# Engineered dissipation for Rydberg quantum simulators

**Oliver Morsch**
INO-CNR and Dipartimento di Fisica, Pisa, Italy

***Atomtronics Benasque (online), 6/5/2022***

- **Why (engineered) dissipation?**
- **Realizing engineered dissipation in a Rydberg experiment**
- **First results**
- **What next?**

**B. Bégoc, G. Cicchelli, S. P. Singh, F. Bensch, V. Amico**

***Collaborations:*** L. Amico, F. Perciavalle, D. Rossini, I. Lesanovsky

MOQS Molecular Quantum Simulations

JSF Julian Schwinger Foundation

IN SUPREMÆ DIGNITATIS 1343 UNIVERSITÀ DI PISA

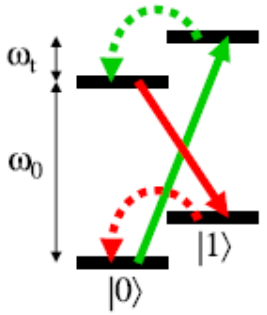
# Why (engineered) dissipation?

# Why (engineered) dissipation?

PRL 115, 200502 (2015) PHYSICAL REVIEW LETTERS week ending 13 NOVEMBER 2015

**Dissipative Quantum Control of a Spin Chain**

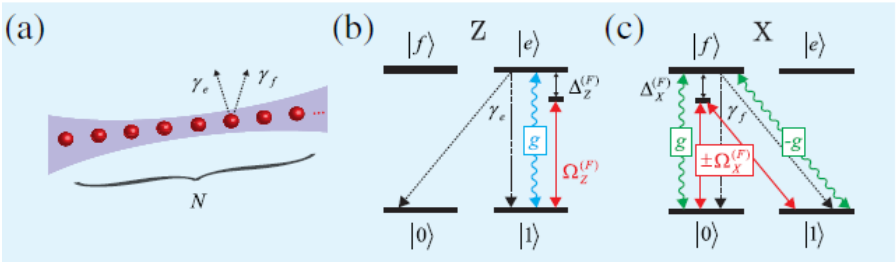
Giovanna Morigi,[1] Jürgen Eschner,[2] Cecilia Cormick,[3] Yiheng Lin,[4] Dietrich Leibfried,[4] and David J. Wineland[4]




PRL 117, 040501 (2016) PHYSICAL REVIEW LETTERS week ending 22 JULY 2016

**Scalable Dissipative Preparation of Many-Body Entanglement**

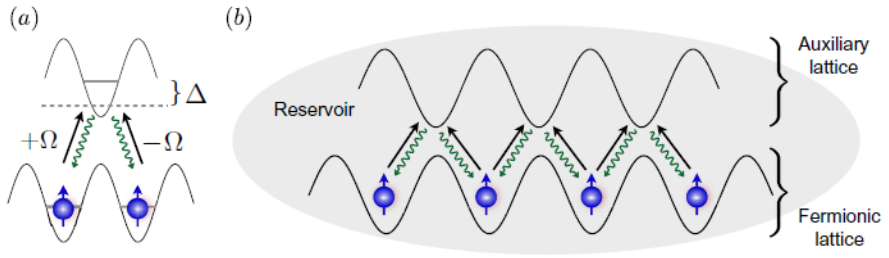
Florentin Reiter,[1,*] David Reeb,[2] and Anders S. Sørensen[1]




## Topology by dissipation

C-E Bardyn[1,5], M A Baranov[2,3,4], C V Kraus[2,3], E Rico[2,3], A İmamoğlu[1], P Zoller[2,3] and S Diehl[2,3,5]

*New Journal of Physics* **15** (2013) 085001 (57pp)



# Dissipation in a Rydberg system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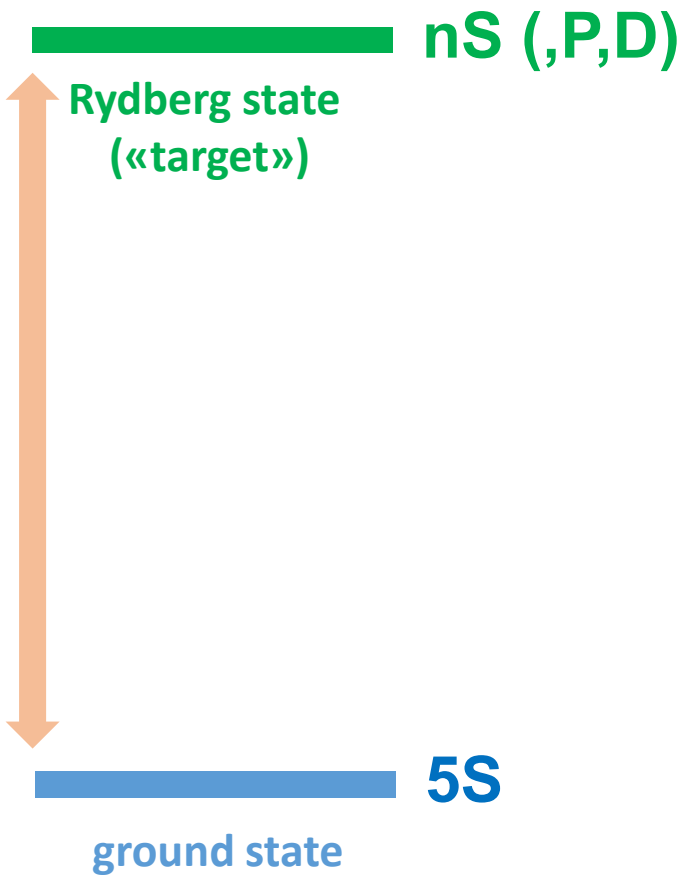

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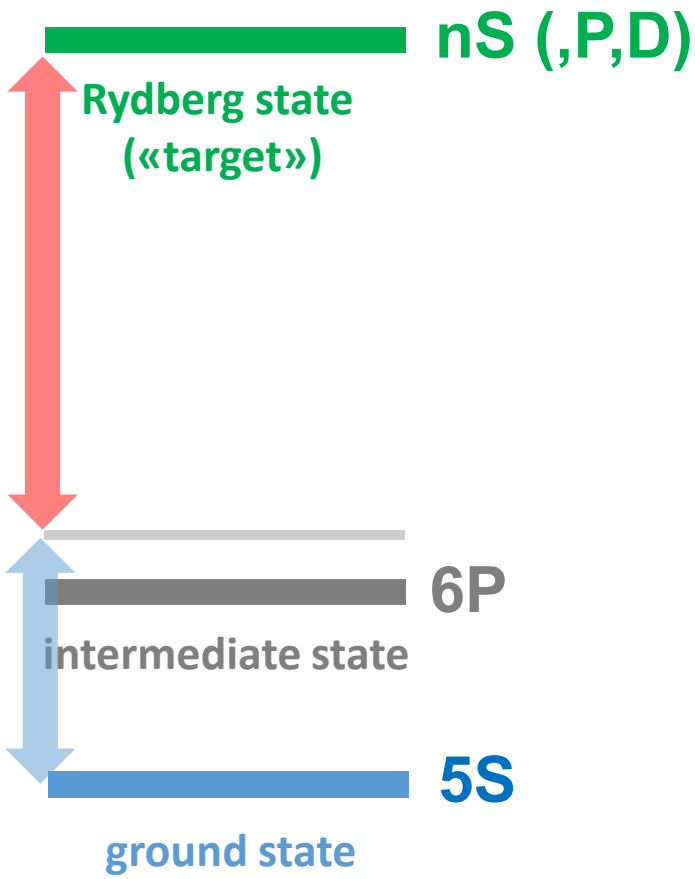

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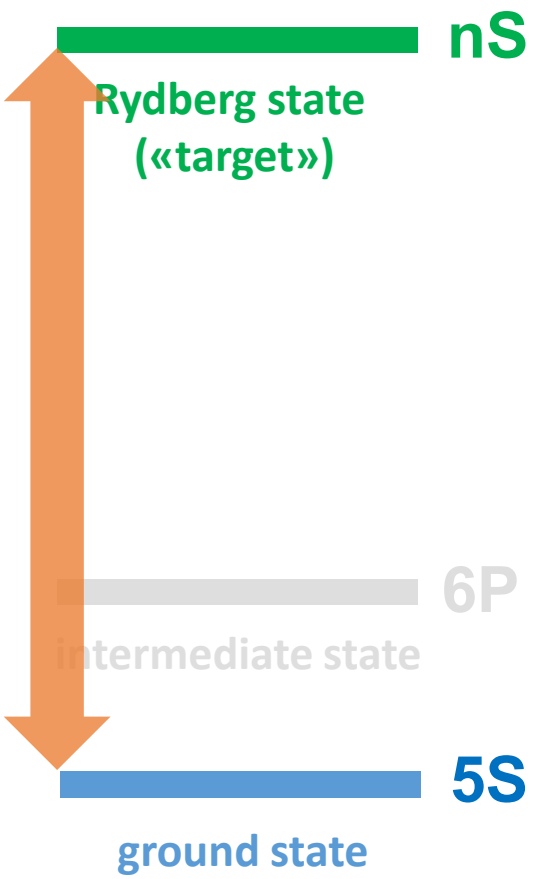

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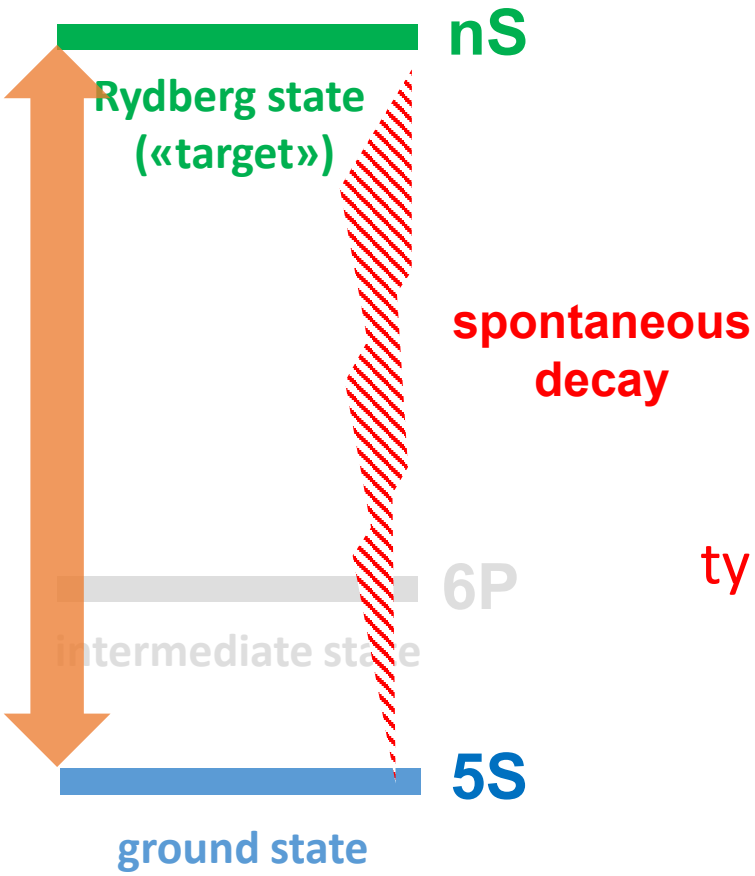


typical timescale: 100 μs

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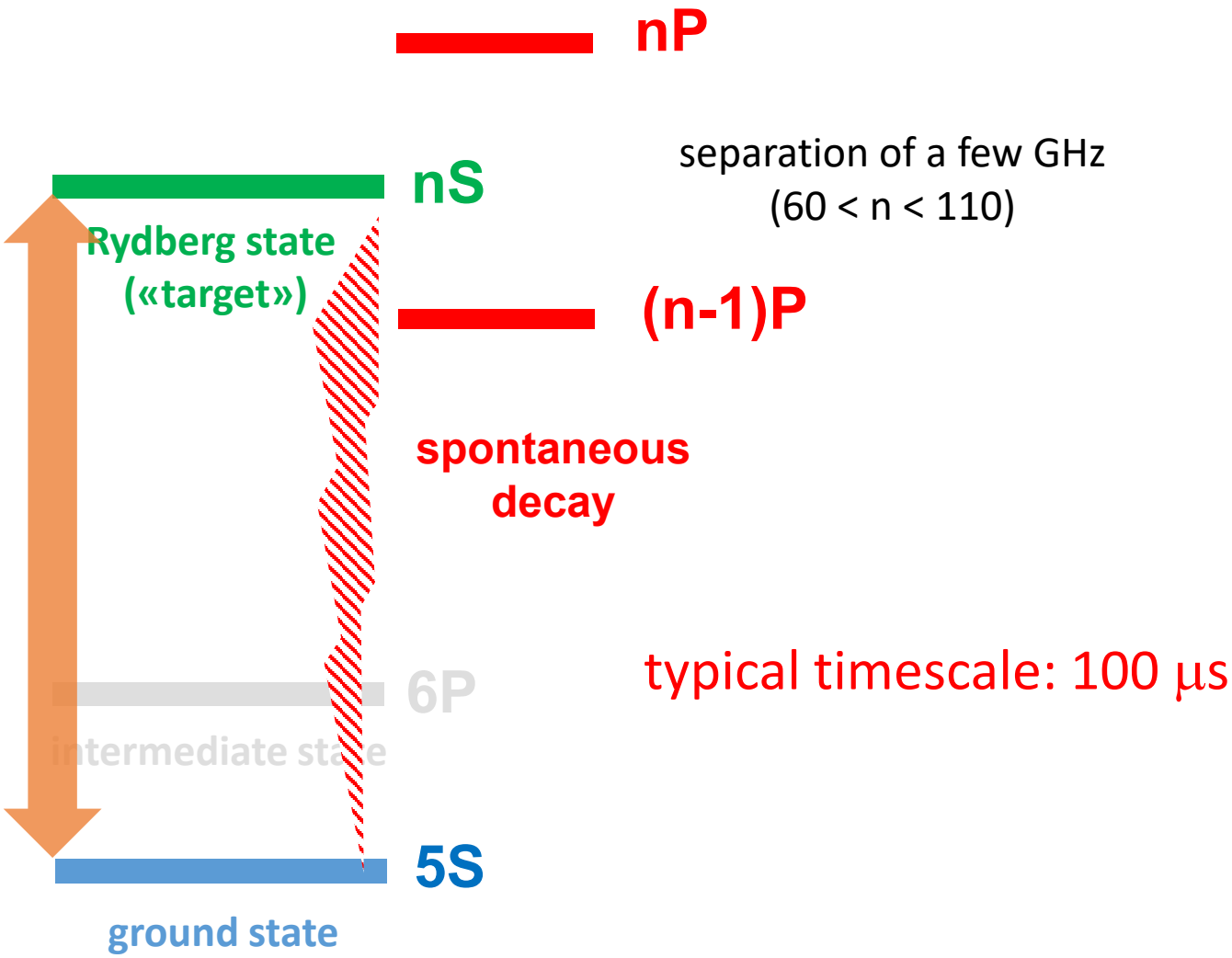

