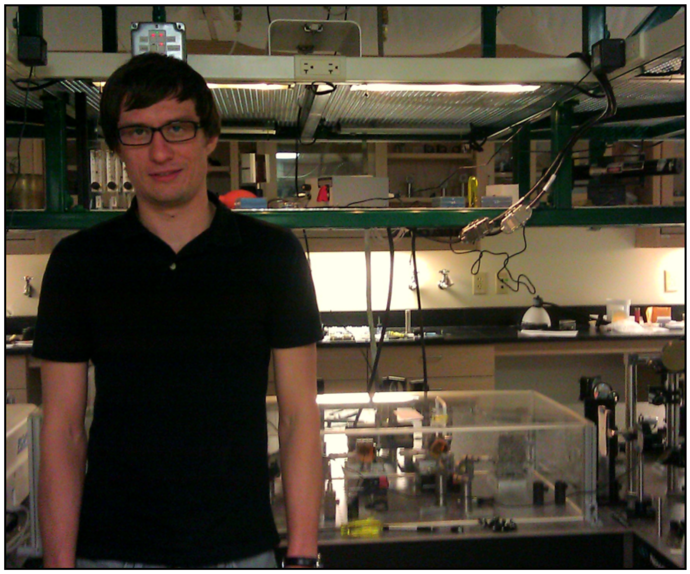
Demystifying Properties of Water with Lasers

By Neelam Phalke, Freshman Majoring in Biochemistry

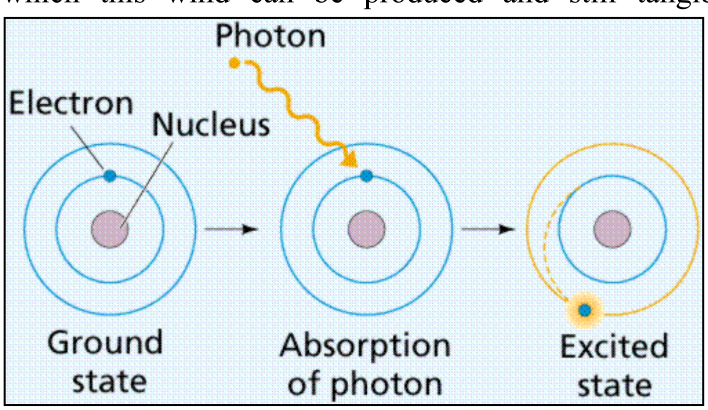


Misha Vinyakin, a second year graduate student at USC, stands by the laser he is working on in a lab on the sixth floor of Seaver Science Center.

Mikhail Vinyakin is a second year graduate student at the University of Southern California. Known around campus as Misha, he is currently a PhD candidate in Nonlinear Ultrafast Spectroscopy, a specialty in Physical Chemistry. Born in Siberia, Misha has always held a keen interest for the sciences, especially Physics. Later in life, his family moved to St. Petersburg where Misha completed his undergraduate studies in Physics at St. Petersburg University. For him, the appeal of Physics was the subject's ability to be applied to real world scenarios that can be experimented upon and researched.

In fact, while studying at St. Petersburg, Misha also took part in research on Ionic Wind. At the age of 19, his name was published in conjunction with those of other scientists on an international publication titled: "Computer Simulation of Corona Discharge: Experimental Investigation of Ionic Wind." The paper was presented at a conference in Malaysia.

Ionic wind functions similarly to electrons which emit light when dropping from orbitals of higher energies back to their ground state. Electrons that have been entirely disengaged from the atom and have excited a nearby atom will emit a wind as they drop back down to their ground states—ionic wind. The surface on which this wind can be produced and still tangibly felt may be as small as the tip of the needle!



