Fast Pulse Generation for Single-Photon Atom Interferometry

Shaan Dias, Gupta Lab

UNIVERSITY of WASHINGTON

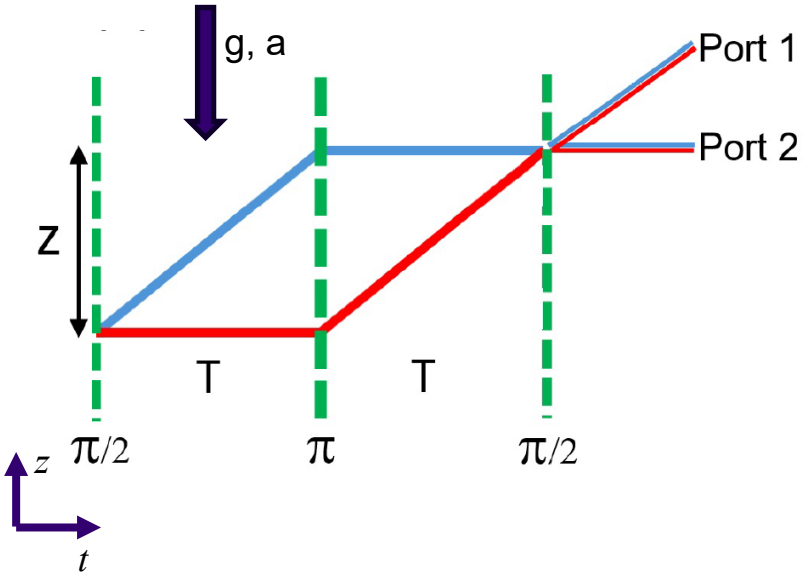
Outline

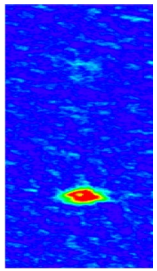
- Background
  - Atom interferometry
  - Single-photon atom interferometry with Yb
- Current Progress
  - Generating fast pulses
- Outlook

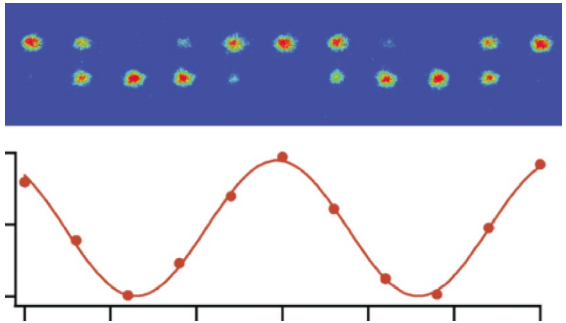
Atom Interferometry (AI)

- Analogous to light interferometry
- Sensitive measurements
  - E.g. test QED, EP
- Sensitivity proportional to space-time area enclosed
  - Large momentum transfer (LMT)

$$\frac{\delta g}{g} = \frac{\delta \phi}{\phi} = \frac{\delta \phi}{nkgT^2}$$



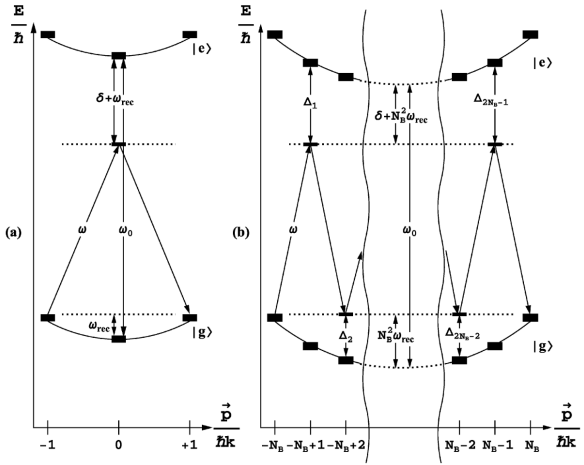




2-Photon vs Single-Photon Processes

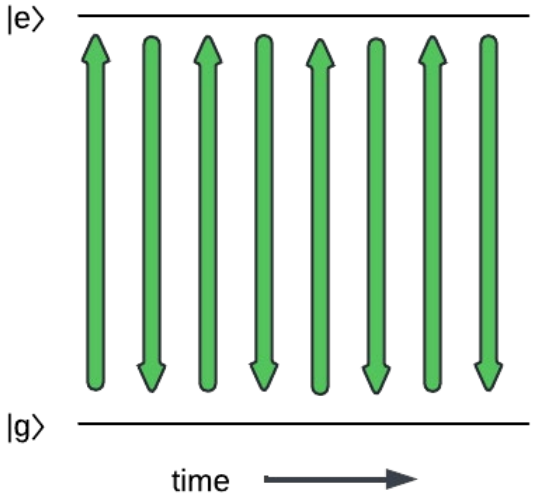
- Have achieved 112 recoil momenta
- 2-photon limits pulse speed