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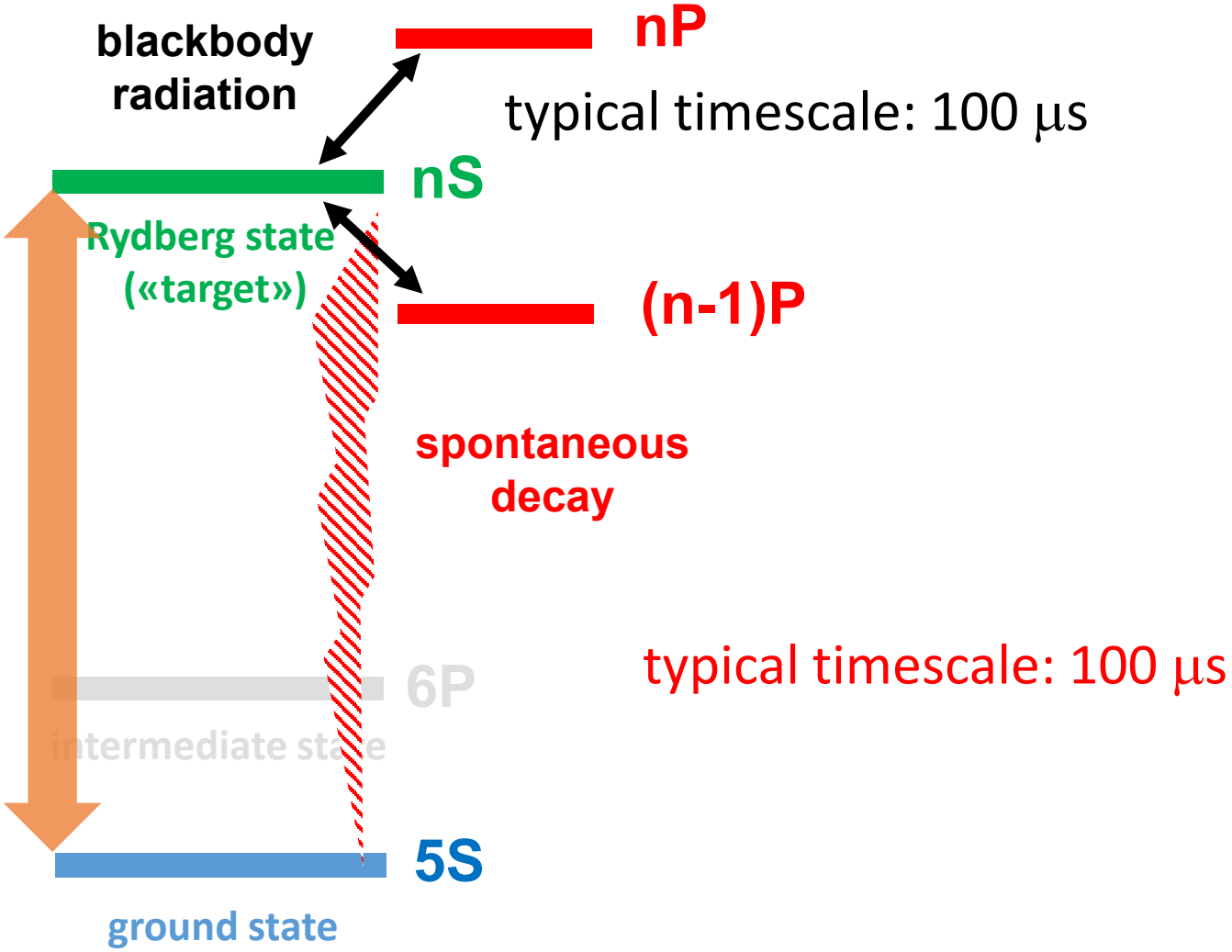

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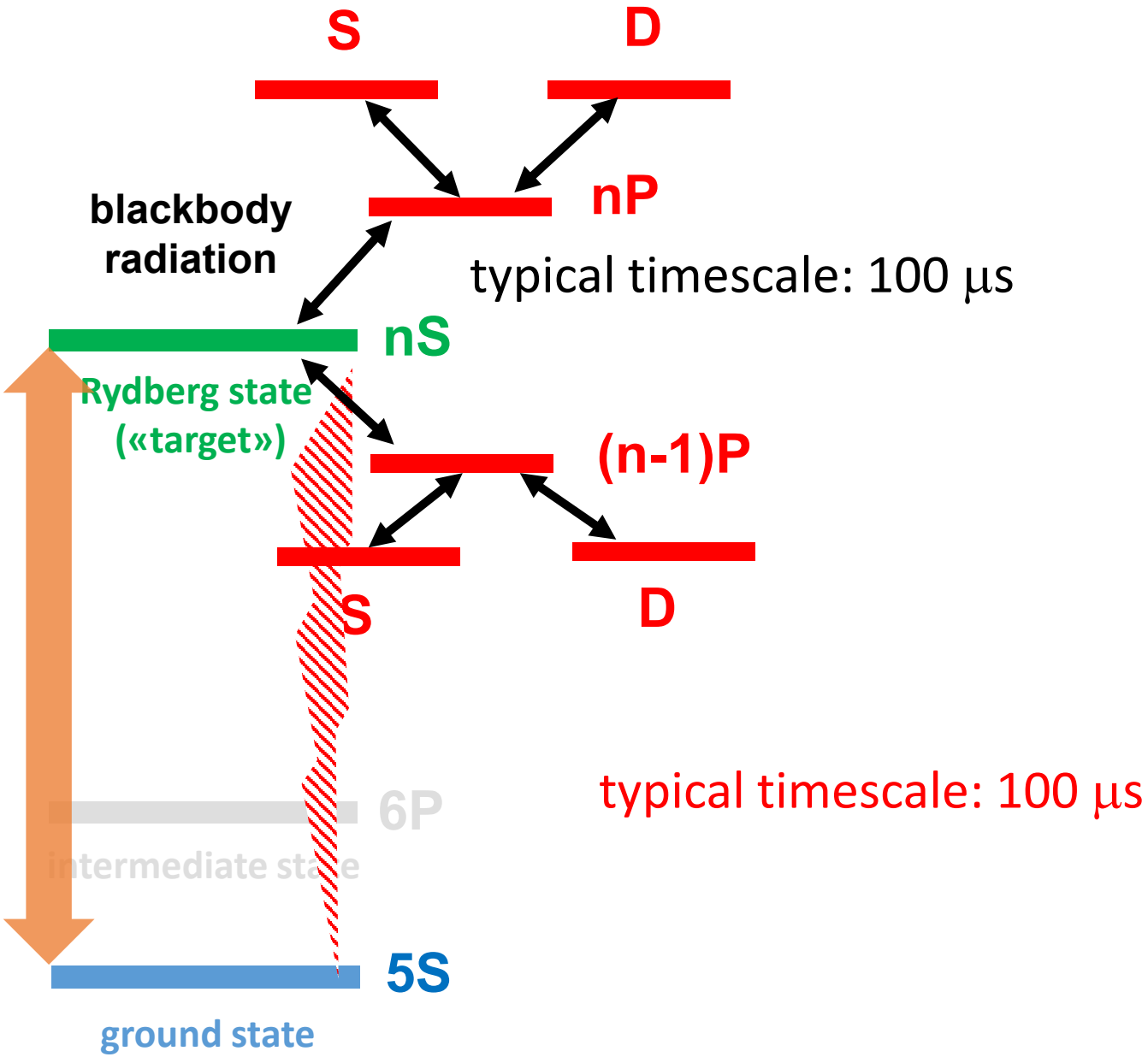
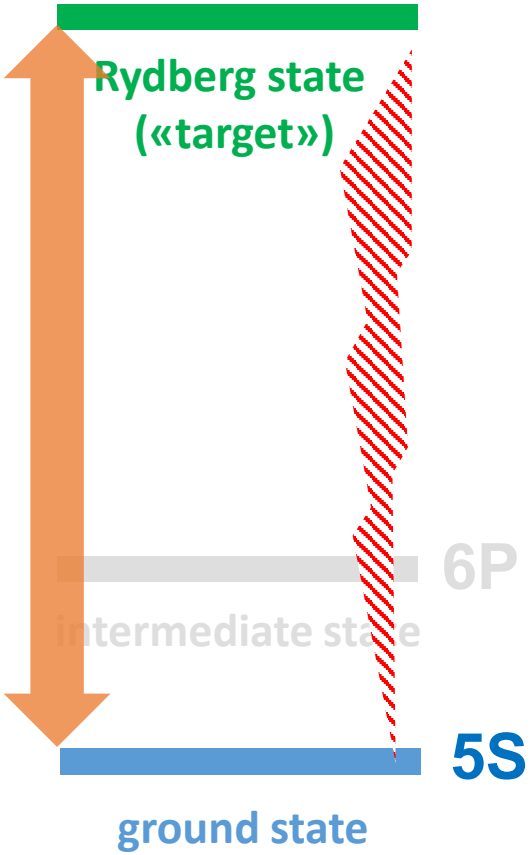
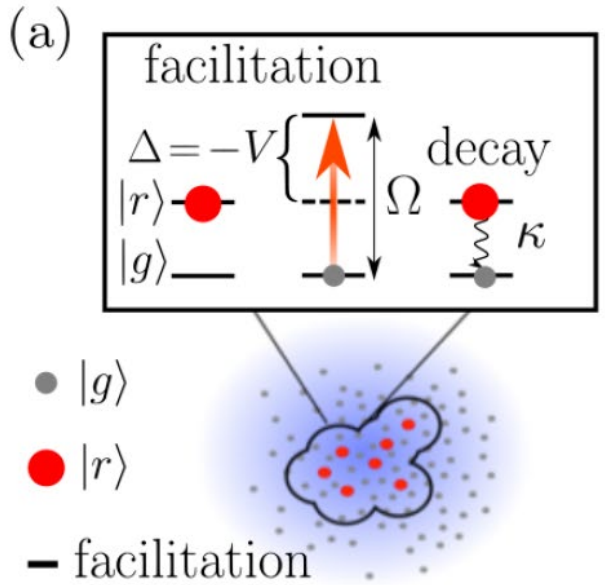


# The problem: deviation from the 2-level approximation




PHYSICAL REVIEW A **96**, 041602(R) (2017)

**Experimental signatures of an absorbing-state phase transition in an open driven many-body quantum system**

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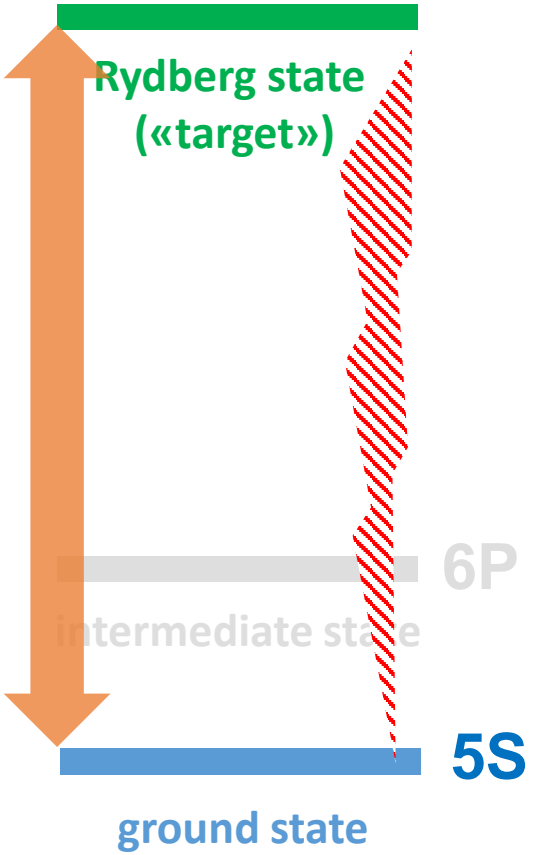