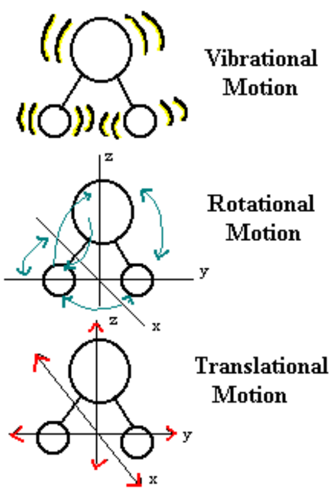
An excited electron absorbs a photon (particle of light energy) causing it to jump up to the next orbital, away from the nucleus. As the electron releases energy to return back to its more stable, original position near the nucleus (the ground state), the photon is released and a vivid light is emitted.

From: *http://www.emc.maricopa.edu/faculty/farabee/biobk/BioBookCHEM1.html*

By relating this topic to windmill power, the immediate conclusion may be that such ionic wind could serve as a potential energy source. However, this is not the case as ionic wind is an extremely inefficient source of energy, as the excitation of electrons requires a high voltage of electricity to be passed through the tip of the needle**.** On the other hand, ionic wind, because it requires such a small surface, has the potential to replace bulky laptop fans in the future.

Enthralled by his studies of Physics, Misha was certain he wanted to continue pursuing the subject after graduation from St. Petersburg. An advertisement from USC at St. Petersburg called for students who desired to continue their educational pursuits and conduct research in beautiful Los Angeles, California. Jumping at the opportunity a year and a half before he would even graduate, Misha applied to USC and was called on to work in a lab studying superfluid helium. However, the research did not appeal to his interests, although it did help him familiarize himself with a different school and environment and assimilate into a widely different country. After a semester of research, Misha made the difficult decision to switch to working under a different professor, Dr. Alex Benderskii, who studies the molecular interfaces of liquids using vibrational spectroscopy.

Research



http://www.landfood.ubc.ca/courses/fnh/301/water/wprin.htm

Spectroscopy is the study of the passage of light through a substance and the analysis of how the light is absorbed and transmitted by the particles of matter.[1] The light that allows us to see colors and objects is the light that is transmitted by those objects. The absorption and transmission of light by matter can be studied in relation to energy, composition of matter, rate of chemical reactions, and molecular structures of the substance.

All particles have three types of motion: vibrational, rotational, and translational[2]. Translational energy is the energy of a molecule's movement through space. Rotational energy is the energy of a molecule's movement about its center of mass. Vibrational energy, the energy that Misha's work studies, is the energy of the stretching of bonds of a molecule.

Misha uses ultrafast spectroscopy to study the surface of water and measure the vibrational energies of the O—H bonds in water molecules. Thus, the purpose of his study is to understand the fundamental motion of water molecules at the surface of liquid water. Eventually Misha and his colleagues in Dr. Benderskii's lab will be able to model the surface of water, and apply the technology to other liquid surfaces.

Specifically, he will study the gas/liquid interface of water molecules and the time scale for the reorientation of water molecules. The surface of any liquid, especially water, is always changing. At the surface there exists an equilibrium between molecules in the gaseous state and liquid state, and the molecules are always changing between the two states. This explains why when you open a half empty water bottle that has been standing for a while, you hear a small "whoosh" as gas particles rush out of the small opening.

Misha is currently working on a laser that will be used to energize the molecules at the surface of the water. The laser is a complicated system that they are slowly building, developing, and perfecting. It requires a special table that uses nitrogen gas to maintain a perfectly level surface such that the laser beam does not deviate from a specifically delineated path that begins with the splitting of the original laser beam into four lasers.

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[1] *http://www.britannica.com/EBchecked/topic/558901/ spectroscopy*
[2] Oxtoby, Gillis, and Campion – *Principles of Modern Chemistry*

Then, a series of mirrors are used to bounce the laser around in order to cause a measurable time delay before the laser makes contact with the substance being studied (in this case, water). Should the surface on which the laser rests not be perfectly level, the angle at which the laser beam hits the mirror could cause it to reflect off the mirror in the wrong direction, throwing off the entire experiment in a potentially dangerous manner.

Dr. Benderskii's lab has two such lasers, each housed in a separate room. Neither laser is fully functional, yet. Misha said he hopes that the laser will be ready for experimental trial in a month. However, it could easily require much more time to prepare the lasers.

