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Prospects for an X-ray Laser at MAX IV

The research field of lasers is an incredibly exciting one. If nothing else, this becomes apparent when one looks at the Nobel prizes in physics from recent years, of which several were awarded for improvements to laser technology. These advancements have created entirely new fields of research, like the attosecond research which allows scientists to view the movement of electrons inside the atom, which was awarded the Nobel prize this year. More than that, lasers are used for many things, from measuring distances and mapping out cities to creating miniature stars by igniting fusion in balls of hydrogen.

Bearing all these amazing applications in mind, we will now consider how one can advance laser technology even further. Lasers create light by making electrons in atoms lose energy and create a photon in the process. By a method called stimulated emission, these photons cause other electrons to emit photons in phase with each other.

One of the remaining limitations with lasers is that the wavelength of the laser cannot be arbitrarily shortened. Shorter wavelength corresponds to the laser photons having higher energy, which in a traditional laser would require that the electrons had higher energies in the atoms. A short wavelength laser would have several interesting new properties. One of the most interesting types of short wavelength light is X-rays. These are well-known for their many uses in medical applications, but they are also highly interesting in various scientific measurements. For instance, the storage ring at MAX IV in Lund generates high intensity X-ray beams which enable scientists to look inside objects and materials to better understand them.

If we bring these two interesting concepts together, we get an X-ray laser, which combines the useful research properties of both lasers and X-rays. As mentioned before though, it is not entirely easy to make an X-ray laser. The problem is that electrons in atoms cannot have high enough energies to create photons with X-ray energies. If they had that much energy, they would simply fly away from the atom, so they cannot create any laser light.

In order to reach the energies required for creating X-rays, particle accelerators are used. By accelerating electrons to nearly the speed of light, and then letting them create photons by making them move in a zig-zag motion, the created light will be X-rays. In order to get laser light however, one must control this process carefully so that all the light is in phase.

A machine that does this is called a Free Electron Laser (FEL), and a few such machines already exist. Given the capabilities of these, the interest in FELs is large in both academia and industry. Therefore, having one in Lund would be very useful. The purpose of my project is to see if one could implement an FEL using the existing equipment at MAX IV, which would be a cheap way of improving the capabilities of the facility. To test this, I used parameters from the beamline FemtoMAX at MAX IV to simulate the FEL. By changing some things about the electrons from the accelerator, the radiation from the FEL would also change. By analysing these changes, I could find the optimal settings for the FEL, and see if it was possible to implement an X-ray laser at MAX IV.

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