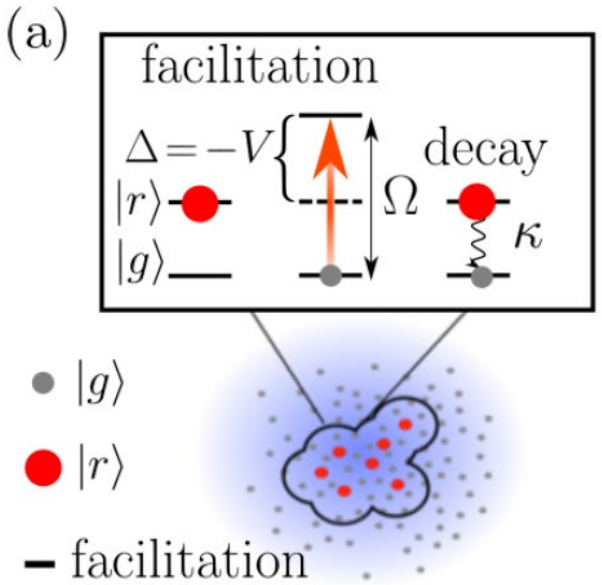


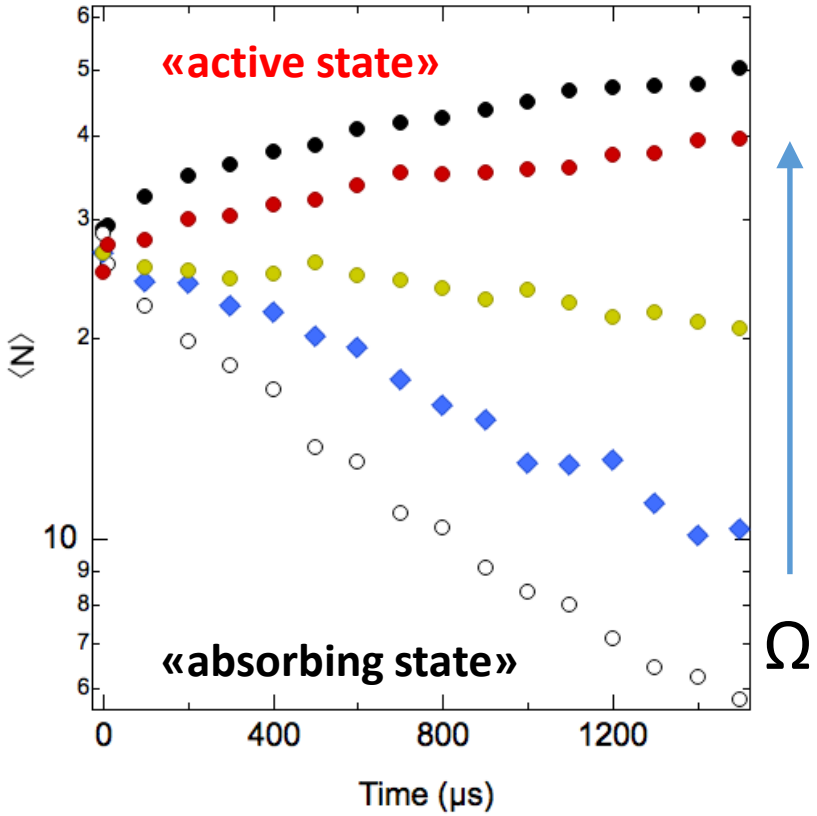


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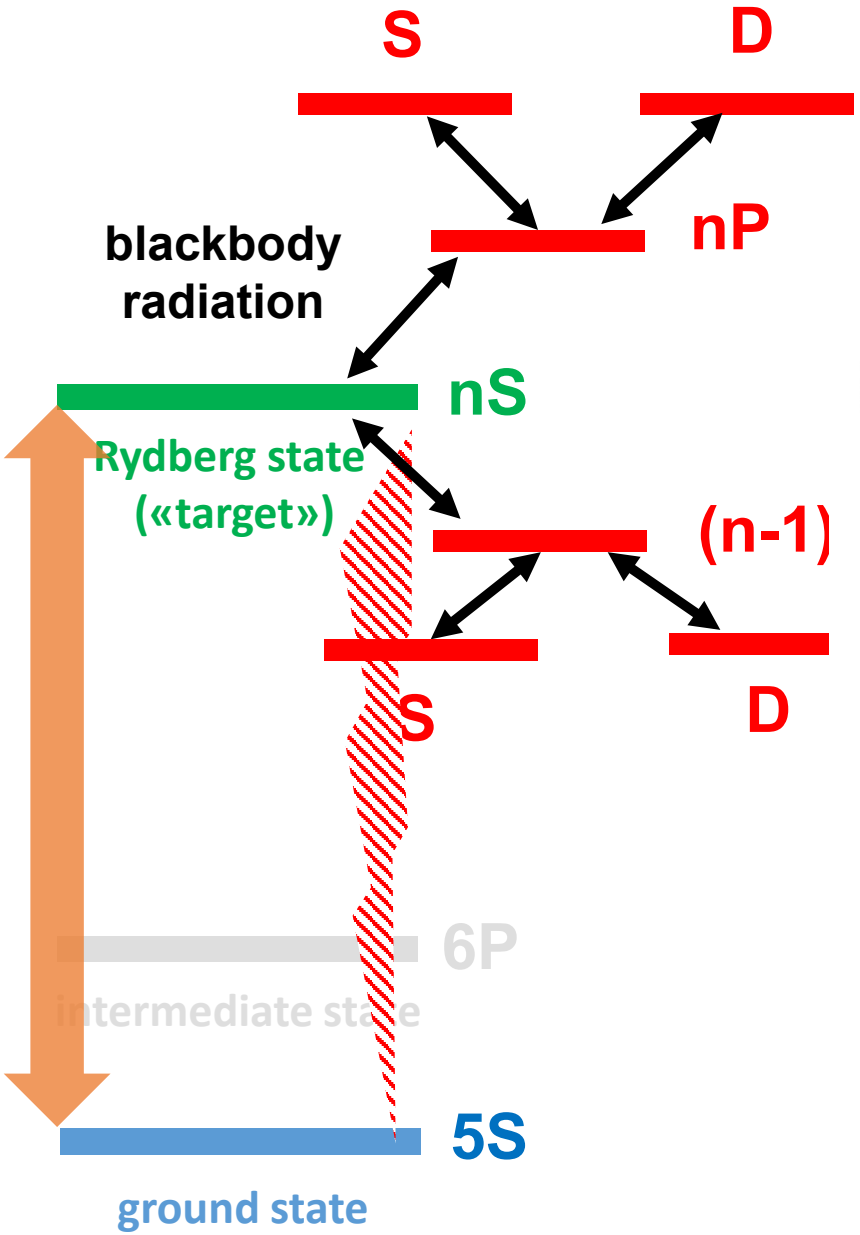


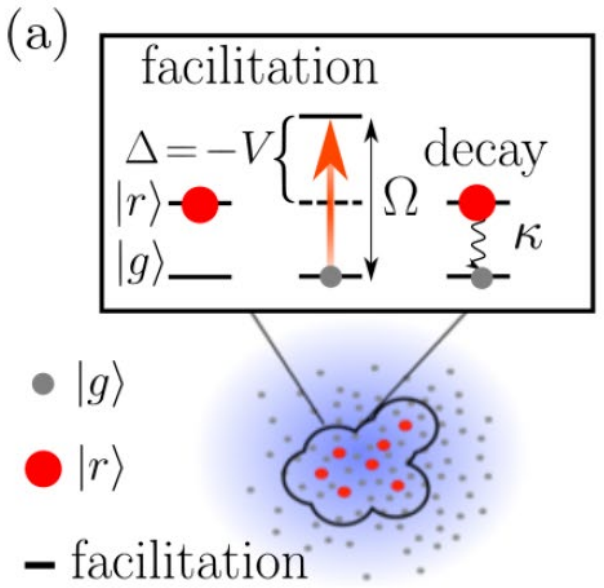


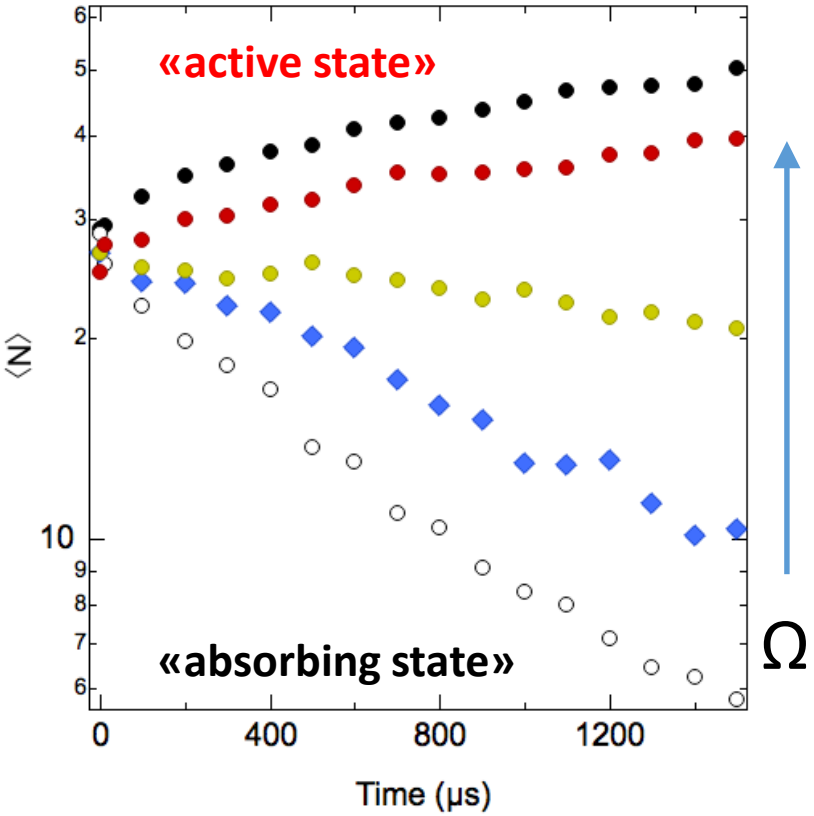


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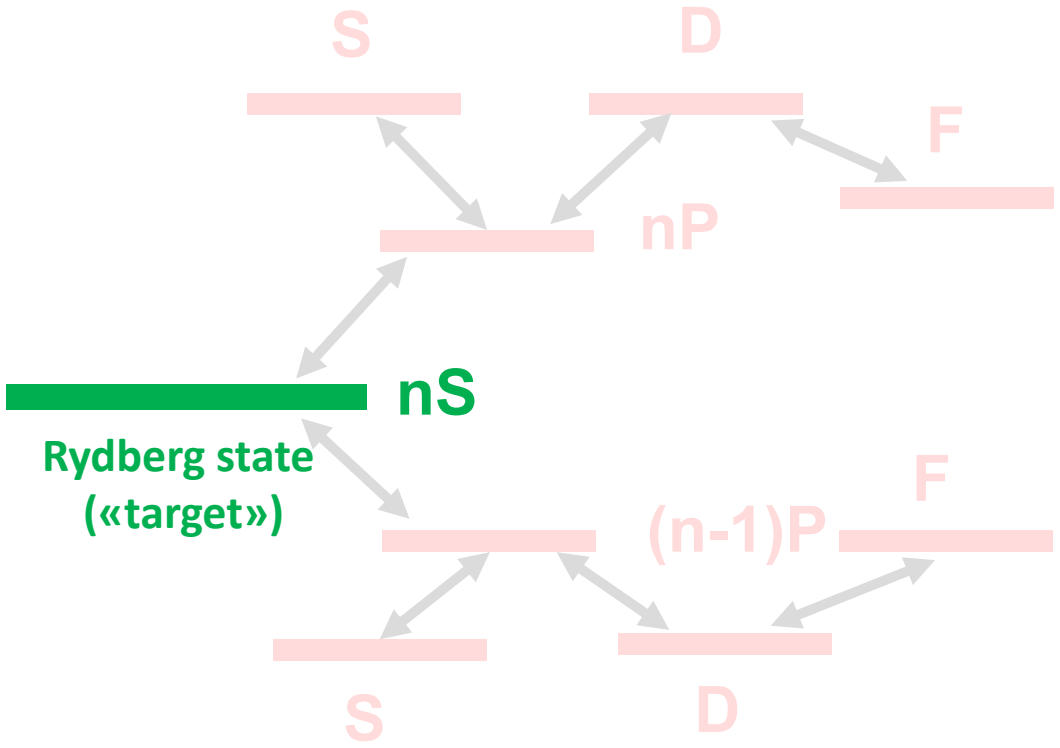
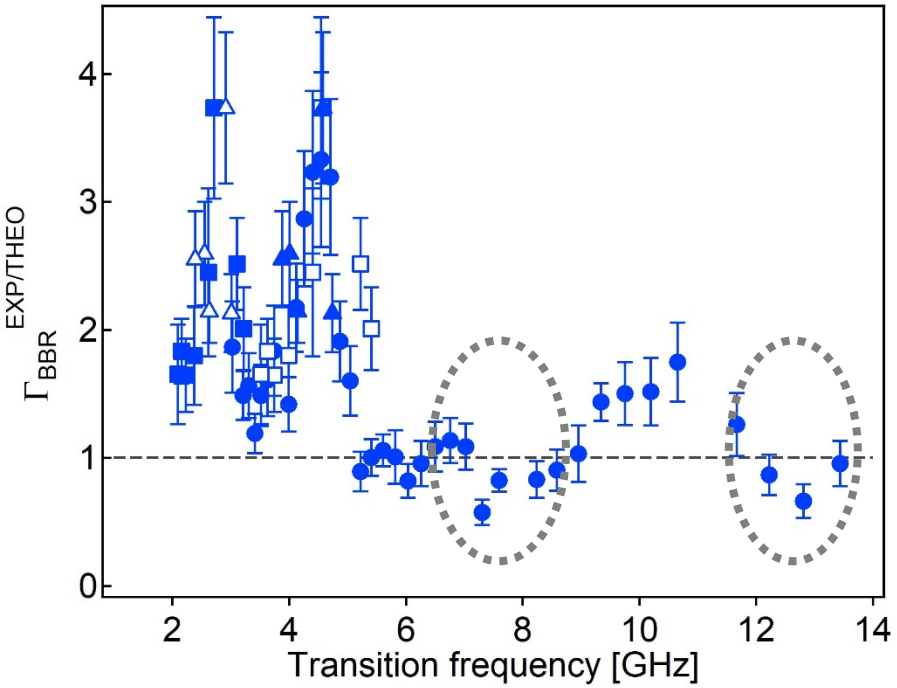
# Possible solutions: suppress BBR transitions…

