To control light at the smallest timescales

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Did you know that we could fit more attosecond laser pulses in a single second than there have been seconds in the entire history of our universe? An attosecond is an extremely small unit of time, opening the door to probing impossibly fast things. With this technology, we can actually detect the movement of electrons. Because electrons form the chemical bonds that drive biological processes and power our electronics, catching them in motion means we can literally watch chemistry happen live.

To be able to apply these pulses in precise and varied ways, we want to be able to control the different features of such pulses. Imagine the pulse being a band of soldiers marching forward. Intuitively, the way these soldiers will be moving forwards will depend on the terrain they are moving through. Rocky terrain might force them to split up, shift into a chaotic formation and walk out-of-sync, while open fields let them walk in straight lines. This is exactly how ultrashort laser pulses are affected when propagating through materials like glass or crystals. The shape of the laser pulse is directly correlated to what material, and how much of it, it has passed through.

In my project I utilize a device called a birefringent delay device for interferometry, which essentially splits the soldiers into two groups and later recombines them back into one group. In physics, we often split a pulse so one half can interact with a sample while the other half bypasses it. By recombining them and comparing the two groups of "soldiers", we can see exactly what changed during the "march". The aim of my thesis is to outline whether or not it is possible to make a birefringent delay device that, while the soldiers are split up, the two lines have the same step rate. In physics terms, this "step rate" would be called the carrier-envelope phase (CEP), and keeping it locked in between the two groups is exactly what my thesis aims to achieve.

And, why is this relevant? Well, being able to control the relative CEP of laser pulses and keeping it constant allows for more precise control of how it will affect the research targets of the pulses. This allows for better understanding of how the pulses affect electrons and a deeper understanding of how light interacts with matter at the highest intensities and energies. This, in turn, can have implications for the medical field for greater control of targeting cancers in the body. For example, perhaps understanding exactly how high-energy light destroys the chemical bonds in DNA, we can better target radiation therapy. Furthermore, these technologies can give us the power to move electrons with incredible precision and opens the door for ultra precise cutting and manufacturing. By being able to precisely dictate the marching rhythm of the pulses we can not just observe the microscopic, but also be able do direct it as needed for a plethora of applications.