Popular Science Summary

Going beyond the speed of light, undistorted and unattenuated!

The speed of light is absolute, and nothing can exceed it. Or can something? Light pulses travel at their group velocity. This is the velocity at which envelope of the pulse travels. In vacuum all frequencies travel at the same velocity, but in a material there can be a frequency dependence. This is called dispersion and causes some frequency components to travel slower than others, this results in the pulses spreading out in time. Dispersion can be a real issue, for example in telecommunication where pulses travel in fibres and where it is desired to keep the pulse length as short as possible. But for other applications dispersion can be extremely useful. For example for laser stabilisation and for making pulses peaks travel faster than the speed of light! The latter is the subject of this thesis, where we attempted and succeeded in attaining this so called ‘fast light’.

Naturally the laws of physics cannot be violated, and as it turns out pulse peak that travels faster than the speed of light does not break said laws. As a matter of fact the statement “nothing can travel faster than the speed of light in vacuum” is a bit incorrect. One should rather say: no information can travel faster than the speed of light in vacuum. This is a little unfortunate with regards to information transfer, since the ‘fast light’ cannot transfer information and hence it cannot be used for faster data transfer. This has to do with how information is defined, which is a little beyond the scope of this summary, but the physics are fascinating nonetheless!

To actually achieve fast light one can turn to a couple of different methods, but most suffer from one or more drawbacks. Fast light pulses can be attenuated or distorted or have rather minor advancement with respect to their duration.

The method used in this project does not have any of these problems and has a large advancement. This method in broad terms, works as follows, we start out with a crystal that contains the element ‘Europium’. These atoms absorb light at a range of frequencies, and this absorption can be manipulated. But for that to work the crystal must be cooled down. It is put in a cryostat and cooled to only a few Kelvin. At this temperature one can create so called ‘spectral windows’ and ‘spectral structures’ within the range at which the atoms absorb light. A spectral window means that there is a range of frequencies where there is no absorption, surrounded by frequencies where there is absorption. A spectral structure is made by accumulating absorption at certain frequencies. By creating these structures and spectral windows in a smart way we can change the dispersion properties and slow down the light pulses. This structure that is created is a set of strongly absorbing frequency ranges with a narrow transparent region in between them. This is the opposite effect of what we wanted, but that can be changed by some turning the accumulated spectral structure from absorbing to amplifying. This is achieved by exciting the atoms from their ground state to their excited state. This project showed that it is possible to achieve the strong fast light effect without the drawbacks of other methods.