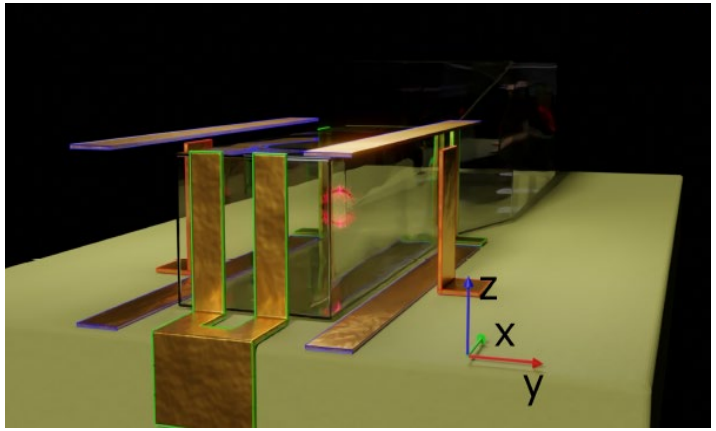


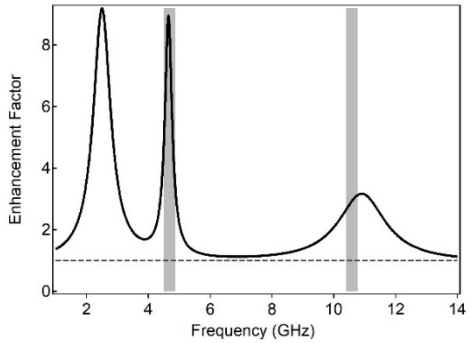




Archimi et al., ArXiv 2111.15333



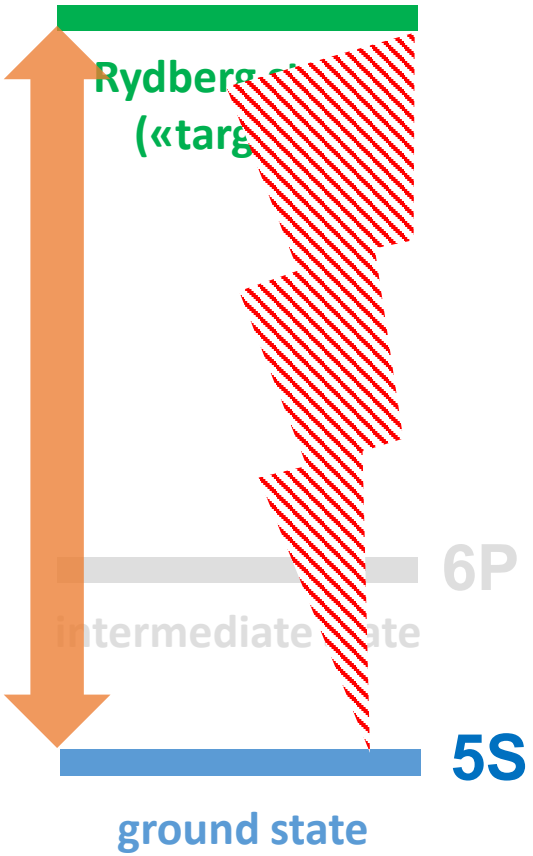


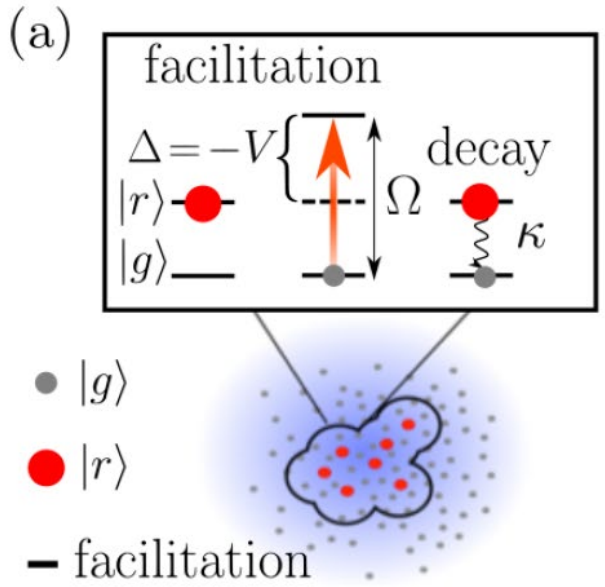


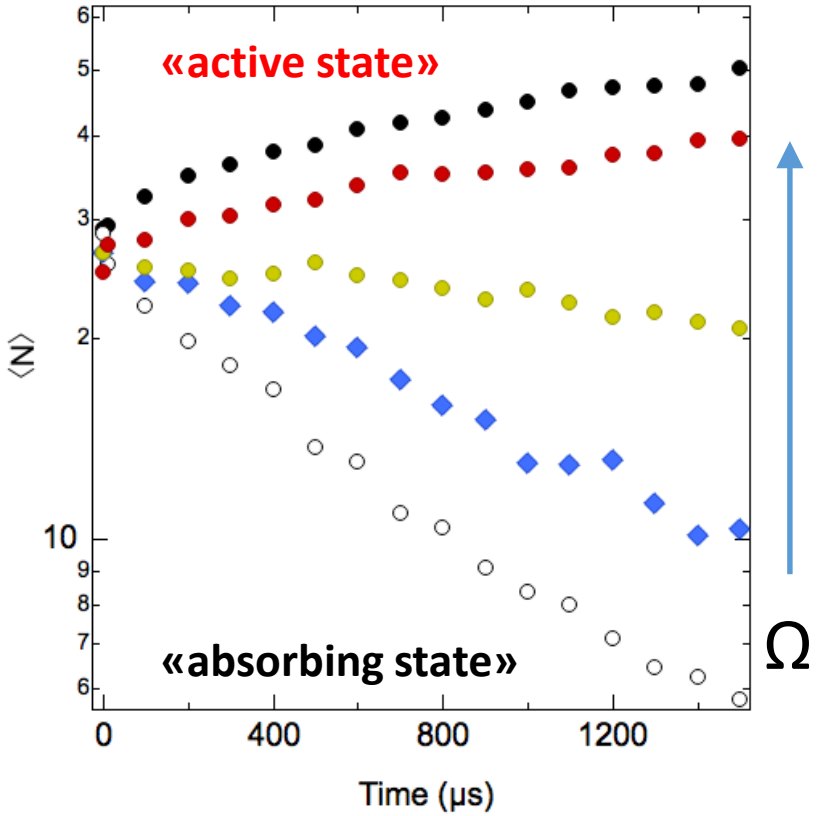




Lowest resonant microwave modes

# … or enhance («engineer») spontaneous decay

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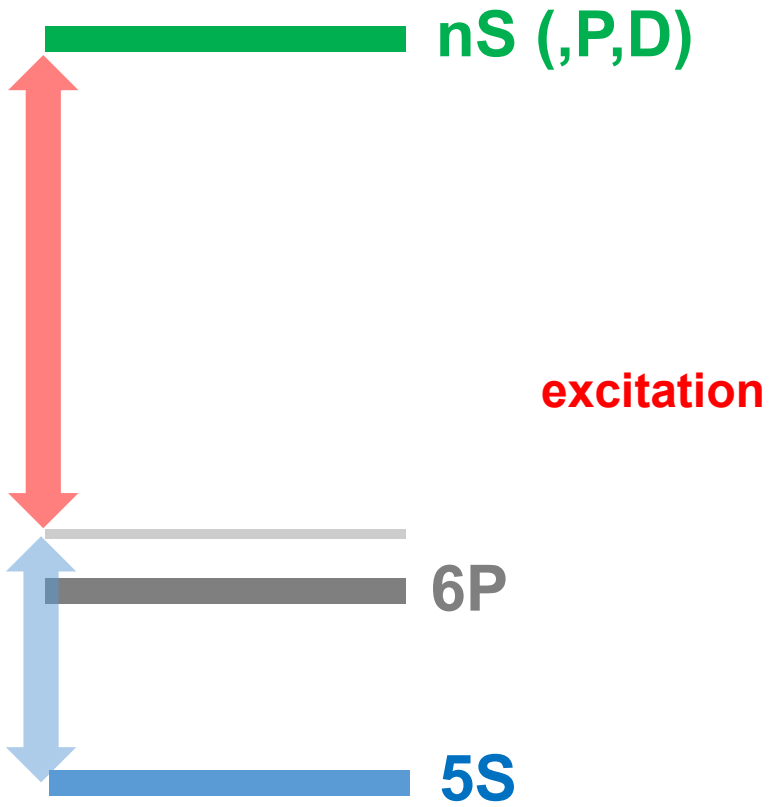
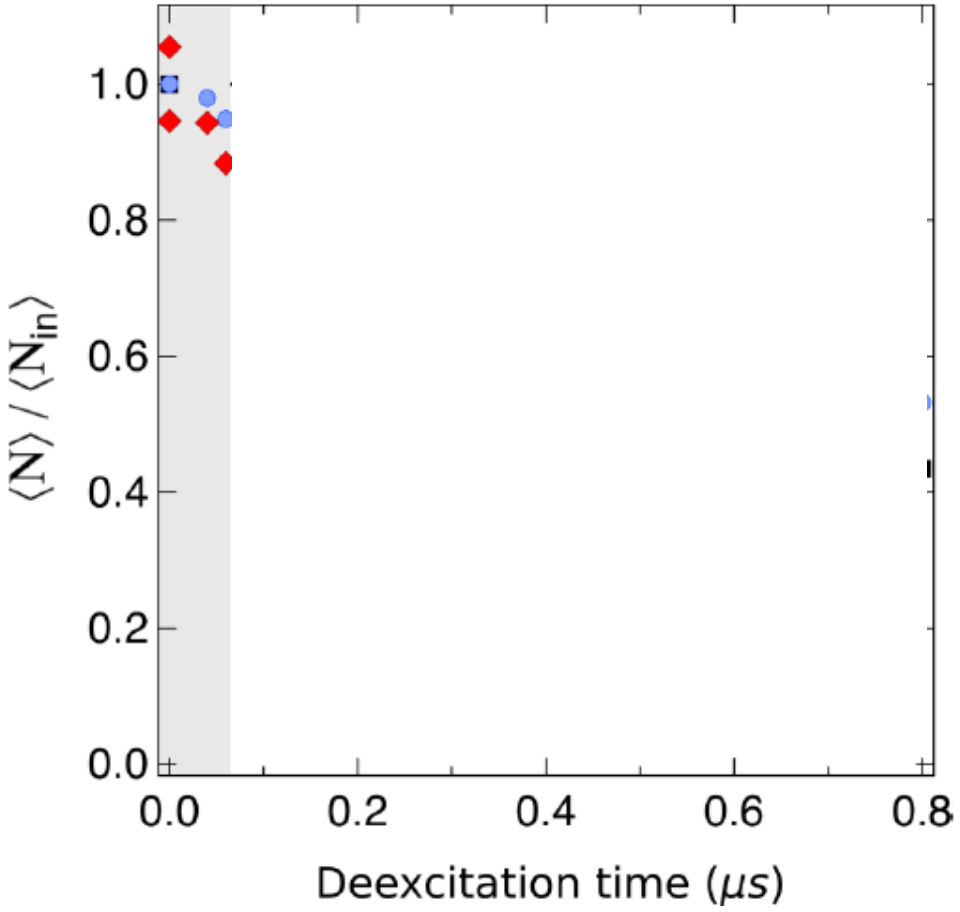
# Engineered dissipation (or «depumping»)




PHYSICAL REVIEW A **96**, 043411 (2017)

**Deexcitation spectroscopy of strongly interacting Rydberg gases**

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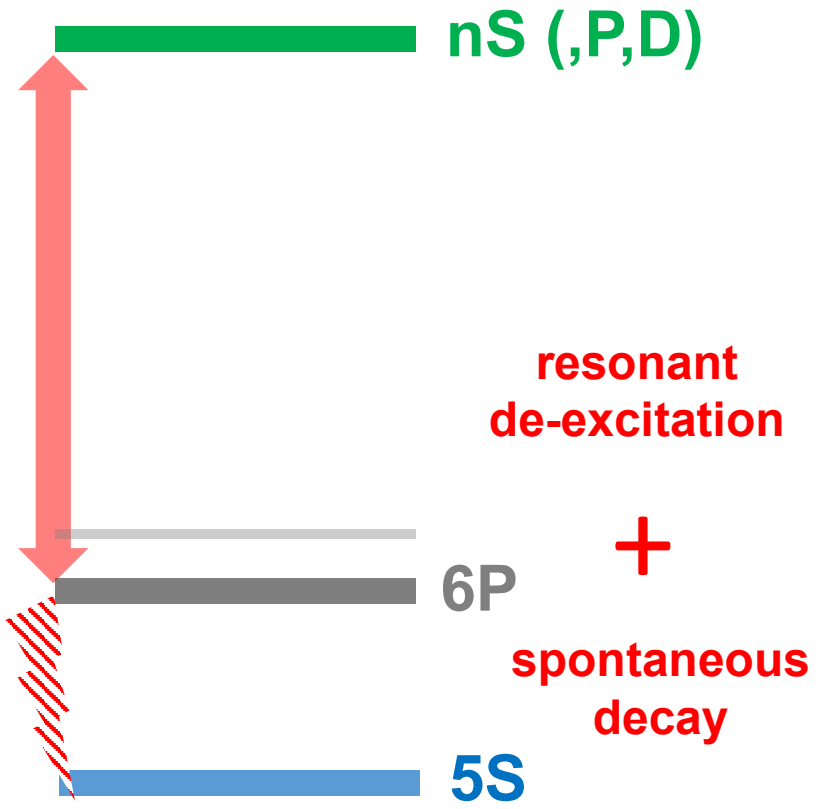


