Manipulating Lasers

A laser is a very special kind of light. For example, light from a laser is emitted in only one direction, in contrast to other sources, such as incandescent bulbs, in which different directions occur. Lasers can contain one or different colors combined, like sun light. It can even contain ones that you can not see!

There are many applications for lasers, many of which you are familiar with. For example, we use them to read CD's and DVD's, and in medicine, they are used as scalpels. But, not everything is already known about lasers. There are many possible future applications! Some of these require manipulating the relative movement between light of different colors. That's what I do. For this, we need to separate the laser in its components, then retard or advance a color with respect to the others, and finally to combine the colors again. This manipulation is very powerful, and is leading to new exciting applications of lasers.

-Yves Paul Coello

Control of amplitude and phase of ultra-broadband laser and CARS imaging

The ultimate goal of this project is to teach our laser how to detect and even cure cancers and other diseases. Many diseases such as cancer were associated to some chemical (for example, proteins) changes in the cell. By detecting those chemicals, we can diagnose the related diseases and image the abnormal cells or tissues. By changing some characteristics of the laser, we can teach laser how to distinguish target chemicals or proteins from others so that the laser can image the tissues and tell us which cells are not healthy. Furthermore, we can tell the laser to react with some chemical in the unhealthy cells and kill them with other cells intact. The characteristics we change are the amplitude and phase of the laser.

-Bingwei Xu

Dual Fluorescence Project

We are currently using our shaped femtosecond laser pulses to excite molecules such as DMABN and HPTS in order to observe their dual fluorescence. In each case, the excited state molecule can be involved in a charge transfer (intramolecular or solvent-mediated), which is accompanied by an intersystem crossing and a shift in the fluorescence wavelength. We are investigating the effects of spectral phase shaping on the population ratio between the two excited states. Charge transfer states are typically proposed for optical switches, and are usually involved in the conversion of photon energy to electricity. Our project aims to determine if pulse shaping is capable of manipulating the yield of charge transfer that results from single and multiphotonic excitation.

-Christine Kalcic

Optimization of results

In our lab, we work with laser pulses of femtosecond duration: 10-15 seconds long. Unlike normal laser light, femtosecond pulses cover a range of wavelengths (colors). We can shape a pulse by choosing when different wavelengths arrive – like choosing when the notes arrive in a song. In my research, I look for ways to intelligently choose laser pulse shapes that optimize some outcome, where this outcome can be anything from selectively breaking or exciting a molecule to producing fluorescence in tumor cells.

-Janelle Shane

Silver Nanoparticles

My project involves controlling the transfer of energy from one place to another, several microns away, through small particles of silver in a fractal arrangement. We are working at understanding how the orientation and phase of incoming light affects precisely where the energy is transferred. Understanding and controlling this effect will allow growth of the field of plasmonics, which bridges optics and electronics, and will allow further miniaturization of electronic devices, such as computer chips.

-Jess Gunn

Molecular Separations

Many biological molecules exist in two versions that are related to each other in the same way as a right and left hand. In the laboratory, it is usually very difficult to prepare a specific single-handed molecule because equal amounts of both right-handed and left-handed forms are normally produced. Since handedness is involved in biological activity, the use of drugs that are not entirely single-handed can be dangerous, hence the requirement to prepare pure single-handed drugs. In response to this challenge, my research aims to identify molecules by creating an environment where specially prepared light pulses break up a right-handed molecule in one way, and a left-handed molecule in a different way. The information gathered from this response could be used as a tool for optical discrimination between such molecules.

-Johanna M. Dela Cruz

Biomedical Imaging

This project involves developing a medical imaging technique that is non-invasive and non-destructive. Using different types of low power laser pulses we are able to obtain images of the same spot on a sample that show different detail in the sample. By compiling these images we obtain a final image that has much better contrast and resolution. Further manipulations of the images via mathematical software will result in even better resolution images. The ability to obtain high quality images of biological specimens in a non-invasive and non-destructive way has immediate applications to the medical field.

