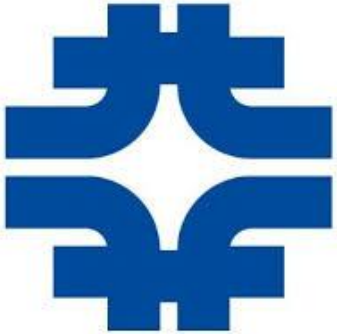
My Experience with Superconducting Quantum Materials and Systems(SQMS) and the VALOR internship

Supervisors: Yao Lu and Ziwen Huang
Intern: John Coddington

About me

- Graduated from Lincoln-Way Central High School in New Lenox, Illinois



- Participating in the VALOR Internship here at Fermilab

- Incoming Freshman at Bradley University for civil engineering

Illinois Accelerator Research Center (IARC)

The Project

Learning goals

- **Schrodinger equation**
- **Pauli Matrices**
- **0, 1, +, and - states**
- **QuTiP**

Project Goal

- **Wave pulse optimization for single Qubit gates**

Basic Quantum Mechanics

$$i\hbar\frac{\partial}{\partial t}|\Psi\rangle = \hat{H}|\Psi\rangle$$

$$|0\rangle = \begin{pmatrix}1\\0\end{pmatrix} \qquad |1\rangle = \begin{pmatrix}0\\1\end{pmatrix}$$

$$\sigma_x = \begin{pmatrix}0 & 1\\1 & 0\end{pmatrix}, \quad \sigma_y = \begin{pmatrix}0 & -i\\i & 0\end{pmatrix}, \quad \sigma_z = \begin{pmatrix}1 & 0\\0 & -1\end{pmatrix}$$

QuTiP

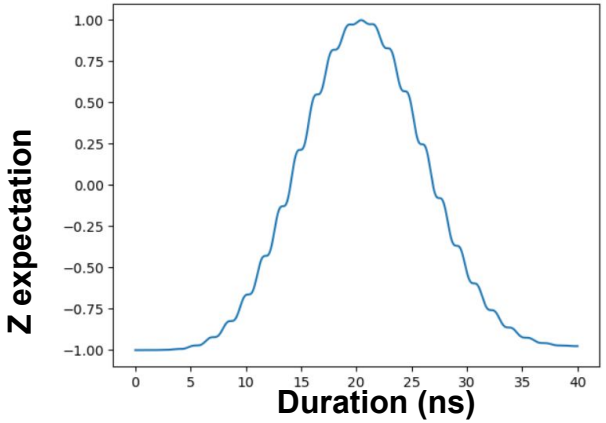
Quantum Toolbox in Python

$$|+\rangle = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle) \qquad |-\rangle = \frac{1}{\sqrt{2}}(|0\rangle - |1\rangle)$$

Rabi Oscillations

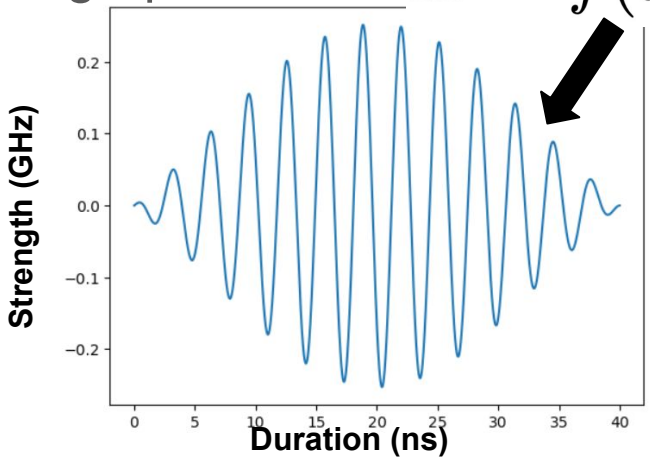
```
t_list = np.linspace(0,40,40001)
t_end = t_list[-1]
t_middle = t_end/2
drive_list = np.exp(-(t_list-t_middle)**2/(0.5*t_end)**2)
drive_list = drive_list-np.amin(drive_list)
drive_list *= np.cos(2.0*t_list) * 0.4
#drive_func = q.Spline(t_list[0], t_list[-1], drive_list)

H = [H0, [sx, drive_list]]
result = q.sesolve(H, psi0, t_list, e_ops = [sx, sy, sz])
```

