Sub-nanosecond 780 nm pulse generation from a continuous wave laser for ultrafast hyperfine-resolved Rydberg excitation

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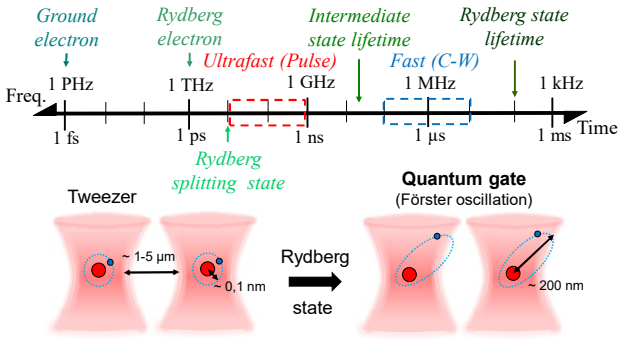
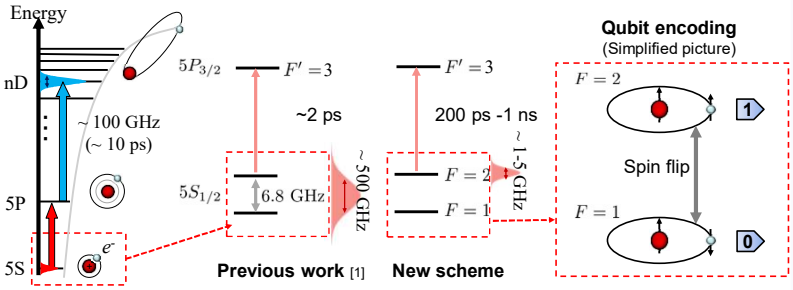
Introduction

1. Ultrafast Rydberg excitation





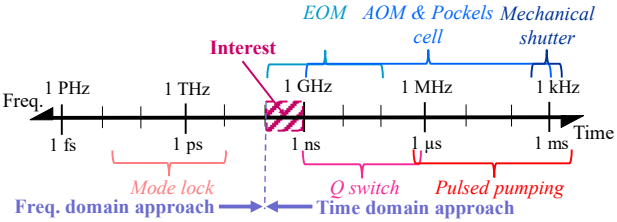
■ **Make atoms interact using huge dipole moment of Rydberg state (C_3 ~ GHz.µm³).**

2. Dynamic study of collective spontaneous emission

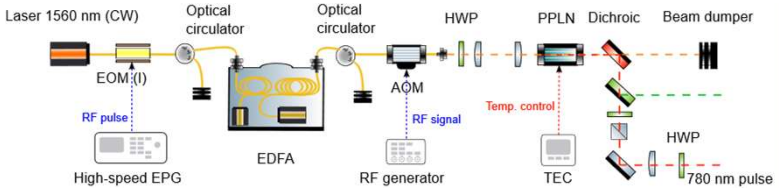
■ **When fully inverted emitter are indistinguishable within their emission (d << λ/2π).**
→ Quantum interference between emitters enhances the spontaneous decay rate
$\Gamma_{collective} \propto N^2$

■ **Speed of dynamics study bounded by the linewidth of the transition Γ= 6 MHz.**
→ The doppler shift need to be less than **Γ (~ v < 2 m.s⁻¹)**

System



Sub-nanosecond Pulsed laser

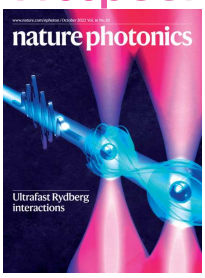


■ **C-W laser sliced with an Electro-Optical Modulator (EOM)**
→ 20 GHz modulation bandwidth.
→ Up to 40 dB of Extinction.

■ **Amplified with an Erbiun Doped fiber (EDFA)**
→ 1 kW maximum peak power.

■ **Converted using a Periodically Poled Lithium Niobate (PPLN)**
→ ~40% conversion efficiency at saturation.
→ Crystal phase-matching bandwith 40 GHz.

Prospect & Reference



Next

■ Fine-tune the apparatus to optimize performance.
■ Implement sub-nanosecond Phase control.

Reference

[1] « Ultrafast energy exchange between two single Rydberg atoms on the nanosecond timescale » Y. Chew et al., *Nat. Photonics* **16**, 724 (2022)

Acknowledgement

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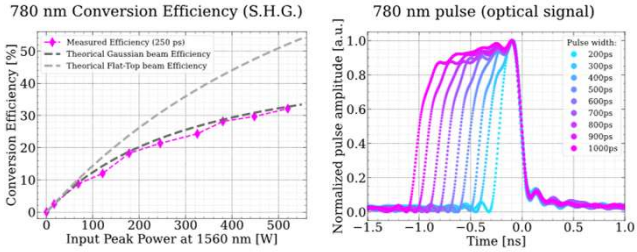
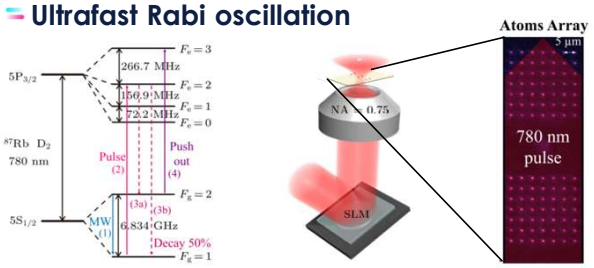
Results (Preliminary)

Pulse width & peak power

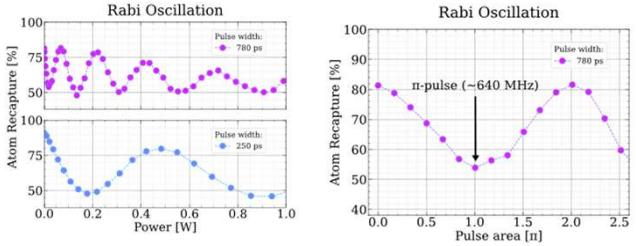


■ **S.H.G. conversion match with prediction (Peak power > 150 W obtain!).**

Ultrafast Rabi oscillation



■ **Population transfer from $5S_{1/2}$ |F=1,MF=1⟩ to $5P_{3/2}$ |F=2,M_F=2⟩.**
(State readout method have only a maximum contrast of 50%)



■ **Able to excite coherently atoms with sub-nanosecond timescale.**
(~ 80% of the population can be transferred!)
■ **4 π-pulses reached for 780 ps before transferring only 50% of the population.**