A Project Report/Thesis/Dissertation on

***SUSTAINING COHERENCE IN QUANTUM SYSTEMS DESCRIBED BY JAYNES-CUMMINGS HAMILTONIAN USING MEMORY PARAMETERS***

*Submitted for the partial fulfillment of the requirement for the award of the Degree of*

***Bachelor of Science (Honors)***

In

***Chemistry***

by

***Lokesh***

Under the Supervision/Guidance of

***Dr. Manas Ranjan Dash and Dr. Natasha Awasthi***

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**DIT UNIVERSITY, DEHRADUN, INDIA**

May 2024

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**DECLARATION**

This is to certify that the Project / Thesis / Dissertation entitled **“Sustaining Coherence in Quantum Systems described by Jaynes-Cummings Hamiltonian using Memory Parameters**”in partial fulfillment of the requirement for the award of the degree of **Bachelor of Science (Honors)** in **Chemistry** submitted to **DIT University, Dehradun, Uttarakhand, India,** is an authentic record of bona fide work carried out by me, under the supervision /guidance of **Dr. Manas Ranjan Dash** and **Dr. Natasha Awasthi.**

The matter embodied in this Project/Thesis/Dissertation has not been submitted for the award of any other degree or diploma to any University/Institution.

***Signature***

***Name of Candidate: Lokesh***

***Roll No: 211075007***

***Date: 24, May 2024***

***Place: Dehradun***

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**CERTIFICATE**

This is to certify that the Project / Thesis / Dissertation entitled **“Sustaining Coherence in Quantum Systems described by Jaynes-Cummings Hamiltonian using Memory Parameters**”in partial fulfillment of the requirement for the award of the degree of **Bachelor of Science (Honors)** in **Chemistry** submitted to **DIT University, Dehradun, Uttarakhand, India,** is an authentic record of bona fide work carried out by **Mr. Lokesh, Roll No.** – **211075007** under my supervision/ guidance.

***Signature***

***Name of Supervisor: Dr. Manas Ranjan Dash***

***Date: 24, May 2024***

***Place: Dehradun***

***Signature***

***Name of Supervisor: Dr. Natasha Awasthi***

***Date: 24, May 2024***

***Place: Dehradun***

**LIST OF ABBREVIATIONS**

|  |  |
| --- | --- |
| INT | Interaction |
|  |  |

**ACKNOWLEDGEMENT**

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**ABSTRACT**

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**CHAPTER 1 - INTRODUCTION**

* 1. **General**

Quantum computing, at present, is just crawling out of its infancy. The idea of computation using actual quantum systems has been around for a few decades. The inception of this idea starts with Richard Feynman’s suggestion of a *Universal Quantum Simulator*, “if you want to make a simulation of nature, you'd better make it quantum mechanical” (Feynman R. P., 1999).

Numerous advances have been made since then. However, Quantum computers of today are limited by their number of qubits. They are vulnerable to noise and require sophisticated infrastructure to function. This generation of noisy quantum computers, termed as *Noisy Intermediate-Scale Quantum (NISQ)* generation, is far from realizing any practical application of Quantum Computing. (Hassija, Vikas, et al., 2020).

When it comes to the choice of quantum system suitable for the purpose of simulating physics, many candidates like superconducting circuits, trapped ions, quantum dots, optical systems have been developed. Despite the system opted, the errors due to noise is ubiquitous. Broadly, the term *noise* encompasses various factors ranging from interaction with the environment and other qubits to the faults in instrument and measurements (Resch, S., & Karpuzcu, U. R.,2022).

Despite its definition changing with context, *coherence* in quantum systems can be explained as a system maintaining a definite phase relation between different states in a superposition. In layman terms, it is the ability of a quantum system to maintain a quantum state. Noise plays the antagonist here. Interaction of a quantum system with any kind of noise leads to the loss of coherence, termed as *decoherence.* The duration for which a system sustains coherence is coined as *Coherence time.* Longer coherence time is critical to computation as it allows for more complex calculations. Different quantum systems show different coherence time (DiVincenzo, D. P., & Loss, 1999).

Various efforts have been made to sustain coherence for longer durations. Memory channels have shown promise of maintaining coherence and postponing decay of quantum entanglement. (Awasthi, Singh, & Joshi, 2023). My work is one more of such endeavours.

* 1. **Objective**

This study is weaved around discovering the effect of memory channels on optical qubits.

Specifically, the study deals with the evolution of the quantum state of optical qubits under the influence of decoherence channels, with and without memory. The concurrence of our system of study is measured against decoherence parameters and the results with and without memory channels are compared. The comparison demonstrates the resilience of optical qubits with memory channels over memoryless channels.

* 1. **Organization of the Thesis**

The study has been organized into 3 chapters.

Chapter 1- Introduction: The chapter introduces the foundational concepts of the study and the objective that guides it.

Chapter 2- Literature Review: The chapter sheds light on the literature and work published relevant to the motion.

Chapter 3- Methodology:

Chapter 4- Results and Discussion: The results of the study are presented and discussed in this chapter.

Chapter 5- Conclusion and Scope for Future Work: The study is concluded and recommendations for potential future work are discussed in this chapter.

**CHAPTER 2 – LITERATURE REVIEW**

**CHAPTER 4– CONCLUSION AND SCOPE FOR FUTURE WORK**

**REFERENCES**

**BIBLIOGRAPHY**

# Bibliography

Feynman, R. ‘.–4. (n.d.).

Feynman, R. P. (1999). Simulating physics with computers. *International Journal of Theoretical Physics, 21*(6), 133-153. Retrieved 5 23, 2024, from https://link.springer.com/article/10.1007/bf02650179

**APPENDICES**