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Shaping Light

What happens after light is absorbed by matter? Finding answers to this seemingly simple (but in fact very difficult) question is of central importance in many research areas, for example in the study of photosynthesis and the development of new solar cell materials. When matter is excited by light, a whole cascade of extremely fast processes can be triggered, often taking place within less than a trillionth of a second. A routinely used tool in the scientist's toolbox for following these events are short bursts of laser light. By shooting sequences of these laser pulses at their sample, researchers can monitor the processes following light absorption in a stroboscope-like manner. In this project, a device for reshaping single laser pulses into such pulse sequences has been implemented, calibrated and tested.

Lasers are capable of producing bursts of laser light as short as a few femtoseconds (1 femtosecond = 0.000000000000001 seconds), which can be seen as small packets of light racing through space. An important property of such short laser pulses is their shape (the way the intensity and characteristics of light develop over the pulse duration) which can strongly affect how the laser pulse interacts with matter. Exploiting this, researchers can use specifically tailored laser pulses to control the behaviour of single molecules and tiny metal structures only tens of nanometres[1] in size.

But how is it possible to shape a laser pulse? Just as a musical chord consists of several notes, a laser pulse can be seen as the superposition of many light waves with different wavelengths, referred to as the *spectral components* of the pulse. This is illustrated in figure 1 showing a beam of laser pulses after the spectral components have been spread out. The key point is that the shape of a laser pulse is completely determined by the intensity of these light waves and the way they are shifted with respect to each other. This means that the shape of a pulse can be changed by manipulating its spectral components, and this is exactly how researchers mould laser pulses according to their needs. In a typical experimental setup for pulse shaping, the spectral components of a pulse are spatially separated (using for example a prism) and manipulated individually. Subsequently, they are recombined to form the (shaped) output pulse.

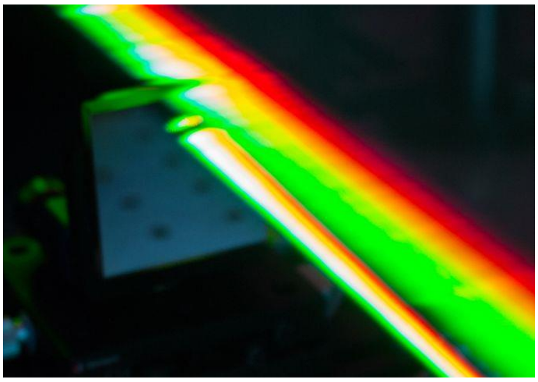

Figure 1: Spreading out the spectral components of short laser pulses makes it clear that the pulses contain light of different colors.

One way to manipulate the spectral components is to send them through a liquid crystal light modulator. This device is a transparent liquid crystal display subdivided into many pixels whose optical properties can be regulated by applying a voltage.

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[1] One nanometer (nm) is a billionth of a meter

This can be used to manipulate the spectral components travelling through these pixels in a controlled way. In this work, a pulse shaper based on such a liquid crystal light modulator is presented. An important part of the project was the calibration of the device: which spectral component passes through which pixel and how exactly the light is affected by the liquid crystal pixels is not known beforehand and needs to be determined experimentally. By performing a number of simple pulse shaping experiments, we could show that the device could be calibrated successfully, meaning that we are now able to manipulate the shape of laser pulses in a controlled way.

The pulse shaper implemented in the context of this project is not only intended for modifying the shape of single laser pulses, but also for reshaping single pulses into multi-pulse sequences. After all, splitting a single pulse into several sub-pulses can simply be seen as a rather complex change in the pulse’s shape. As mentioned in the very beginning, these pulse sequences can be used to interrogate molecules and follow ultrafast processes taking place within only tens or hundreds of femtoseconds after light is absorbed. So far, we could not demonstrate the generation of such pulse sequences. Nonetheless, the implementation and calibration of the pulse shaper is an important step towards using specifically sculptured bursts of laser light to illuminate the events that unfold after light is absorbed by matter.

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Master’s project in physics 60 hp 2016
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