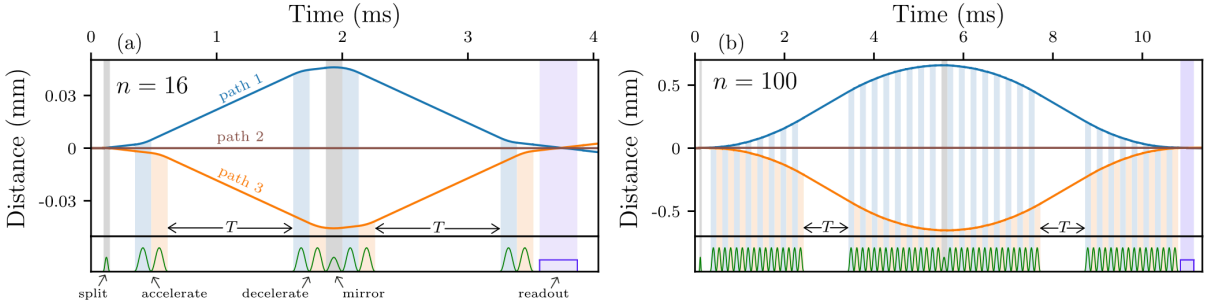
2-Photon



S. Gupta et al. C. R. Acad. Sci. **2**, 479 (2001)

Single-Photon

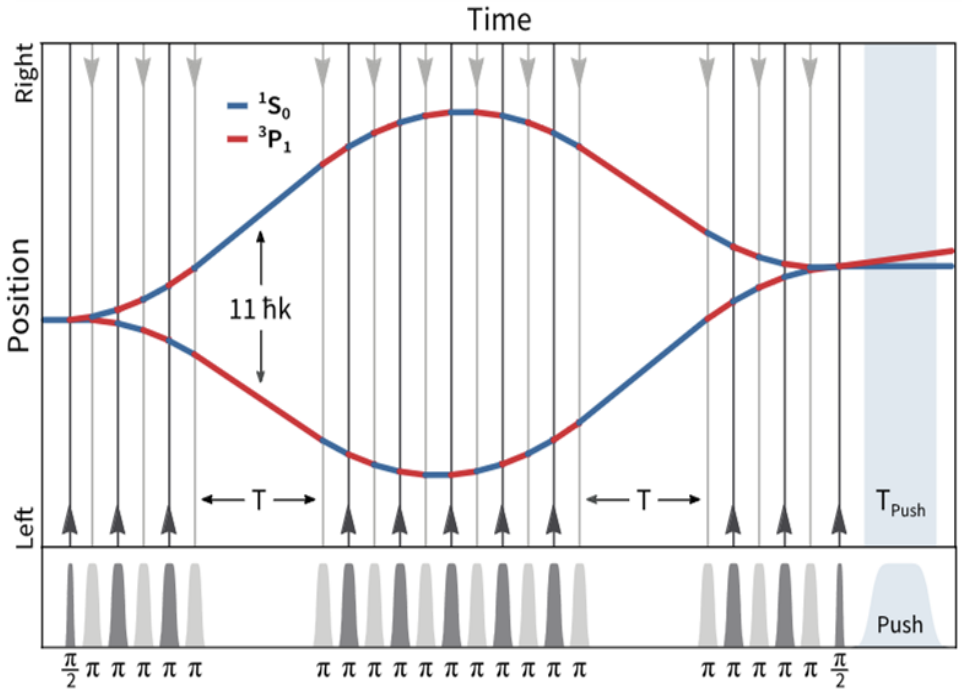




B. Plotkin-Swing et al. Phys. Rev. Lett. **121**, 133201 (2018)

Realizing Single-Photon LMT Clock AI

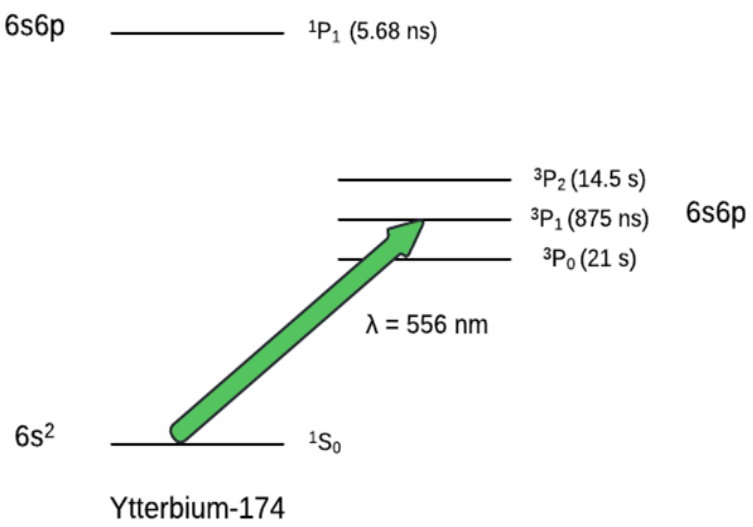
- Jason Hogan's group at Stanford
- Single-photon process performed on clock transition using strontium



