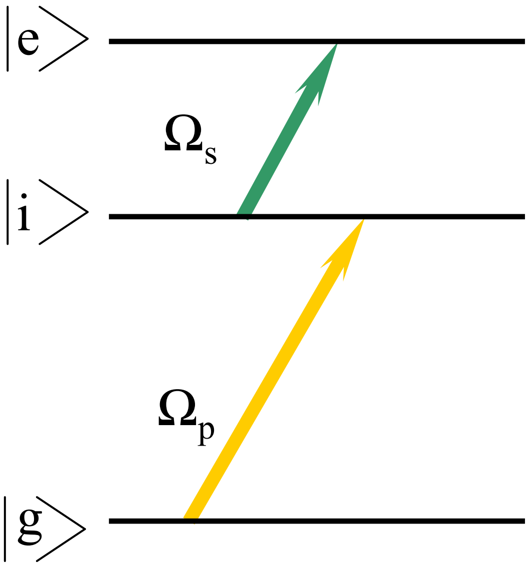
$$\boldsymbol{f} = \frac{\boldsymbol{s}}{1+2\boldsymbol{s}}$$

Theory says:
$I_s = 3.28$ mW/cm^2
1-Parameter fit gives:
$I_s = 9.2$ mW/cm^2

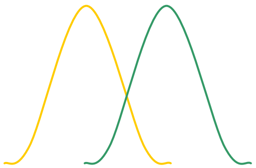
Ref: M. Shah *et al.*, Phys. Rev. A 75, 053418 (2007)

Application example: STIRAP

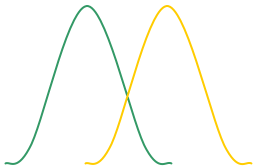
- STIRAP = Stimulated Raman Adiabatic Passage



Efficiently move the population
from g to e without passing through i



= Intuitive Pulse Ordering

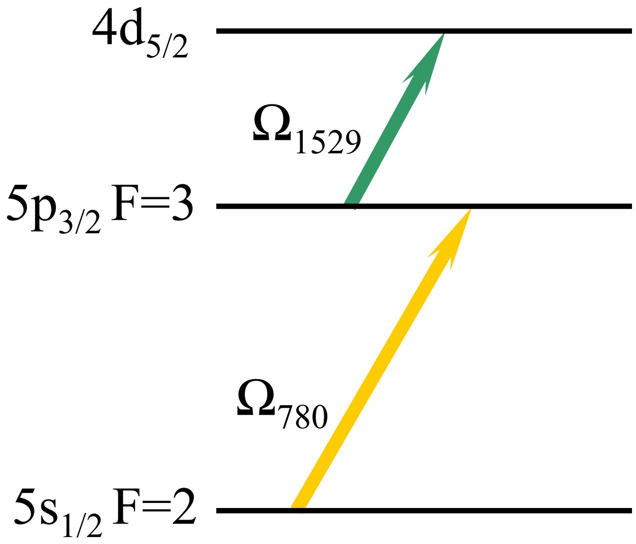


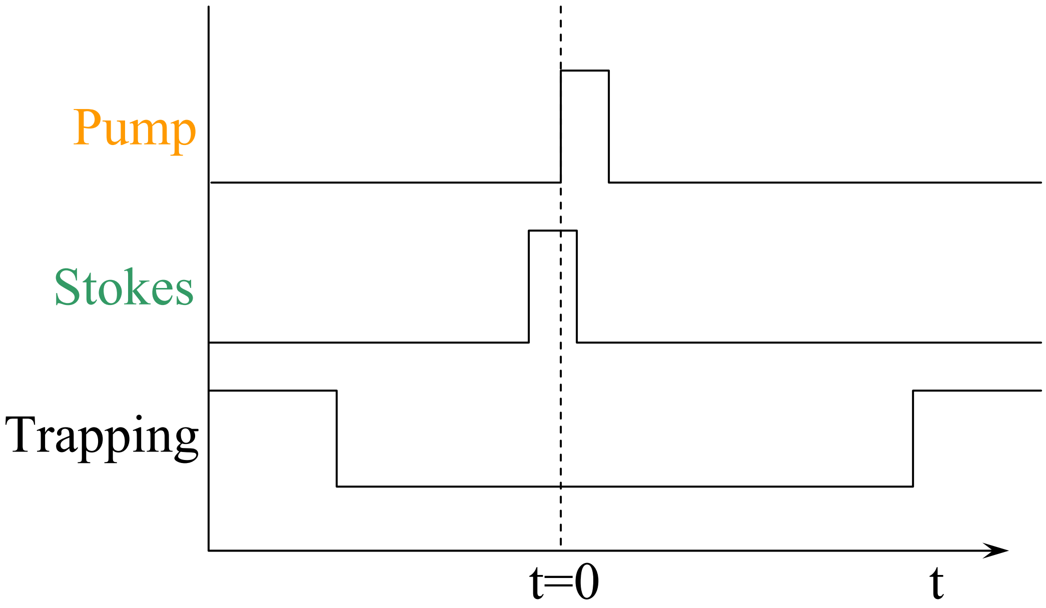
= Counter-Intuitive Pulse Ordering

Applications of STIRAP

- State Preparation in Quantum Computing
- Reaction Channel Activation in Chemistry
- Atom Optics
- High-Order Harmonics Generation