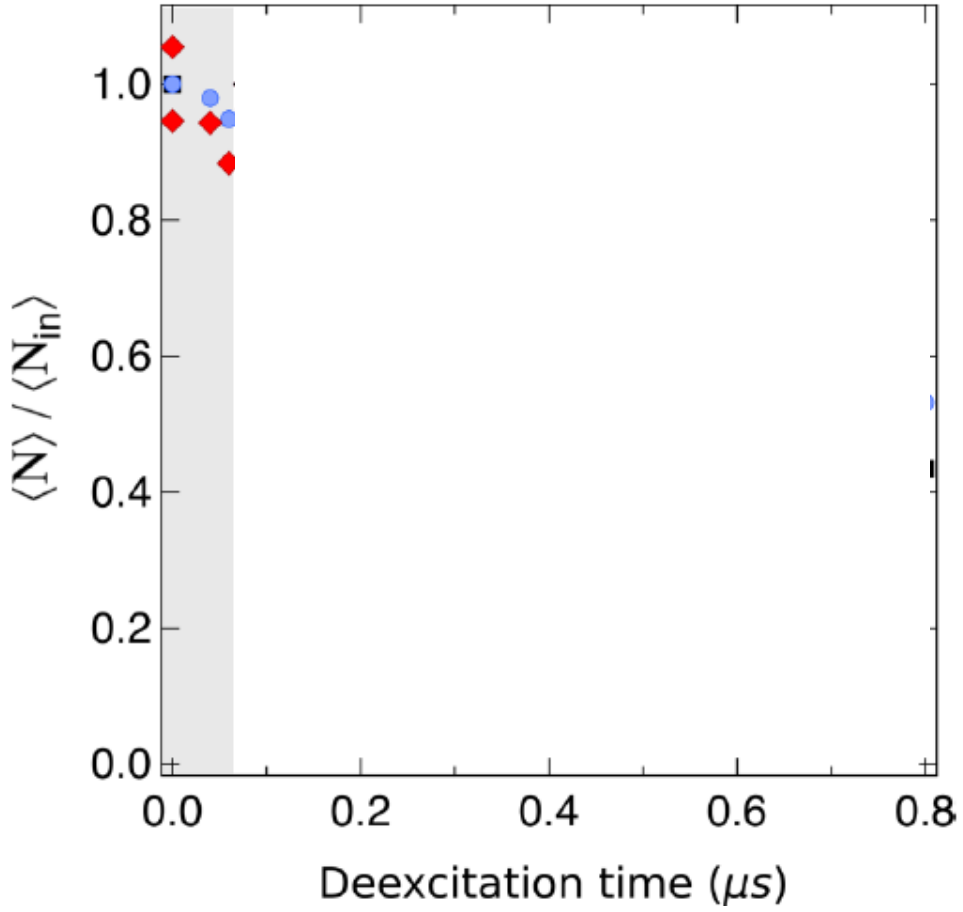


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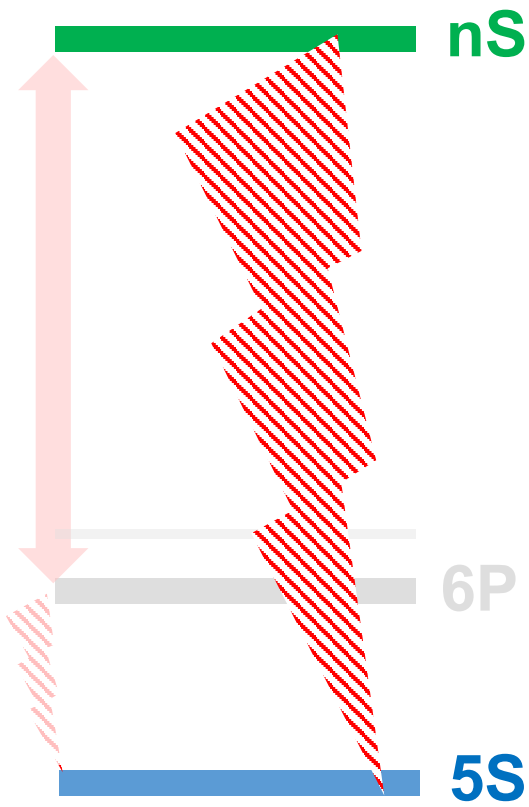
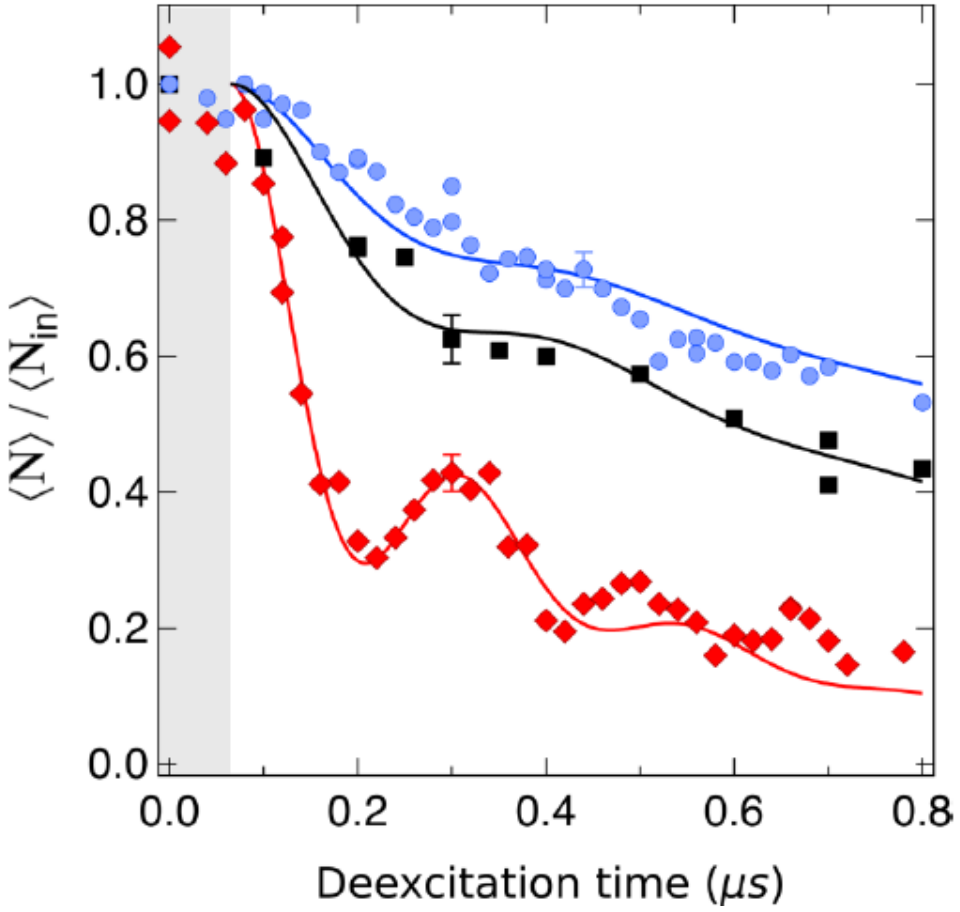



engineered dissipation

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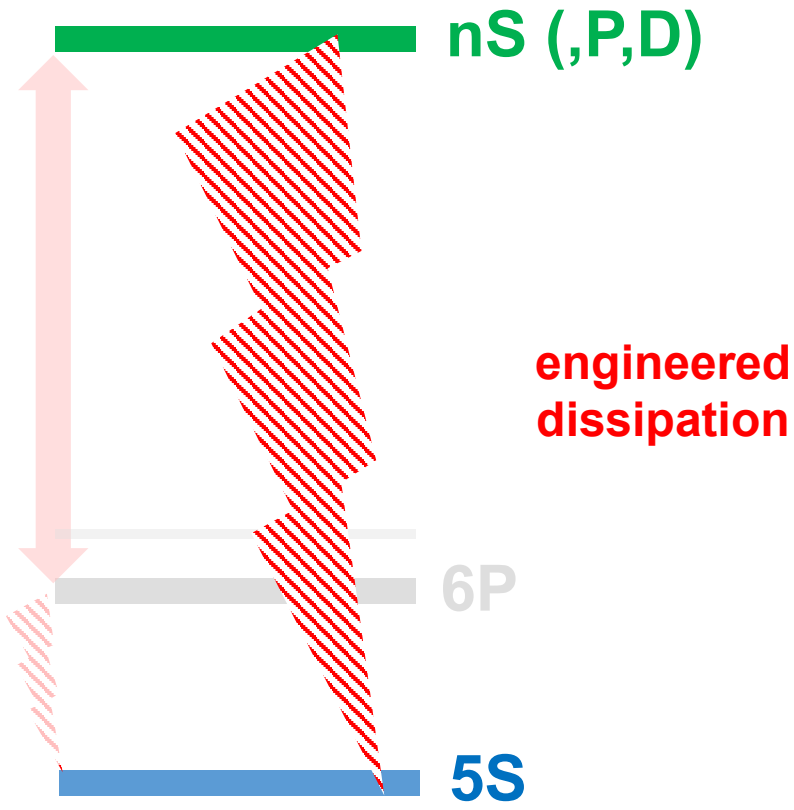


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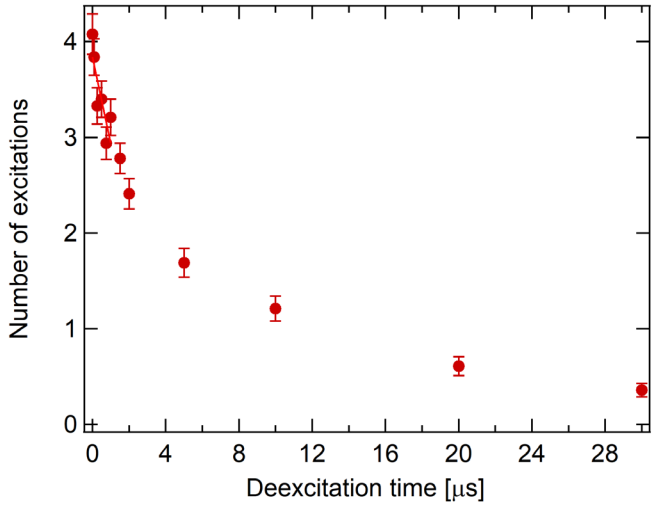

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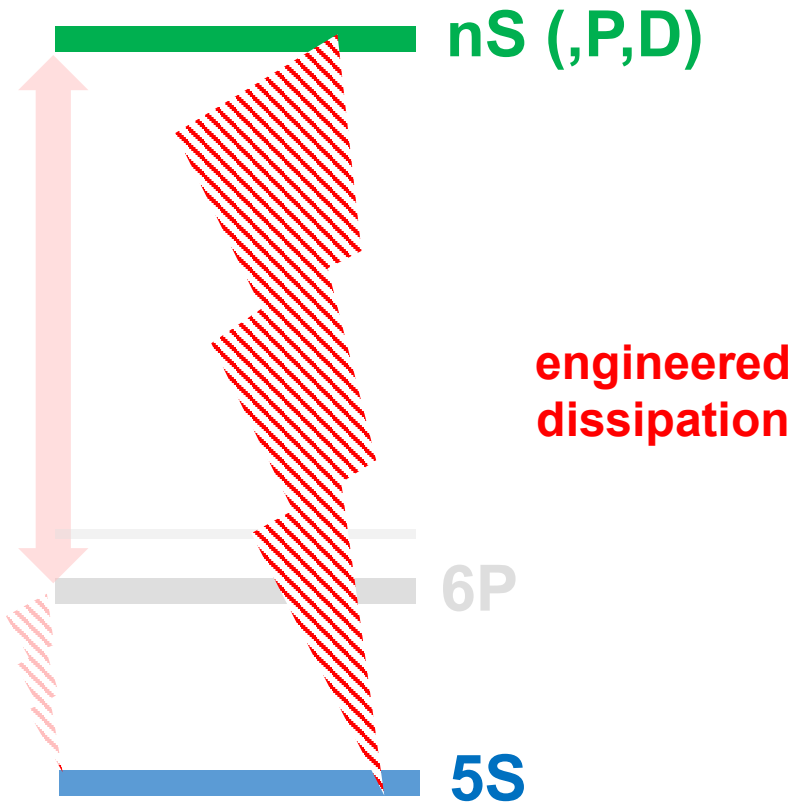
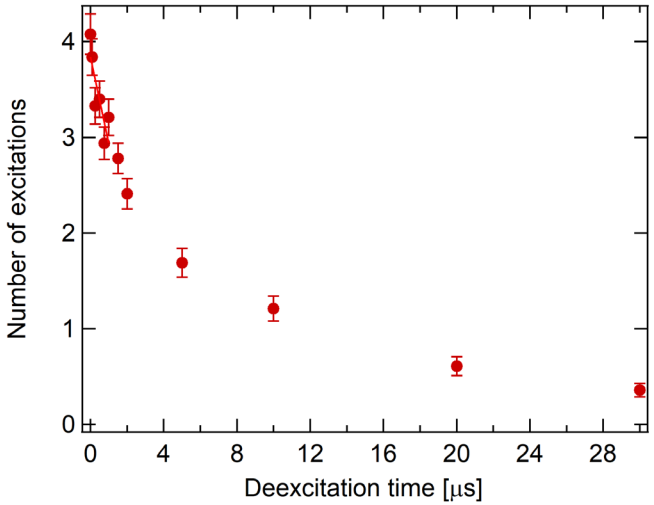
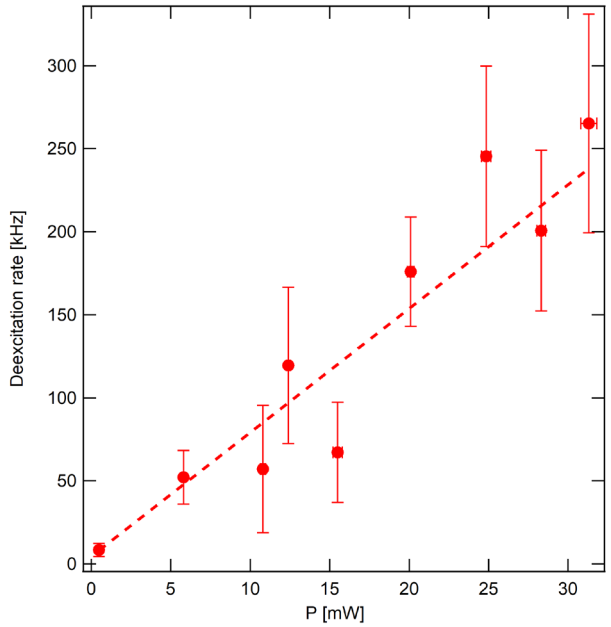
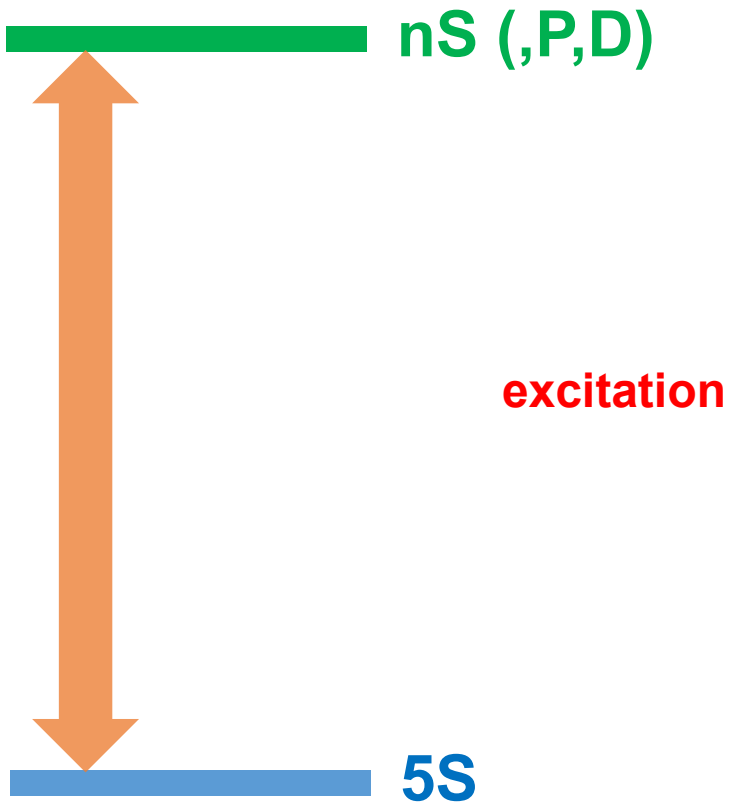