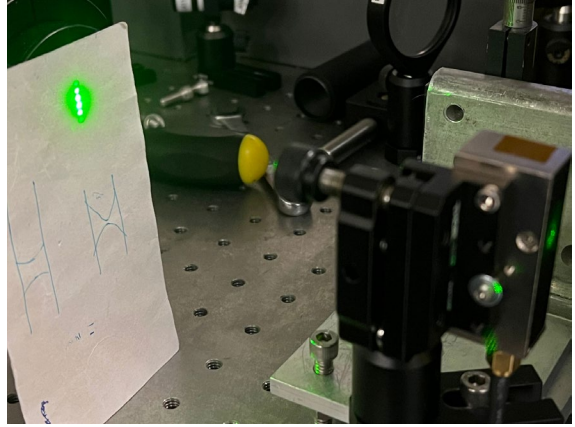
J. Rudolph et al. Phys. Rev. Lett. **124**, 083604 (2020)

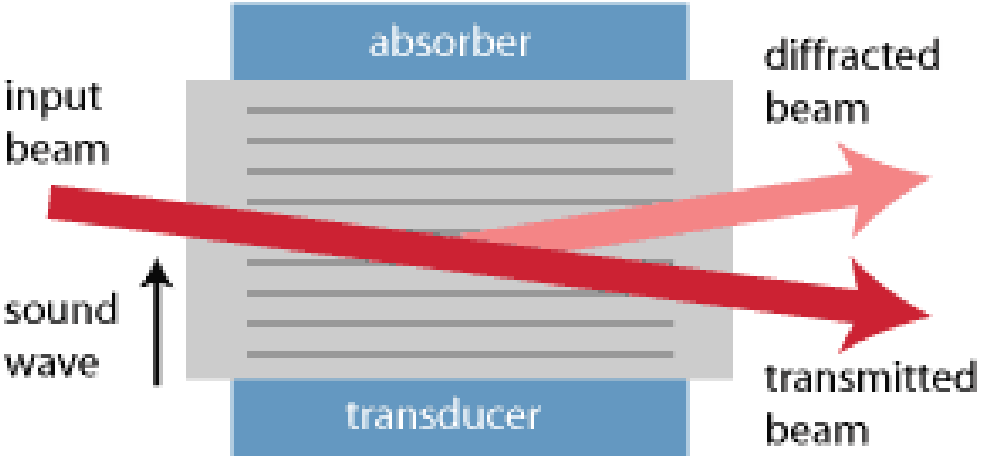
Applying with Ytterbium Atoms

- Vertical configuration to sense gravity
- 875 ns lifetime is faster than Sr, but presents technological challenges
- π, π/2-pulse depends on duration, light intensity



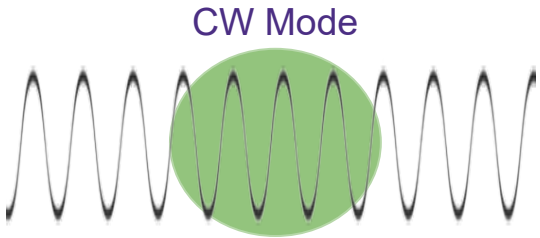
Generating Fast Pulses with Acousto-Optic Modulator (AOM)