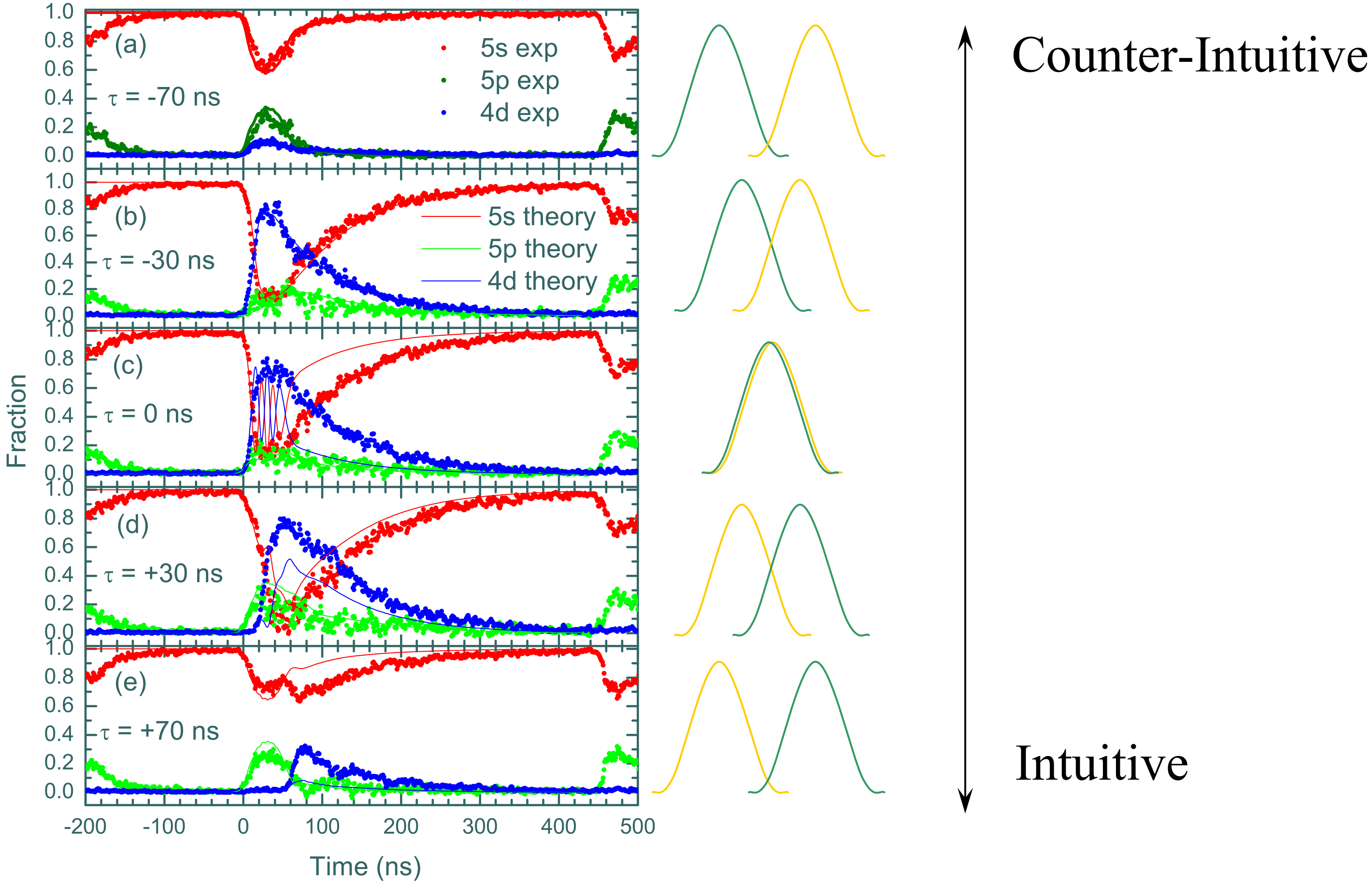
Our System for STIRAP Studies: ^{87}Rb





Ref: Gearba *et al.*, PRA 76, 013406 (2007)

Results



Ref: Gearba *et al.*, PRA 76, 013406 (2007)

Acknowledgements

Team MOTRIMS

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