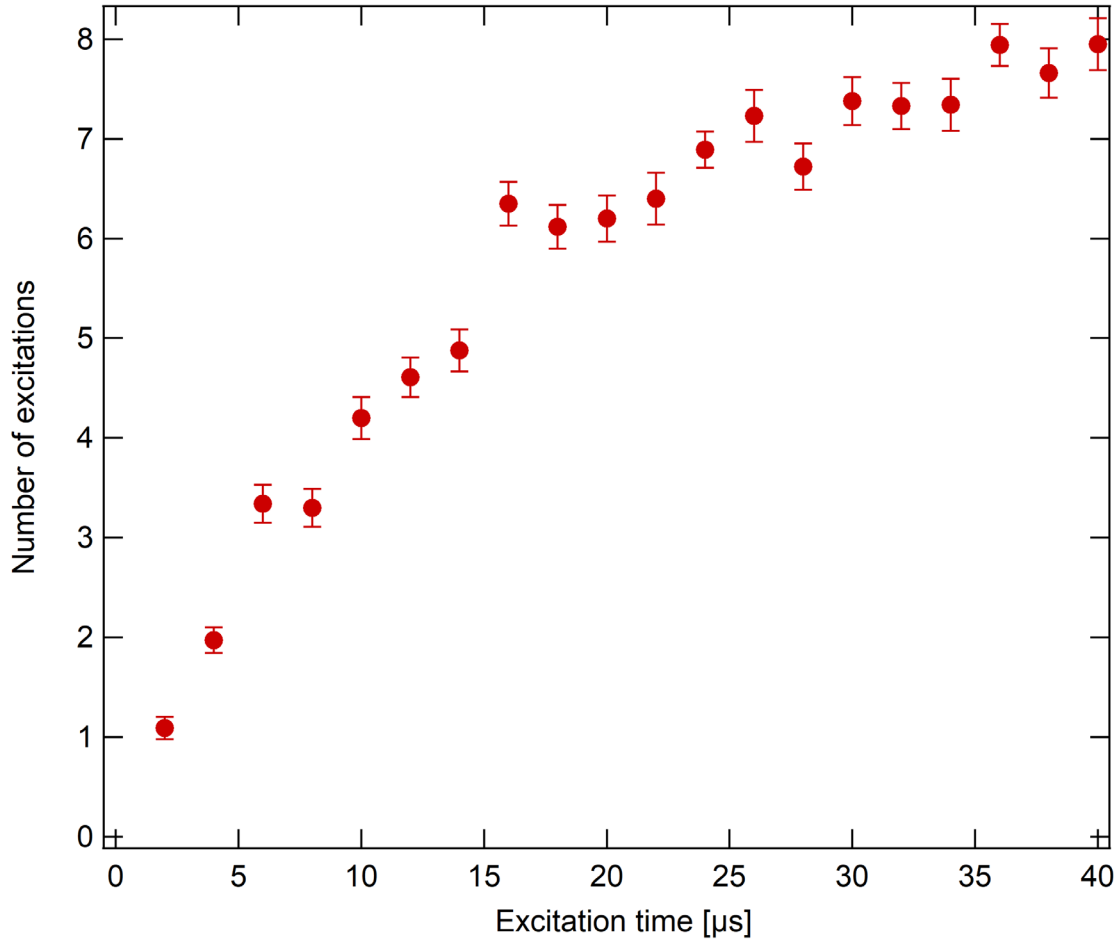

engineered dissipation



# Excitation + engineered dissipation



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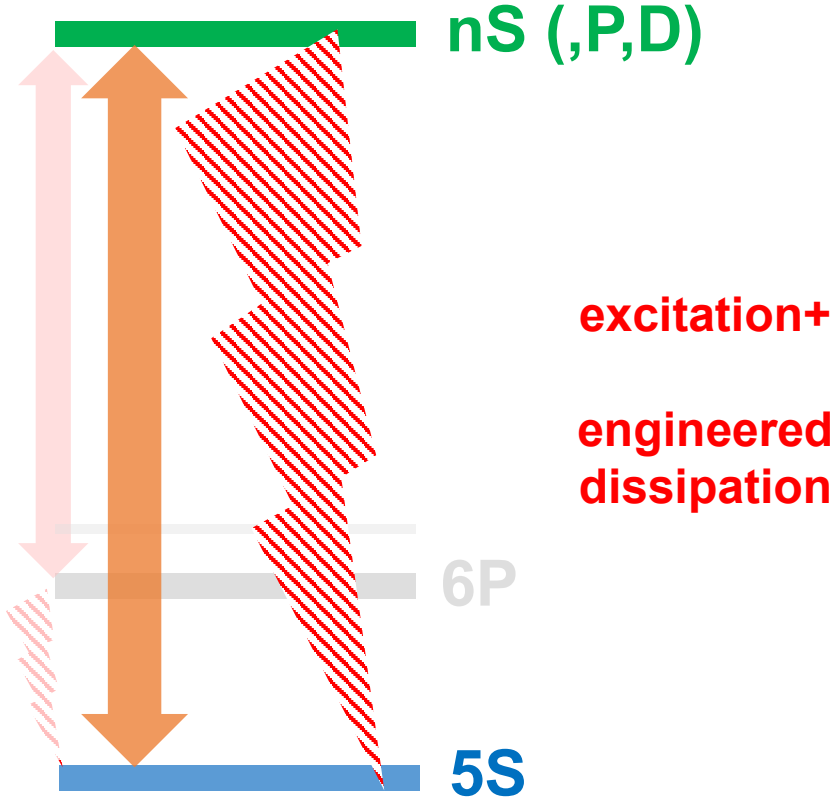
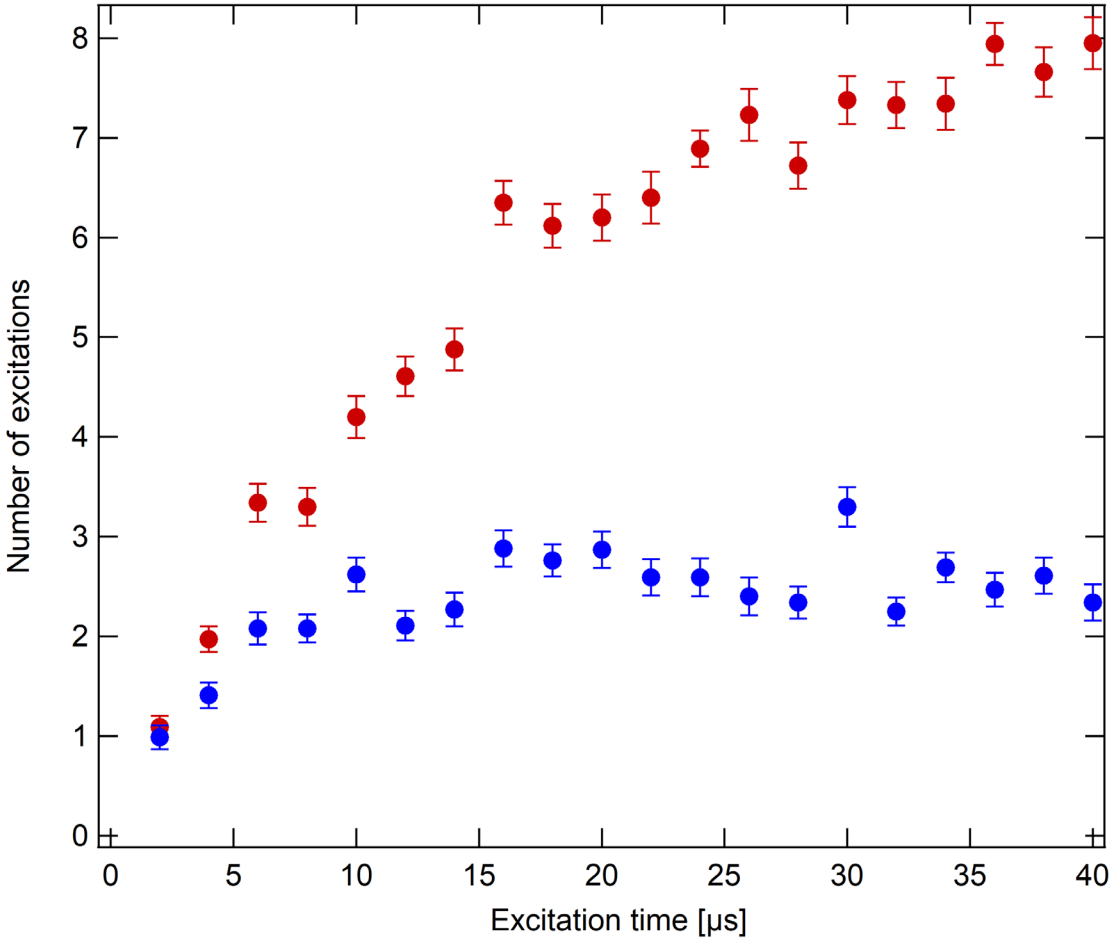



**excitation+**

**engineered dissipation**



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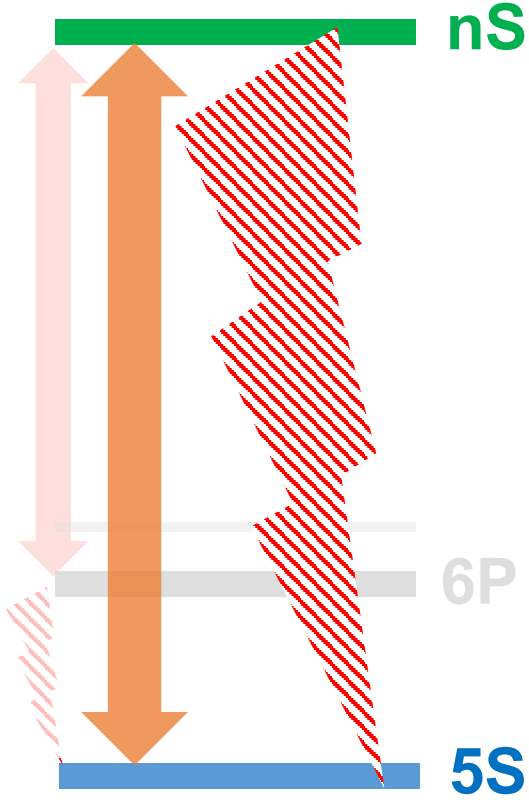


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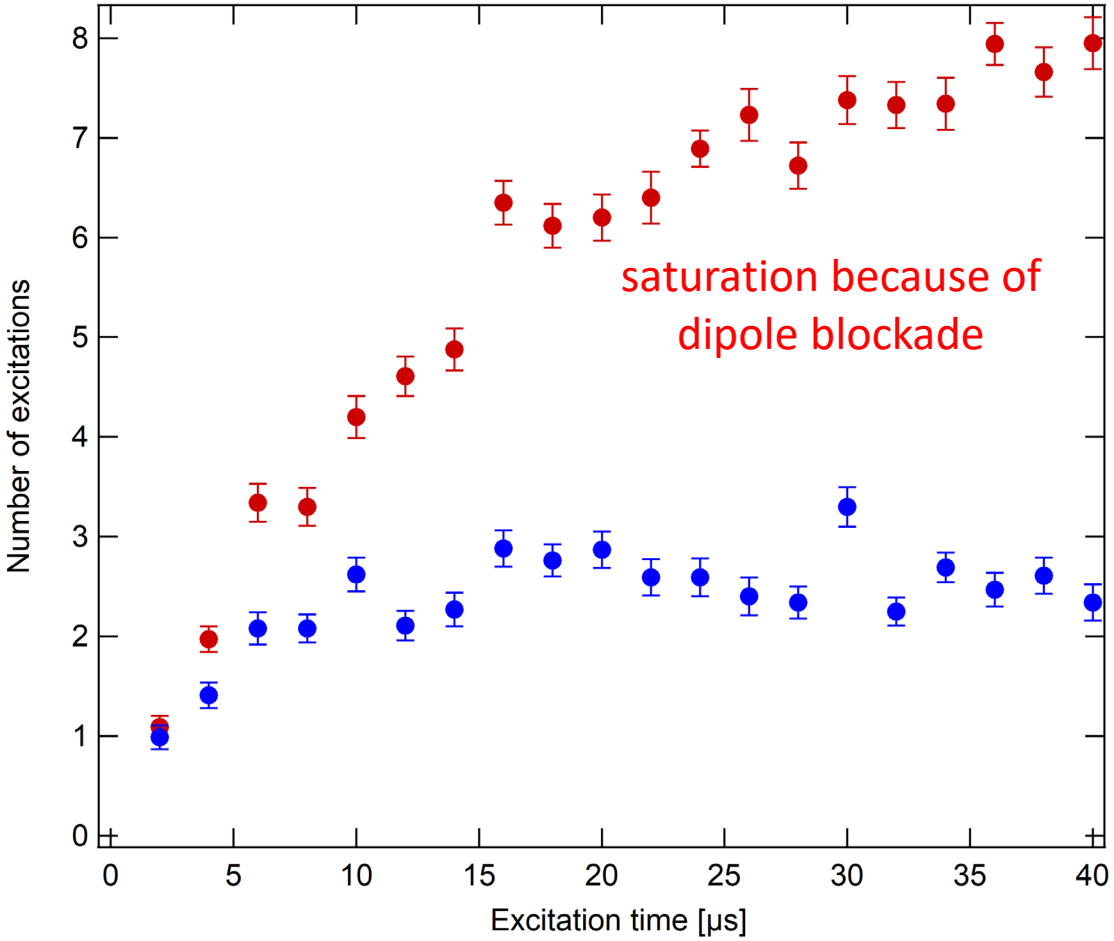

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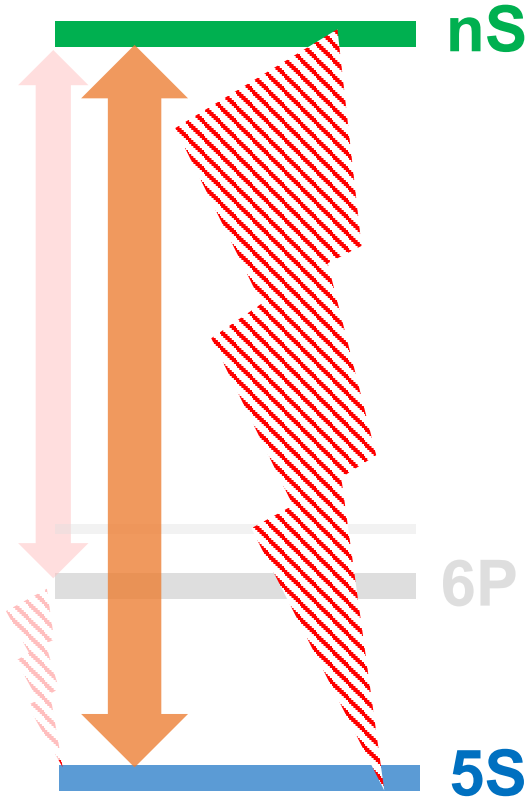


