Advances in Nuclear Fusion

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Brief Description

Fusion is the nuclear process that occurs in stars, due to lightweight atoms fusing together releasing a lot of energy. Currently, a lot of research is going on to devise mechanisms to harness this energy on Earth in a controlled manner. The potential advantages of nuclear fusion energy include long-term, sustainable, economic and safe energy source for electricity generation. Fuel is inexpensive and abundant in nature, amount of radioactive waste and greenhouse gases produced are minimal. This project is to gain an understanding of the fundamentals of nuclear fusion and explore some of the research areas currently being worked on.

Progress

This was mostly a reading based project where I learnt the theory behind the nuclear fusion process and reactors. There was minimal coding involved and I read through a lot of material and reviewed them. The project started off with a meet to discuss the logistics of the process where the mentor shared his motivation for floating this project and about his research interests. Since most of us who had applied for this project are interested in core fields, we decided to collect and read papers related to nuclear fusion with our domain of interest, which in my case happens to be materials.

The first two weeks I did some introduction to python programming which involved pandas, matplotlib, seaborn and numpy. During June, I learnt basic particle physics where I studied about the different particles in nature and their types, such as bosons, fermions, leptons, quarks etc. It also involved nuclear reactions using deuterium, tritium and helium which is the most important aspect of this field. After obtaining a basic knowledge of particles, I moved on to read about nuclear fusion reactors and their mechanisms, the major ones being stellarators and tokamaks.

During the last week of June, our mentor sent us two research papers about advances in stellarators and tokamaks. The first paper was based on oscillations in divertors and magnetic islands to enhance plasma detachment to reduce the heat flux on the reactor walls based on a predator-prey model. The second paper was based on the simulation of plasma turbulence in a stellarator. Initially these papers were very difficult to understand, especially since I am from a non-physics background. But I read each of them multiple times after which I was able to grasp the general idea behind the papers and the figures, although I am still unable to understand many of the finer aspects of it.

There weren't a lot of calculations involved per se since I was reviewing these papers which are based on mathematical models. But I made an attempt to analyse the equations and models provided and summarized them in a report, along with a complete summary, plot description, softwares used and questions that I encountered. Throughout the entire duration of the project, my mentor was very supportive and clarified all the doubts I had and provided me with the right resources to understand it better. Due to time constraints, I was unable to complete the optional plotting and the graphene based paper, but I will be taking it up again later.

Results

GitHub Repository: https://github.com/Hiranmai02/SoC-Advances-in-Nuclear-Fusion
Reports and Notes: Nuclear Fusion Notes Report 1 Report 2
Fusion Survey: Fusion survey
Final Presentation Slides: SoC - Nuclear Fusion
Final Presentation Video: Video Link
Code Explanation: Video Link

Learning Value

I'm an undergraduate in the material science department, interested in pursuing core materials research. This project was extremely helpful in understanding a specific aspect, nuclear materials and their development. It helped me learn in a condensed way, the fundamentals of nuclear fusion and the importance of selecting the right materials for them along with the working of nuclear fusion reactors. My mentor is quite experienced in this field, given that nuclear fusion is one of his main research interests, he clarified my doubts as and when I came across any questions or parts that I couldn't understand. Being from a non-physics background, it was difficult for me to understand many of the intricate details, for which I did not have the prerequisite knowledge. Overall, I gained a generic perspective of the field itself and the resources and pointers to continue learning even after the completion of this project.

Software used

Python - Google Colab

Suggestions for others

I would suggest you to begin from the fundamentals, especially if you belong to a non-physics background. Understanding the working of stellarators and tokamaks felt especially difficult for me because I started directly from a research paper. Possibly, starting from a textbook might help you get a better understanding. Read research papers multiple times and go into the details after you get the basic idea behind the paper and the procedure that they have followed. Spread out the learning evenly, instead of cramming everything in a day. If possible read the references of the papers for more detail. Practice plotting graphs and understanding the equations and data used.

References and Citations

Papers

1. *Self-Sustained Divertor Oscillation Driven by Magnetic Island Dynamics in Torus Plasma T. Kobayashi, M. Kobayashi, Y. Narushima, Y. Suzuki, K. Y. Watanabe, K. Mukai, and Y. Hayashi Phys. Rev. Lett. 128, 085001 – Published 23 February 2022*
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2. *Global fluid simulation of plasma turbulence in a stellarator with an island divertor*
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   Nuclear Fusion, Volume 62, Number 7
   DOI: https://doi.org/10.1088/1741-4326/ac6ad2
3. *Robustness of large-area suspended graphene under interaction with intense laser*
   Y. Kuramitsu1, T. Minami, T. Hihara, K. Sakai, T. Nishimoto, S. Isayama, Y.T. Liao et al.
   Scientific Reports volume 12, Article number: 2346 (2022)
   DOI: https://doi.org/10.1038/s41598-022-06055-4

Code

1. Matplotlib - Corey Schafer
2. Seaborn - Edureka

Other Resources

1. Particle Physics - University of Geneva, Coursera
2. Fusion and Plasma Physics - MIT OCW

Disclaimer

Fair Use Disclaimer: I practiced codes from Corey Schafer's Matplotlib videos and Edureka's seaborn video. I typed out the code while watching the video. I have attached the video links under references.

Copyright Disclaimer: I have not used the code for commercial purposes, only for self-practice.

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https://github.com/CoreyMSchafer/code_snippets/tree/master/Python/Matplotlib

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