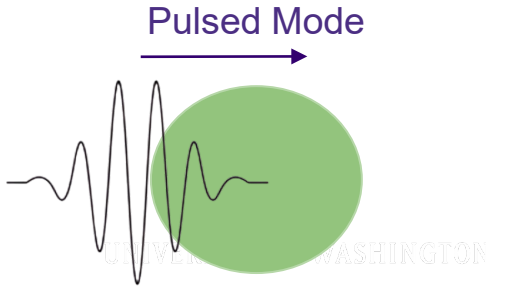




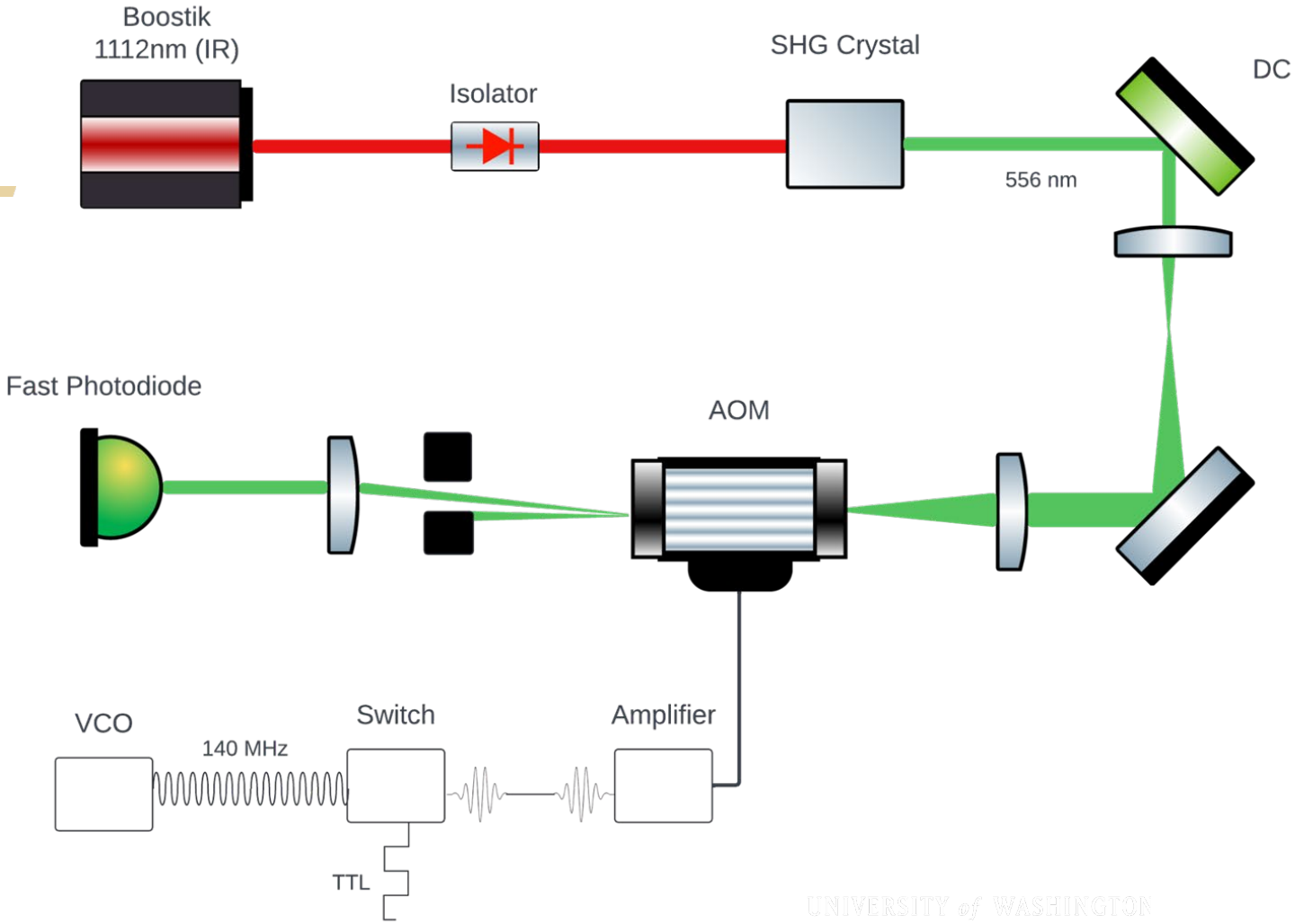
R. Paschotta, RP Photonics Encyclopedia, https://doi.org/10.61835/az1

