SURP 2024: Mid Term Report

Note: We are initiating the Mid Term report submissions to gauge the level of development your projects has gone through from the start.

Instructions:

- **Make a copy of this Google Document, complete the necessary fields in the provided form, and have it verified by the professor, including a digital signature.**
- **Download this document as a PDF file (mandatory) and submit it via the designated Google form:**
- **Deadline: 11:59 PM, Thursday, 12th September 2024.**
- **All students pursuing the SURP Project regardless of the Phase-1 submission need to submit the Mid Term report duly signed by the professor for any future incentives/resume verification/ certificates.**
- **In case of any queries, kindly reach out to the EnPoWER Team.**

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TO BE FILLED BY THE STUDENT

Details of student

Name	Jatin Kumar
Roll Number	22B3922
Year of Study	3rd year
Contact number	9837549025

Details of project

Project UID	EE07
Title of project	OLD - Vibration Noise Analysis for Real-Time Health Monitoring of High-Pressure Compressors NEW - GaN as Neutron Detector
Name of professor guide	Prof. Siddhartha P Duttagupta

Progress Update

Project status: On-going	**Percentage completion (if applicable) :**
List the targets achieved in the project so far	
1. Initial Project: Vibration Noise Analysis for Real-Time Health Monitoring of High-Pressure Compressors Originally, my project centered around vibration noise analysis for real-time health monitoring of high-pressure compressors. This involved exploring advanced signal processing techniques and machine learning algorithms for predictive maintenance, focusing on vibration signatures as key indicators of machine health. The project was essential in understanding how machines emit vibrations and how these vibrations can signify faults such as wear, imbalance, and misalignment.	

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Key Areas of Focus:

- **Data Acquisition:** I focused on capturing vibration signals using sensors to monitor the compressor's performance. This data would serve as the foundation for detecting anomalies or potential faults.
- **Signal Processing Techniques:** By applying Fast Fourier Transform (FFT), I aimed to convert the time-domain vibration signals into the frequency domain. This conversion is crucial for identifying specific vibration patterns associated with mechanical issues such as misalignment, imbalance, or wear.
- **Feature Extraction:** I planned to extract meaningful features from the vibration data, such as spectral peaks, bandwidths, and frequency shifts. These features are key indicators of the compressor's operational state, helping distinguish between healthy and faulty conditions.
- **Machine Learning Algorithms:** The goal was to implement machine learning techniques such as Neural Networks, Support Vector Machines (SVM), and Random Forests to classify the compressor's health. These AI-driven models would enhance fault detection accuracy and allow predictive maintenance before critical failures occurred.
- **Predictive Maintenance:** By continuously monitoring the vibration signals, the project aimed to create a predictive system capable of alerting operators to potential failures. This would ensure timely repairs and reduce downtime.

Project Pause and Discussion:

Although this project was promising, its scope proved to be too broad for immediate implementation, especially within the available timeframe. After a thorough discussion with my professor, it became clear that the time and resources required for full implementation were not feasible at this stage. Both my professor and I agreed that transitioning to a more manageable yet equally impactful project would be beneficial.

2. Transition to GaN as a Neutron Detector Project

Following this decision, Sir advised me to shift my focus to a project involving Gallium Nitride (GaN) as a neutron detector. This transition represented a move into an entirely different but equally compelling domain of radiation detection, where GaN's unique properties could offer significant advantages.

Why GaN for Neutron Detection?

GaN is an ideal material for neutron detection due to its:

- **Wide bandgap:** Allowing operation in high-radiation environments without degradation.
- **Radiation hardness:** Making it resilient against radiation damage, which is essential for long-term reliability in harsh conditions.
- **Thermal stability:** Ensuring that it performs effectively in extreme temperatures, such as those found in nuclear reactors and space missions.

Additionally, with the global shortage of Helium-3 (the traditional material used for neutron detection), the development of alternative materials like GaN has become more urgent. The research into GaN-based neutron detectors promises to fill this gap by offering an efficient, reliable solution for detecting neutrons in high-radiation environments.

