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Optimising the Performance of MAX IV: Everything Evolves...

Since the dawn of time, we humans have been drawn heavily to light, which enabled us to observe our environment. Our profound curiosity in understanding the universe we live in set us apart from other living creatures and resulted in beautiful endeavours such as science, arts and religion. Over time, we have realized that there are things in nature that are either too small or too far away to be observed with the naked eye. So, began a long-lasting search for tools to observe the delicate details of our universe. The first ever microscope was invented around 1600 by Zacharias Janssen, and since then, the research tools have come a long way. Nowadays, large-scale particle accelerators are used for conducting research. Essentially, these are bigger microscopes that allow us to see even smaller things.

MAX IV is a particle accelerator located in a modest town in the South of Sweden, and it is one of the brightest light sources we have in the world at the moment. This facility attracts 1700 users annually, a number which is only expected to rise in the following years. In MAX IV, there is a linear accelerator, which accelerates electrons to near the speed of light and then injects them into the two electron storage rings, the smaller one called R1 and the bigger ring called R3. As you may guess, these storage rings are circular structures, kind of like massive doughnuts that cost millions to build. The path of injected electrons is bent by powerful magnets, causing them to shoot out X-rays. Researchers from all around the world make a worthy trip to MAX IV to use high-quality X-ray light for practices such as X-ray spectroscopy, scattering & diffraction, and imaging techniques.

The different types and strengths of magnets work in harmony in the electron storage rings. Dipole magnets bend the electrons through the curved structure of the electron storage ring meanwhile, the quadruple magnets squeeze the electrons together, ensuring a well-confined stream of electrons. Sextupole magnets play a crucial role in correcting for the imperfections caused by the other magnets in the ring. It is almost like tuning a guitar, a delicate business that can enhance the performance of the electron storage ring.

The performance of an electron storage ring can be measured by the lifetime of the electrons circulating in the ring and the electron injection efficiency. The former measures how long the electrons can survive in the ring, while the latter compares the amount of electrons that made it into the ring during injection to the amount of electrons that tried to get in. If we imagine the electron storage ring as a roundabout, the lifetime tells us how long the cars spend in the roundabout, whereas the injection efficiency tells us how fast and efficiently we can welcome new cars into the roundabout.

In this project, we are using a genetic algorithm written in Python language, to find the optimal current configurations of the sextupole magnets in order to optimise the lifetime and the injection efficiency of the small electron storage ring, R1. The algorithm will attempt different configurations of sextupole magnets and select the best-performing options. This process is similar to natural selection in nature, where only the strongest survive as the generations evolve. The optimisation process will directly benefit the users of the machine and their studies. This will then indirectly help the general public since the scientific discoveries will speed up the invention and design of new tools and gears. Moreover, if the optimisation process is successful and replicable, this process can also be utilised in other facilities worldwide.

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