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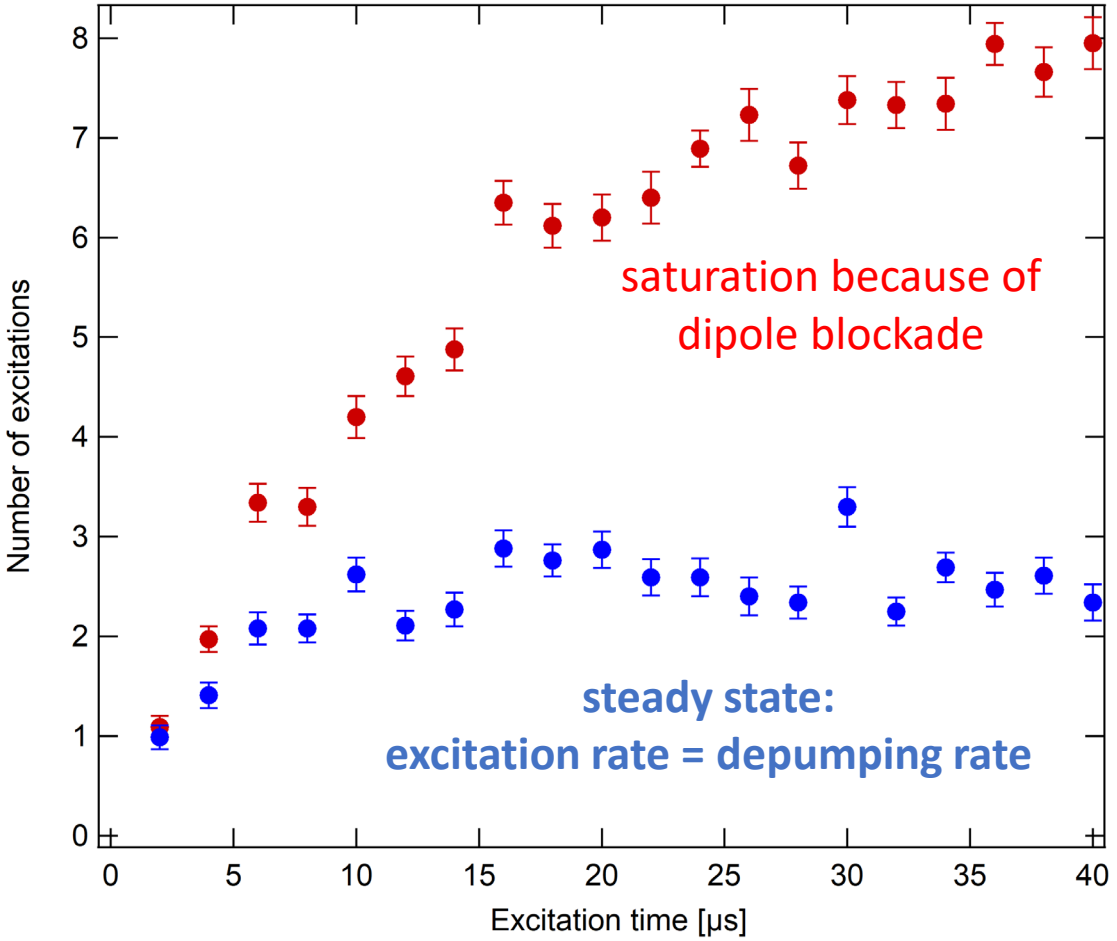

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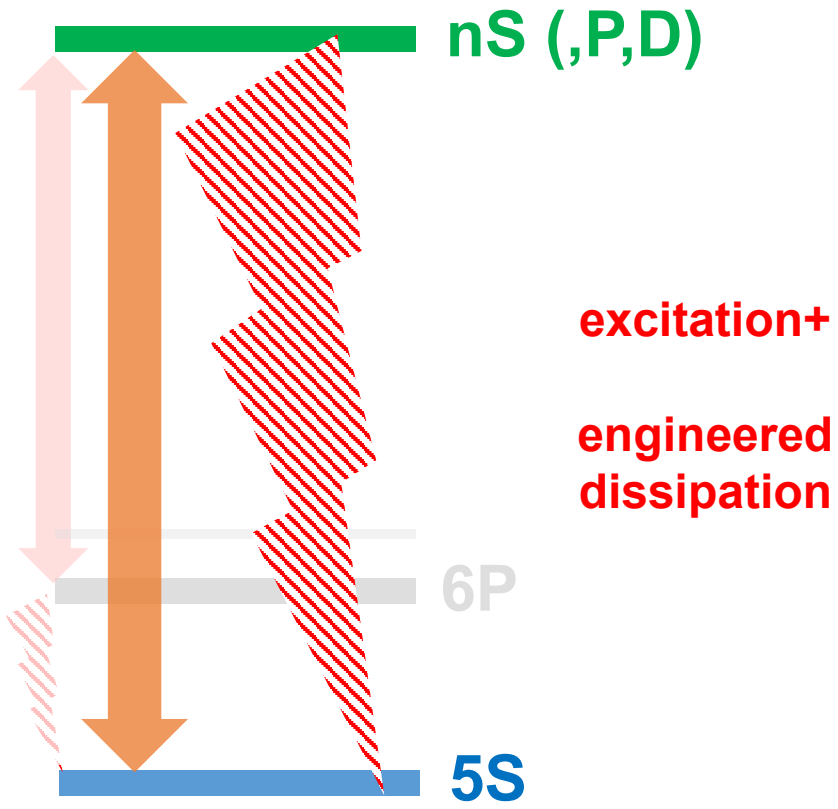


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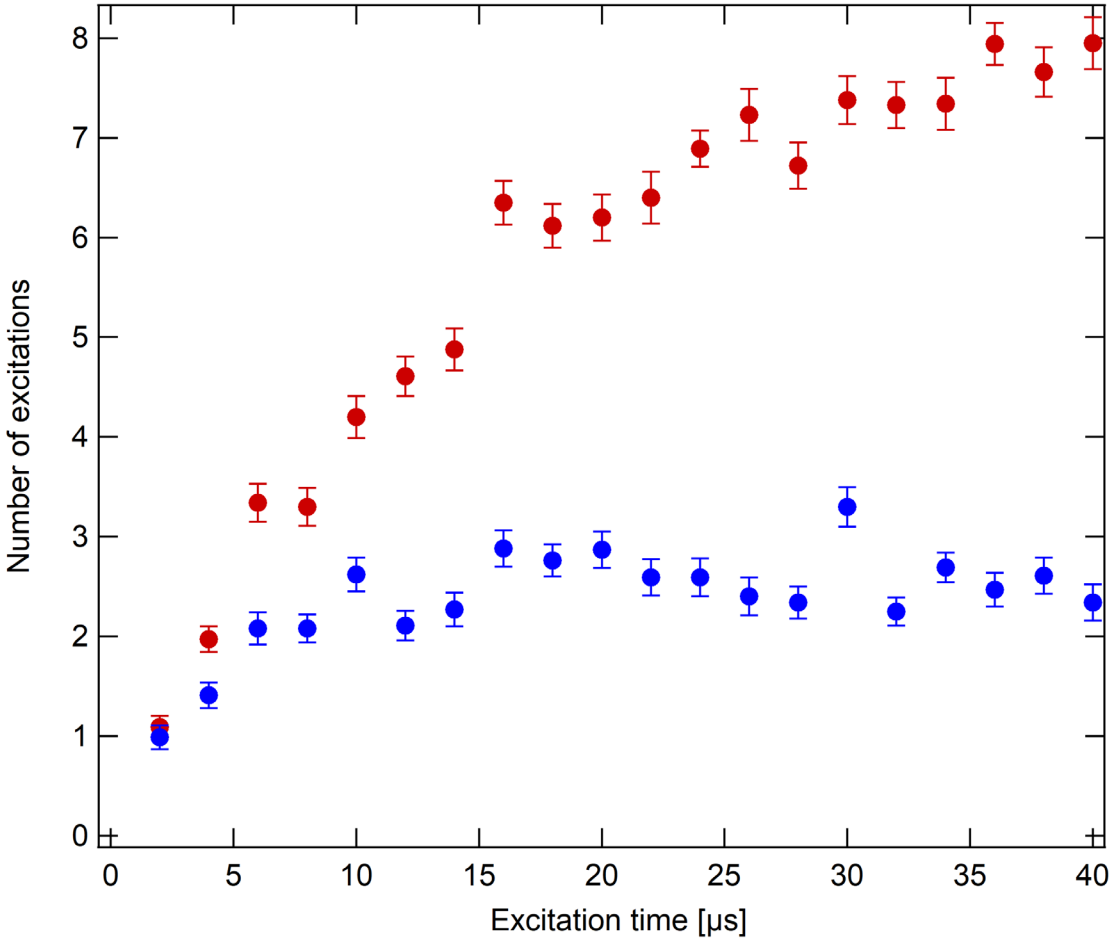


can switch on dissipation at arbitrary time

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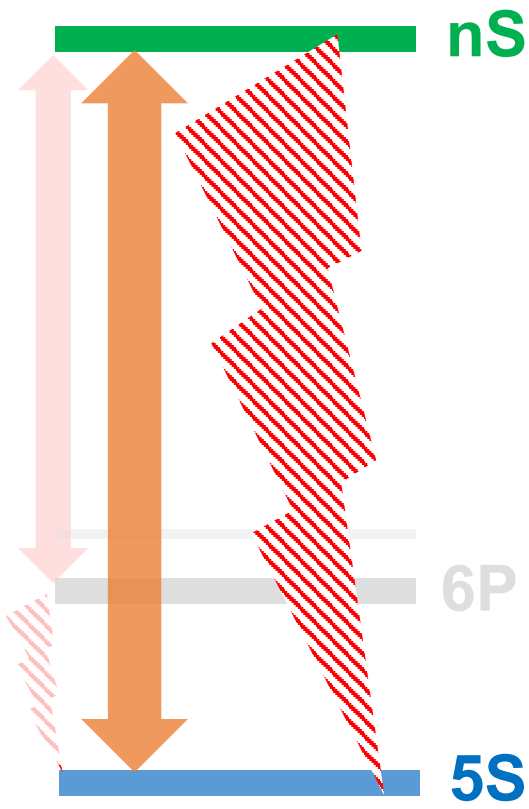


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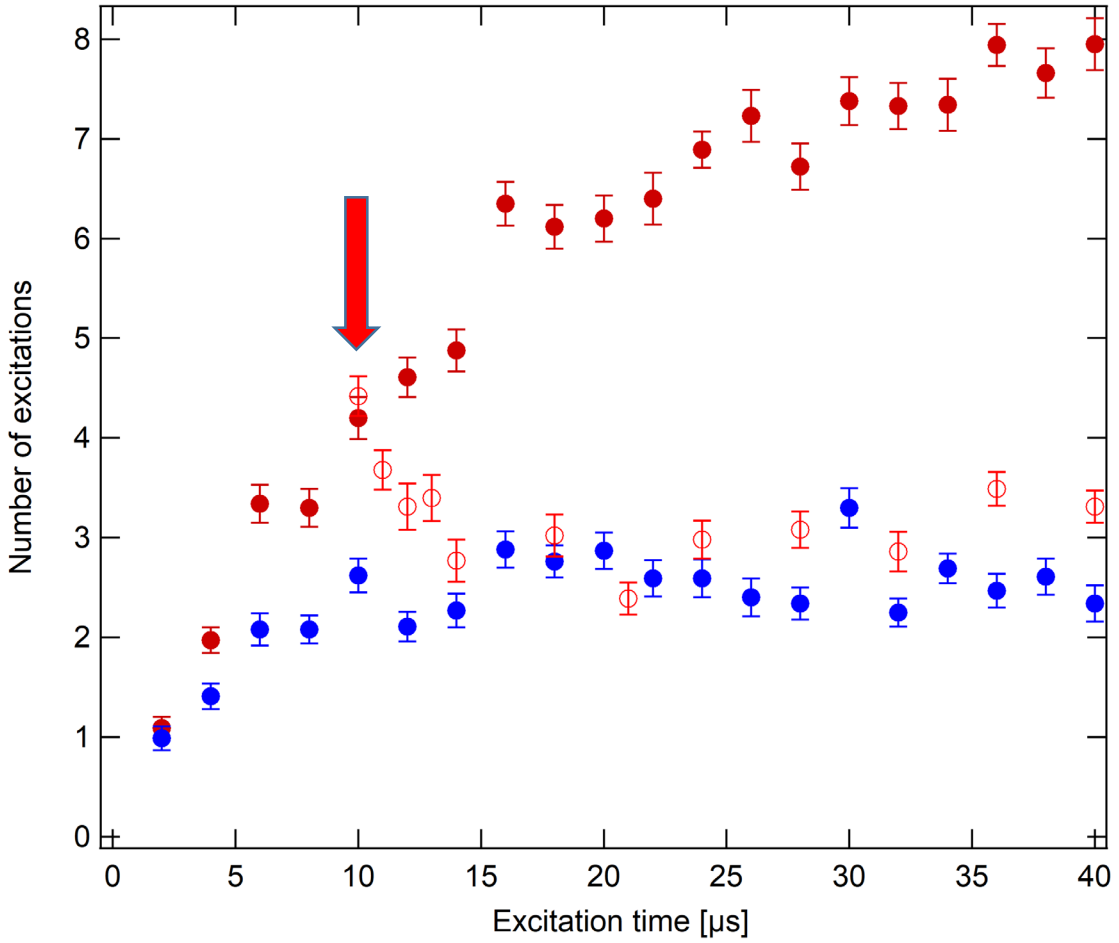


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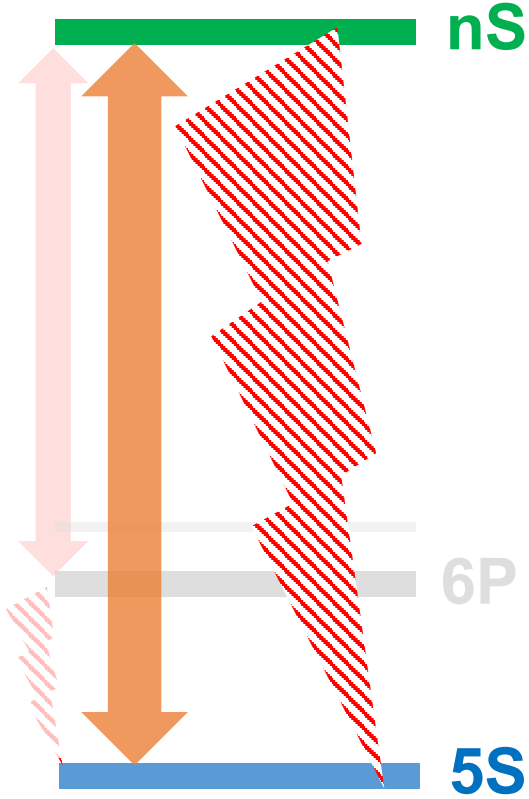