While working with the laser, Misha also does plenty of theoretical research using other models that he has derived for the surfaces of other substances such as propanoic acid, which he said is much easier to analyze than the complex and always changing bonds of water molecules.[3] The "dephasing time" (time in which the molecules change from gaseous to liquid state and back) is fast for propanoic acid, making it easy to analyze and a great system on which the laser can be tested and checked.

The experiment was inspired by similar research conducted at the University of California, Berkeley on bulk water. However, bulk water does not necessarily have the same properties as just water molecules on the surface. The researchers at Berkeley, at the time, did not have access to the lasers that Misha is working with to conduct more specific research on the surface of water. Other than simple inspiration, the experiments to be conducted are unique and original, according to Misha. The results could potentially be breakthrough in Physics!

Once Misha and his colleagues have perfected the lasers and they are fully functional, modeling and understanding the molecular surface of water will have several implications for the world of science, especially for the world of Biology and the study of the plasma membrane.[4] Since plasma membranes have an internal

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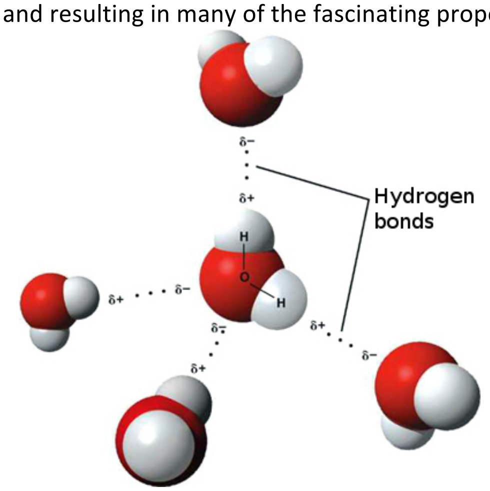
[3] A water molecule is composed of two hydrogen atoms covalently bonded to a single oxygen molecule—meaning the electrons of the hydrogen atoms and oxygen atom are shared. However, oxygen is more electronegative that hydrogen meaning it has a greater affinity for electrons, and pulls the share electrons closer to itself. Since electrons are negatively charge, this gives oxygen a slight negative charge (-δ) and the hydrogen atoms a slight positive charge (+δ). In the basic terms of opposites attract, the negative oxygen ends of one water molecule are attracted to a positive hydrogen end of another molecule forming a temporary bond. These temporary bonds, called hydrogen bonds, are constantly being formed and broken **as the molecules** (don't think this is needed?), giving water a complex molecular structure and resulting in many of the fascinating properties of water.



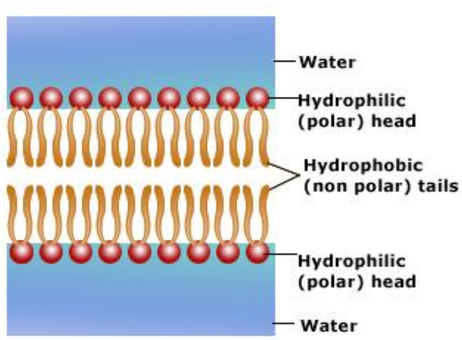
http://thestephenation.blogspot.com/2009/09/hydrogen-bonding.html region that is hydrophobic (will repel water), water molecules require a special path to enter cells. Moreover, this will aid the study of cellular transport in and out of the plasma membrane of molecules of substances other than water, as well.

Misha's research work with spectroscopy may continue for years to come; however, he hopes to gain a job in the Physical Chemistry industry when he graduates. On the other hand, he may choose to continue his research as a postdoctoral student and eventually become a professor of Physics or Physical Chemistry.

References:

[1] http://chem.usc.edu/faculty/Benderskii.html

[4] A plasma membrane is a cellular membrane made of molecules called phospholipids which are special for their hydrophobic (repellant of water) and hydrophilic (attracted to water) regions. The ability of the phospholipids to move and rotate allows plasma membranes to have a notable fluid (rather than rigid) consistency. However, their hydrophobic regions prevent the easy intake or removal of water by the cell



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