-Lindsay Weisel

Energy Transfer with Silver

My research uses a femtosecond laser, a microscope, a camera and a computer to gain information about energy transfer within a silver sample. The sample has very small dimensions, on the order of a millionth of an inch, and the individual silver particles are connected to each other in a framework that allows the energy from the laser to travel around within the sample. We need the microscope so that when we watch this energy transfer with the camera, which looks through the microscope, we are able to see the sample, since the framework is so small. Since this method of energy transfer is faster and more efficient, and the pieces smaller than in current electronics, such as computers, this technology may, in the future, be a better option for communication between electronic devices.

-Mindi Ewald

Warfare Detection

The use of improvised explosive devices (IEDs) has dramatically increased in recent years throughout the world. These devices can be designed to take numerous shapes and sizes and detonate remotely. Current methods for the detection of such devices are often dangerous as one must be near the target of interest to accurately determine the danger of the device. It is for these reasons that methods for standoff detection from a significant range are being examined, through the use of eye-safe, ultra fast lasers.

-Paul J. Wrzesinski

Multi-Photon Imaging

Multi-Photon Excitation (MPE) imaging has been successfully applied in biological microscopy with sub-picosecond (~100fs) pulse duration. Shorter pulse (~10fs) can generate higher nonlinear effect and thus is preferable in MPE imaging. However, due to the high-order dispersion generated by the optical media, the femtosecond pulse can be severely distorted. It is therefore of great importance to measure and control the pulse in biological microscopy. By using nonlinear phase scanning, MIIPS can accurately generate specific pulse phase at the destination spot. This gives us the possibility to study on the effect of electromagnetic field of the femtosecond pulse to the biological sample. For example, high localized focal spot, low photobleaching rate, and selective excitation are all proved to be effective with the control of the ultrashort pulse. This work will open a new area of femtosecond pulse application on biomedical optical microscopy.

-Peng Xi

Biomedical Imaging

In this project we are looking at various biological tissues under a microscope and with the laser. The laser gives us an image of the tissue, and depending on the way we manipulate the pulse of the laser we get different areas of the tissue sample to give off more light (selective fluorescence). The laser hits all of the sample, but only certain parts that we selectively choose light up. The ability to choose which parts of a tissue give off more light has possible applications in cancer research as well as helping further non-invasive research and detection. This is because the chemical makeup of cancer cells is different than the tissues around it. We can take advantage of this and use the laser to selectively excite the different chemicals.

-Bekah Martin

Mass Spectrometry
We are using a state-of-the-art laser that gives very short laser pulses (flashes) that have different colors included in it to differentiate very similar compounds in a very short period of time. In order to do this, we manipulate laser beam using a special apparatus that can change how different colors arrive to the sample relative to one another. This way we can manipulate the laser-matter interaction and causes chemical compounds to breaks apart differently and the patterns of different pieces help us to identify chemical compounds that otherwise extremely difficult.

-Tissa Gunaratne

Mass Spectrometry
In our group,we are trying to use ultrafast laser pulses plus another very powerful tool (Mass spectrometry) to identify molecules and understand intense laser-molecule interaction. By changing the time that photons with different wavelengths arrive at sample, pulses with the same intensity can break molecules in different ways. By comparing the patterns of the fragments, we are able to distinguish different molecules, even for some very similar ones such as isomers. The next step, which is really challenging, is identifying enantiomers. Obviously, if we achieve this goal, it will be significant in many areas.

-Xin Zhu

Using Air to Characterize Laser Pulses
A traveling light wave can be characterized by its amplitude, frequency, and phase. The amplitude is related to its intensity, the frequency tells its color, and the phase tells information about the speed of travel for each color in a medium. For high light intensities, matter responds to light in a nonlinear fashion, typically moving energy from one color to another, revealing vital information about the medium. The spectral phase of these high intensity light pulses determines the efficiency of these nonlinear effects. Therefore, characterization of the spectral phase of a laser pulse becomes paramount. We have discovered a novel method to characterize and compensate the spectral phase of a laser pulse that utilizes third harmonic generation in air, removing the need for costly and restrictive nonlinear crystals previously required for such a measurement.

-D. Ahmasi Harris