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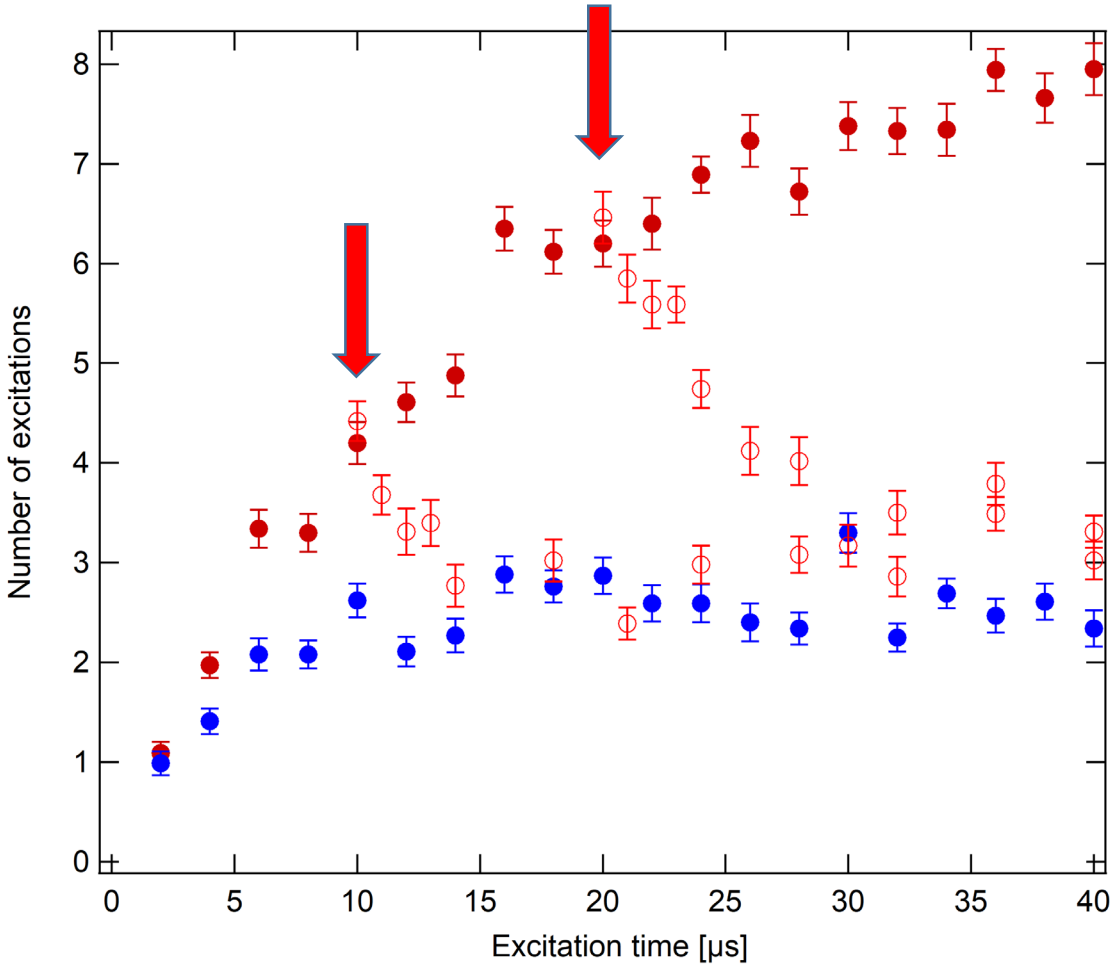


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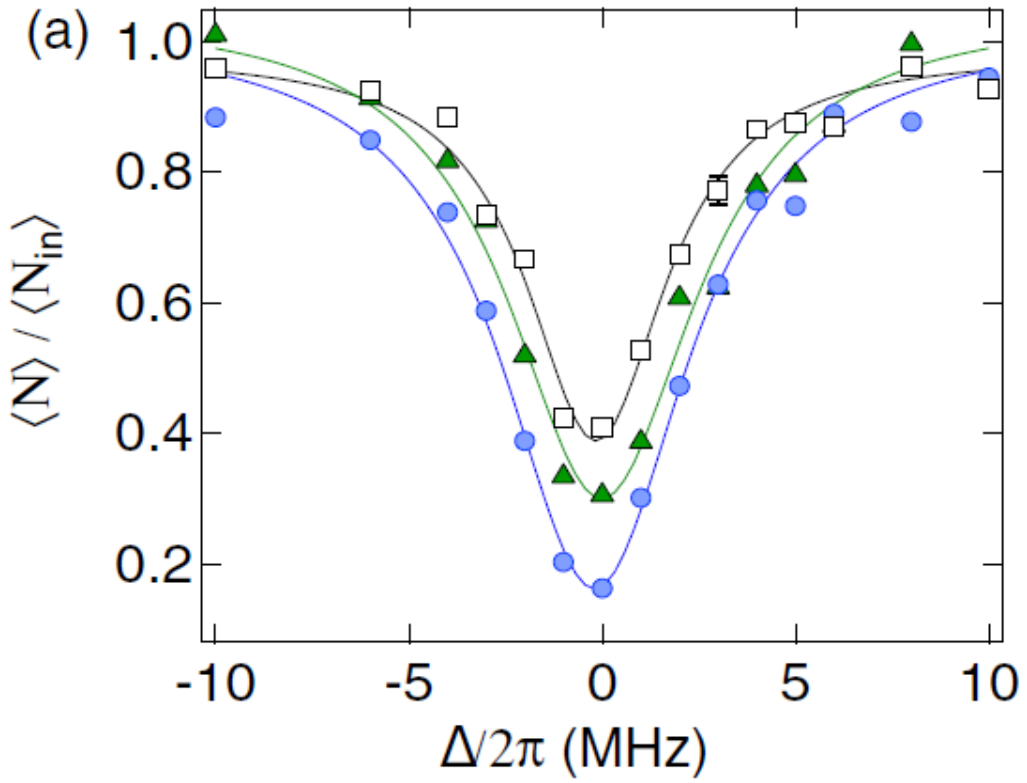
# Complication: interactions




depumping rate is suppressed by interactions between Rydberg atoms

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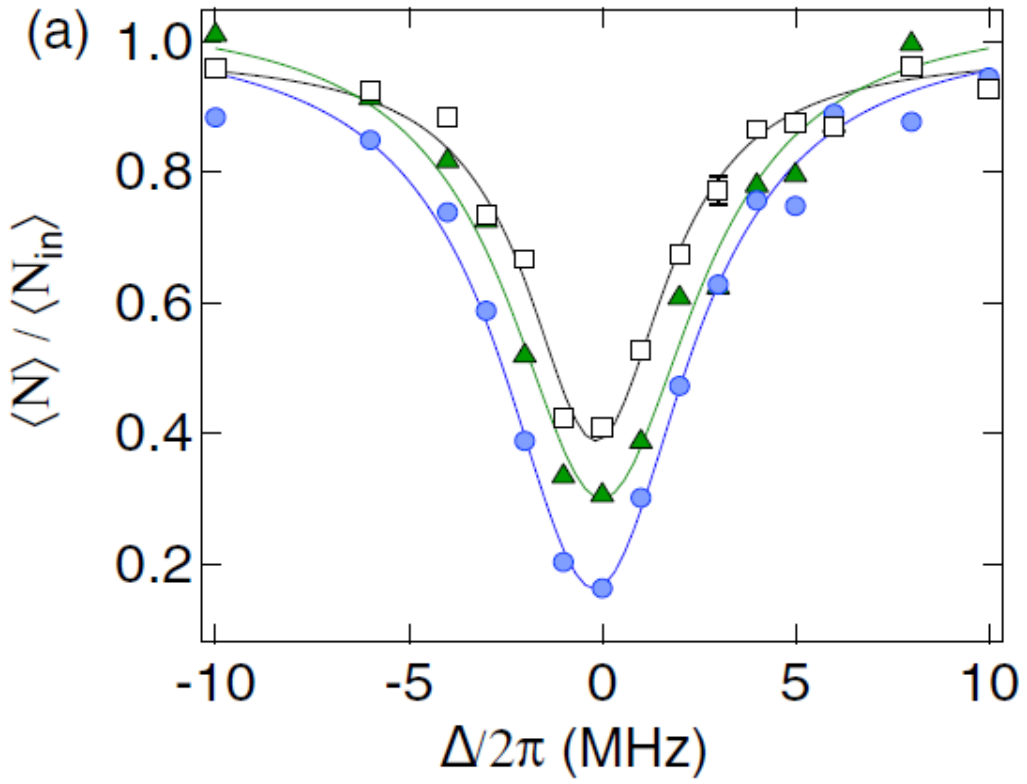


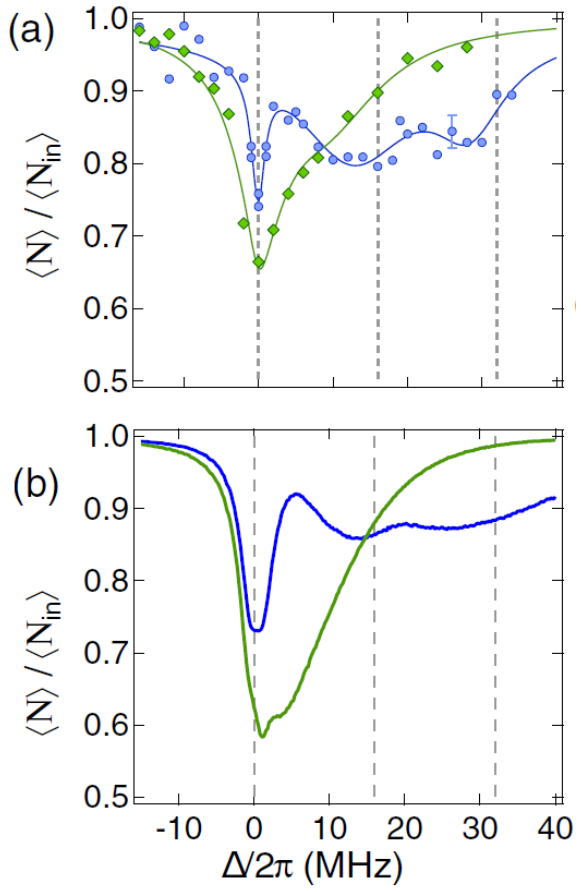


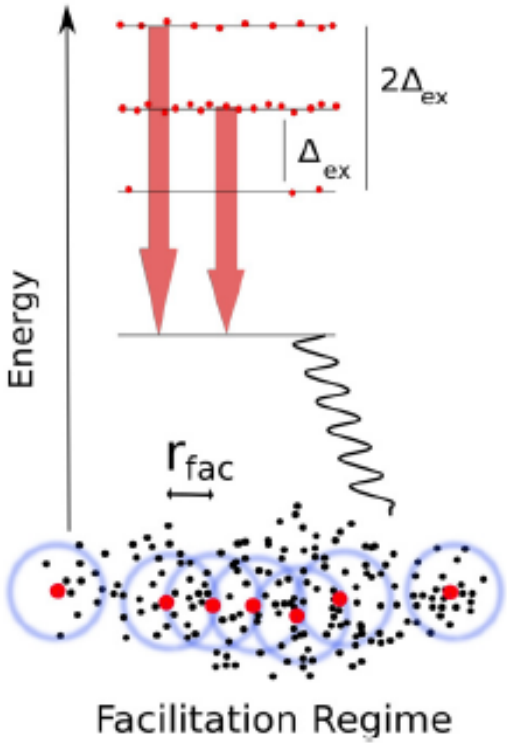


depumping rate is suppressed by interactions between Rydberg atoms

# What next?

PHYSICAL REVIEW LETTERS **127,** 060401 (2021)

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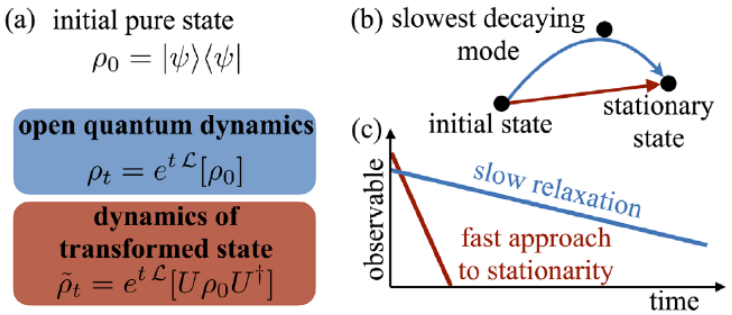
Federico Carollo,[1] Antonio Lasanta,[2,3] and Igor Lesanovsky[1,4]




PHYSICAL REVIEW A **101**, 052102 (2020)

**Fast route to equilibration**

Roie Dann,[1,3,*] Ander Tobalina,[2,3,†] and Ronnie Kosloff[1,3,‡]

- **Shortcuts to equilibration:** unitary priming and time-dependent dissipation control

# What next?

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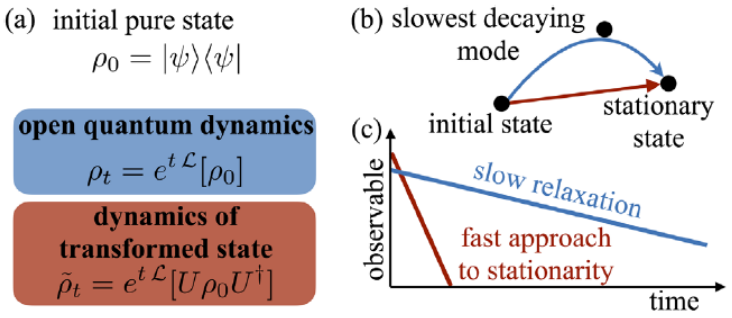


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# What next?

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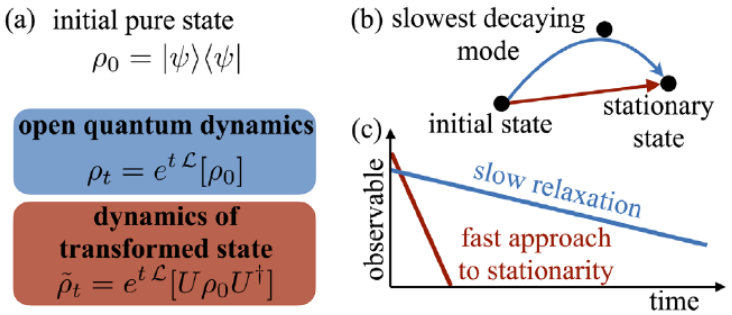


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- **Shortcuts to equilibration:** unitary priming and time-dependent dissipation control
- **Application in Rydberg atomtronics:** local (correlated/uncorrelated) dissipation
- **Other ideas** involving time-/space-/interaction-dependent dissipation?