$$t_r \sim \frac{D}{V}$$



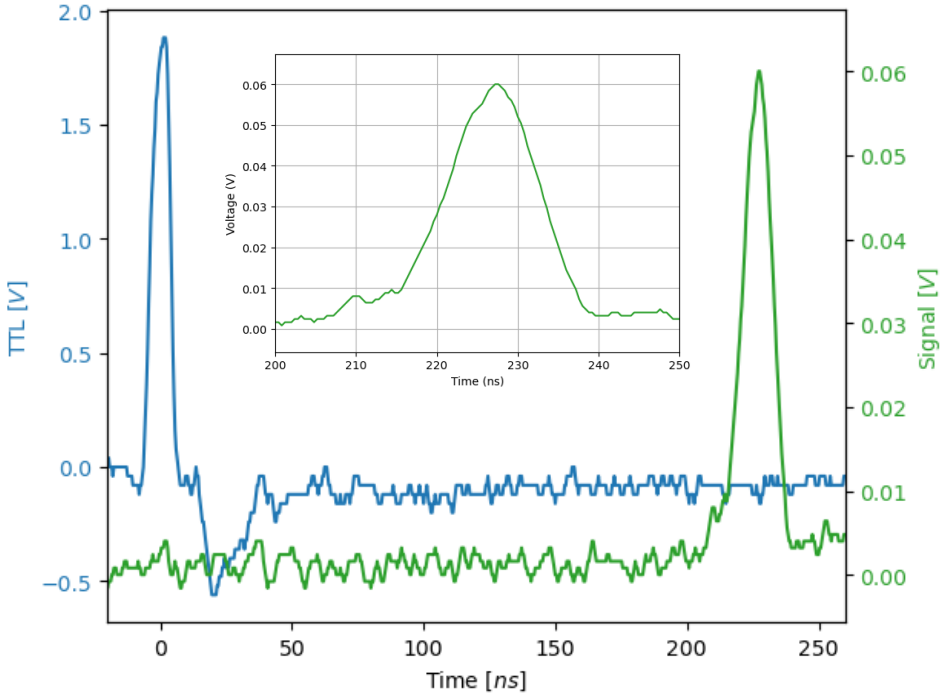


Set-Up

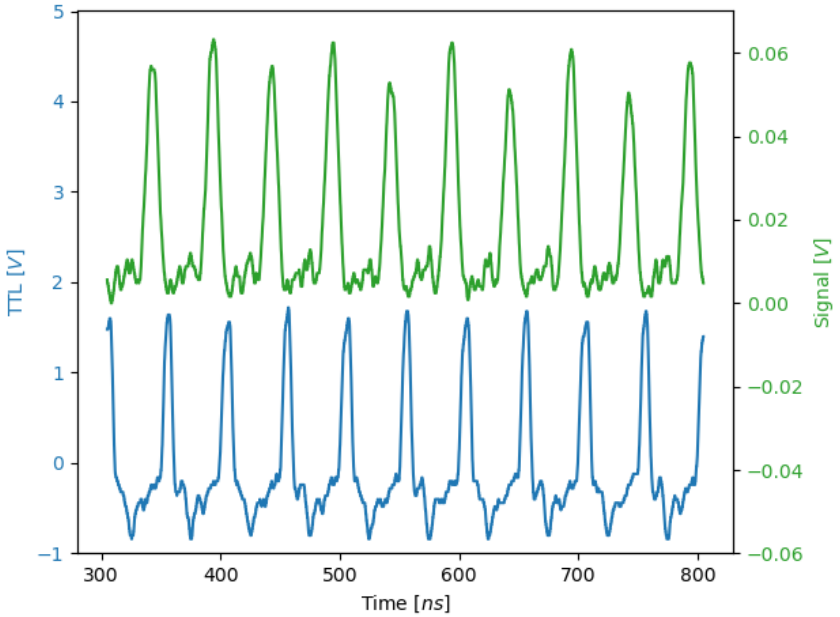

Boostik
1112nm (IR)
Isolator
SHG Crystal
DC
556 nm
Fast Photodiode
AOM
VCO
140 MHz
Switch
Amplifier
TTL