3. Achievements in the GaN Neutron Detector Project

Since transitioning to this project, I have achieved several critical milestones:

A. Material Selection and Theoretical Foundation

- **Material Identification:** GaN's selection as the neutron detection material was a key step forward. Its ability to function in high-radiation environments with minimal voltage requirements makes it an excellent alternative to traditional gas-based detectors.
- **Theoretical Validation:** I have successfully developed a theoretical framework for GaN-based neutron detectors. The neutron detection mechanism is based on the interaction between neutrons and nitrogen-14 (14N) within the GaN crystal lattice, leading to a (n, p) reaction that emits protons, which are then detected through scintillation.

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B. Enhanced Sensitivity through Neutron Conversion Layers

To enhance the sensitivity of GaN detectors, neutron conversion layers such as Lithium Fluoride (6LiF) and Gadolinium (Gd) have been theoretically incorporated. These layers capture neutrons and emit high-energy alpha particles, which ionize the GaN material, thereby boosting the detection efficiency. This theoretical enhancement aligns with the project's objectives of improving GaN's performance in real-world neutron detection applications.

C. Efficiency Modeling and Performance Predictions

I have developed models to predict neutron detection efficiency (η) and charge collection efficiency (CCE), crucial for evaluating GaN's performance in environments such as nuclear reactors or space missions. These models have laid the groundwork for understanding GaN's response under different neutron flux conditions, providing insights into its potential for wide-scale deployment.

5. Conclusion and Report Attachment

This transition from vibration noise analysis to the GaN neutron detector project has allowed me to make substantial progress in a shorter timeframe, focusing on a material that has both current relevance and future potential. I am attaching the detailed report, which outlines the full scope of my work on GaN-based neutron detection so far, highlighting the key achievements and next steps in the project.

A short summary of the work you have done till now in 7-8 lines

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So far, I initially started with a project on **vibration noise analysis for real-time health monitoring of high-pressure compressors**, focusing on predictive maintenance using signal processing and machine learning. However, due to time constraints, I transitioned to working on **Gallium Nitride (GaN) as a neutron detector** under my professor's guidance. I've since developed a theoretical framework for neutron detection using GaN's wide bandgap and radiation hardness, modeled the neutron interaction mechanisms, and enhanced sensitivity through neutron conversion layers. My work now focuses on optimizing GaN for high-radiation environments like nuclear reactors and space missions.

Add pictures / drive links of the experimental set-up/simulations/literature review texts to support the above, if applicable

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References

1. Zhou, C., et al. (2019). Neutron detection performance of gallium nitride-based semiconductors. Scientific Reports, 9(1), 17551.

2. Mulligan, P., Wang, J., & Cao, L. (2013). Evaluation of freestanding GaN as an alpha and neutron detector. Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment, 708, 7-12.

3. Zhu, Z., Sun, Z., Zou, J., et al. (2020). Fabrication and performance evaluation of GaN thermal neutron detectors with 6LiF conversion layer. Chinese Physics B, 29 (10), 106102.

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Future plan

Estimated time to project completion (if applicable) :	4 Months
Provide a brief month-wise plan of how you plan to meet the above deadline	
Future Directions and Broader Implications While the project has already achieved significant theoretical milestones, there is considerable potential for further exploration: • **Material Optimization:** Future efforts will focus on optimizing GaN fabrication techniques and exploring new doping strategies to improve its detection capabilities. • **Applications in High-Risk Fields:** GaN's ability to withstand extreme conditions makes it ideal for nuclear reactor monitoring, space exploration, and national security applications. The project's future work will delve deeper into these areas, ensuring that GaN detectors can operate effectively in complex radiation environments.	

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TO BE FILLED BY THE PROFESSOR

How has the performance of the student been so far?	Satisfactory
Any comments/suggestions/feedback	
Signature of professor with date	PROFESSOR Department of Electrical Engineering Indian Institute of Technology Bombay Powai Mumbai 400 076