Rabi oscillation

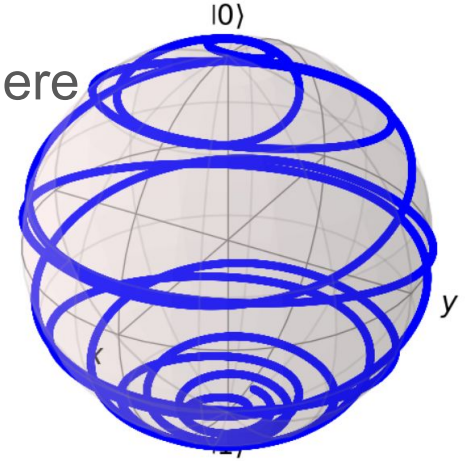


Pulse graph

$$H = f(t)\sigma_x + \omega_q \sigma_z$$

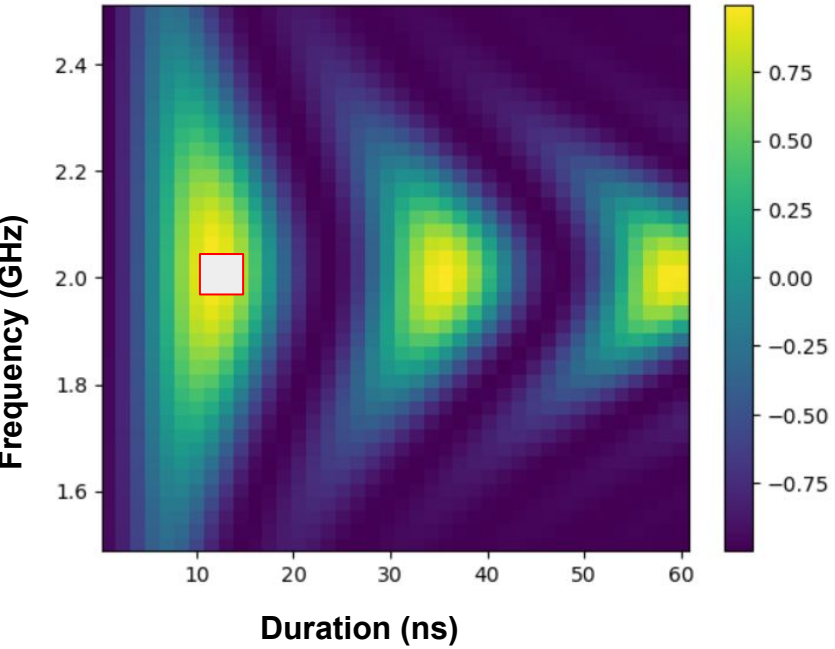


Bloch Sphere



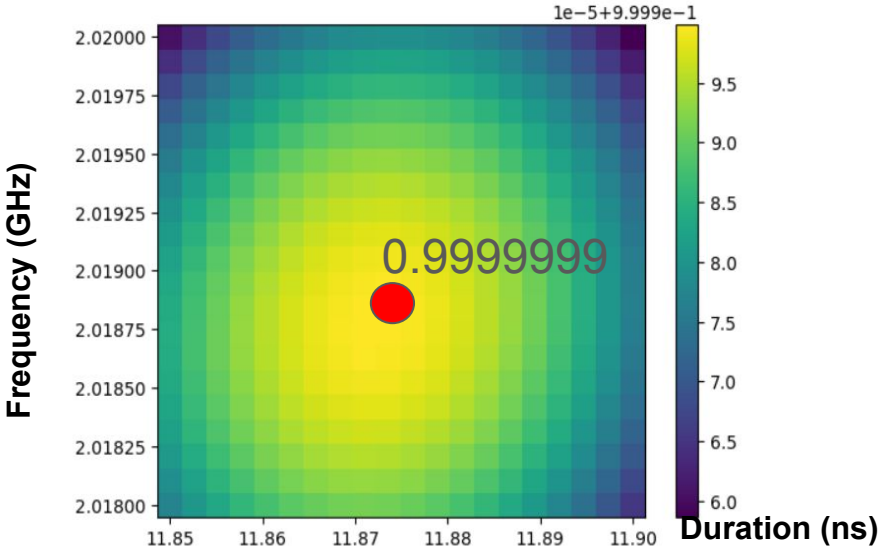
Qubit Plots

Original Plot



Amplitude: 0.7 GHz
Frequency range: 1.5-2.5 GHz
Duration: 59 ns from 1-60 ns

Honed Plot




```
np.amax(result_list)
```

```
(0.9999999161854798+0j)
```

Amplitude: 0.7 GHz
Frequency range: 2.018-2.020 GHz
Duration: 0.05 ns from 11.85-11.90 ns

Summary of Project Work

- Throughout the morning working times I obtained a basic understanding of quantum mechanical ideas such as the Schrodinger equation, Pauli matrices, qubit states, and the use of python programming packages to simulate quantum mechanical interactions.
- Used basic understanding to Engineer the wave pulse to achieve a high fidelity for a state transfer in a qubit through QuTiP simulations

Daily Workshops

A Big Thank you to:

My supervisors

My parents

My teachers in school

The heads of the Valor and Target Programs

And finally everyone here today