Generating 10 ns Pulses

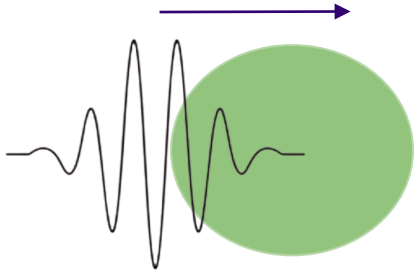
Single Fast Pulse

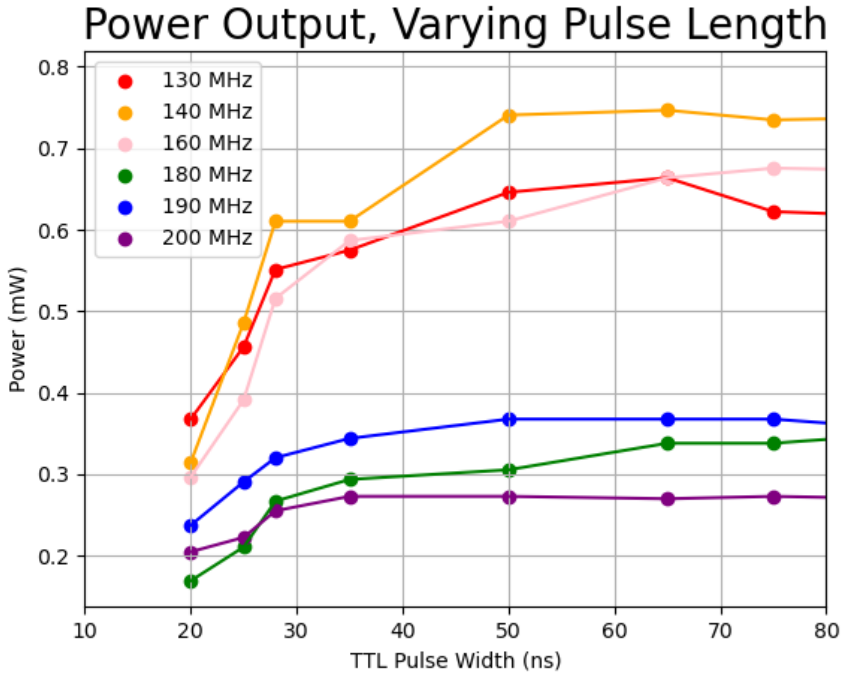


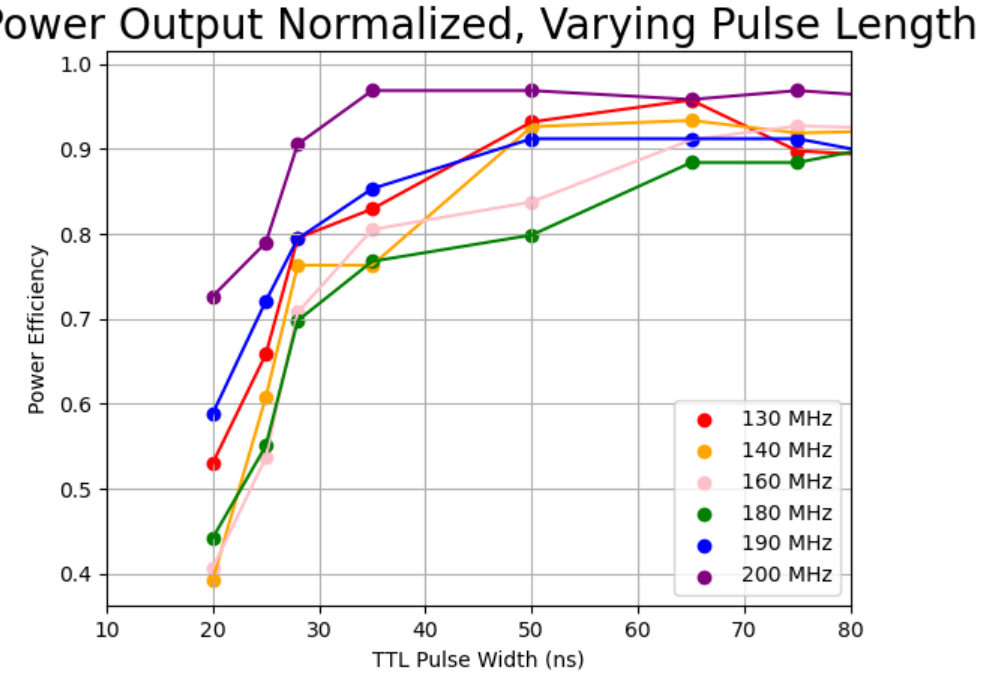
Series of Fast Pulses



Power Efficiency vs Pulse Length

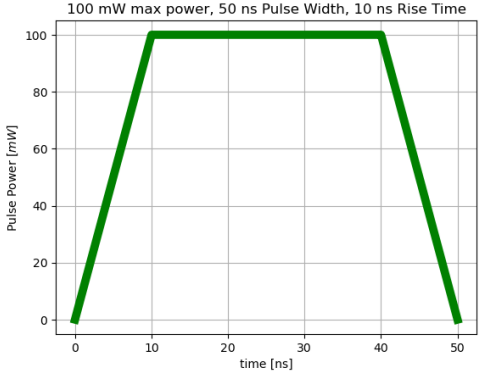




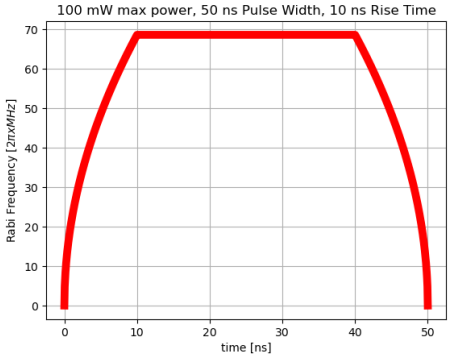


Calculating π-Pulse Length

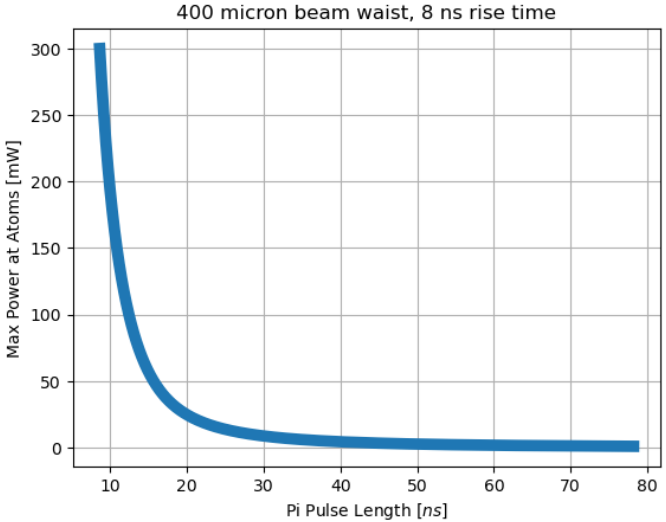
Approximate pulse profile



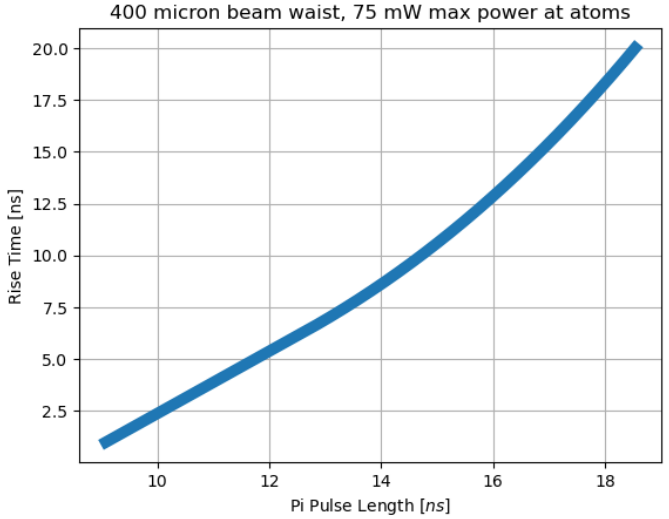
Corresponding Rabi Frequency



π-Pulse Length vs Power



π-Pulse Length vs Rise Time



Outlook

- Successfully demonstrated ~10 ns pulses
- Established power, rise time requirements for ~10 ns π-pulses

- Develop electronics to produce faster rise time, shorter pulses with more tunability
- Test with atoms to determine π-pulse duration, efficiency
- Reproduce with 2nd AOM, perform single-photon LMT clock AI!!

Questions?

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