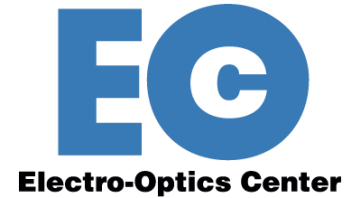


PENNSSTATE



Adventures in Engineering: Lasers and Mechatronics

**Robert Morris University
The Penn State Electro-Optics Center**

**15 November 2014
Westinghouse Science Honors Institute**

**Presented by:
Benjamin Campbell, Ph.D.**

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Educational Background

Penn State **1998 - 2003**

B.S. Physics, Electronics Option

Minor: Mathematics

Minor: Business

Minor: Astronomy and Astrophysics

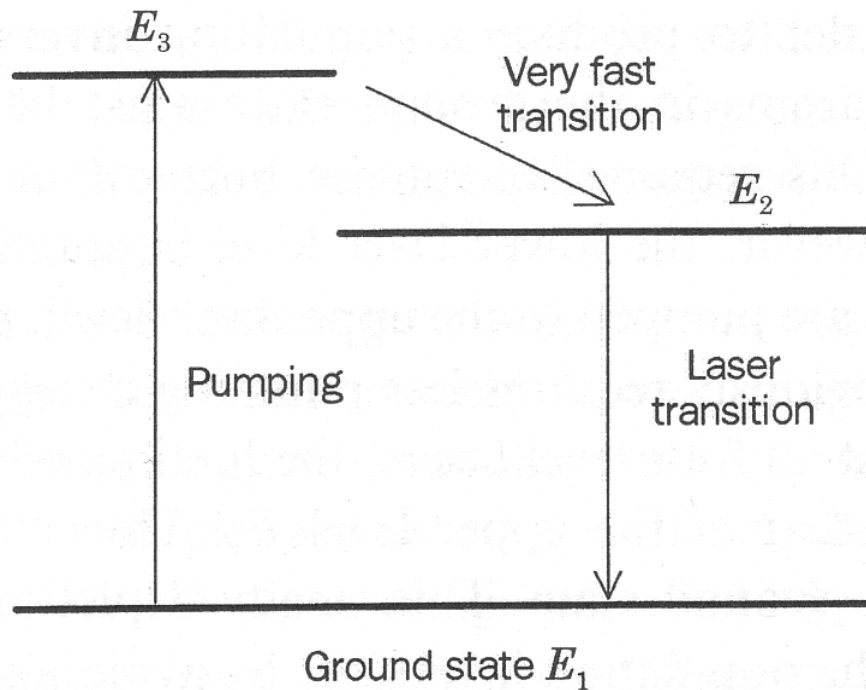
M.S. Electrical Engineering

Robert Morris University **2005 - 2008**

Engineering Ph.D.

What is a Laser?

Light Amplification by Stimulated Emission of Radiation

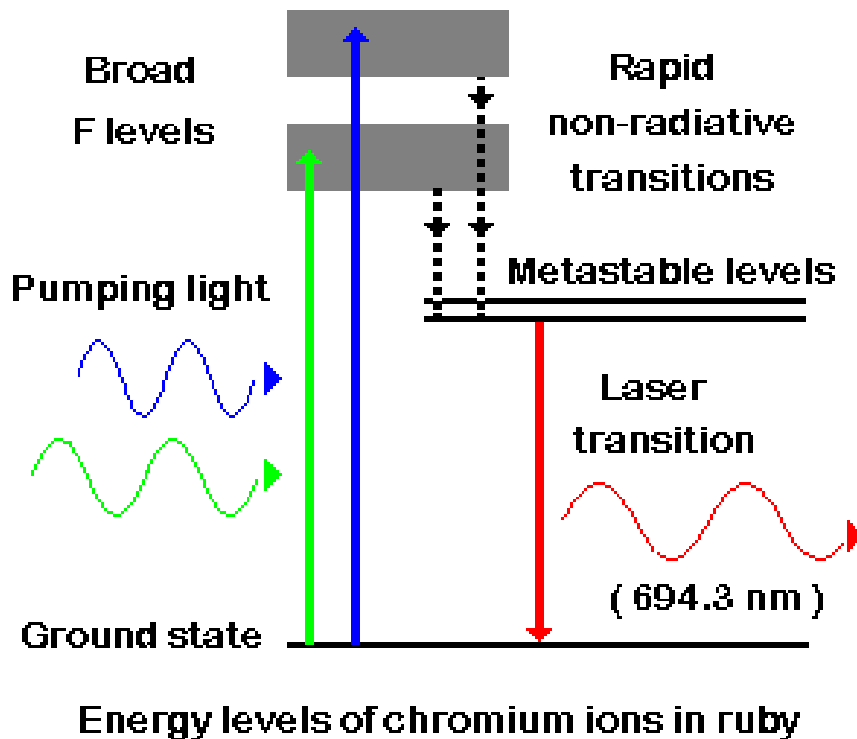


A model of a three-level laser

- Assume that all the atoms start out from the ground state.
- Then most of them are pumped up to a higher energy level E_3 .
- They quickly fall from the short-lived level E_3 to the metastable upper level E_2 , which has a much longer lifetime (typically thousands of times longer).
- The result is the population inversion between energy level E_2 and depopulated level E_1 , which are the laser transition levels.

How Do Lasers Work?

Pumping for a Population Inversion



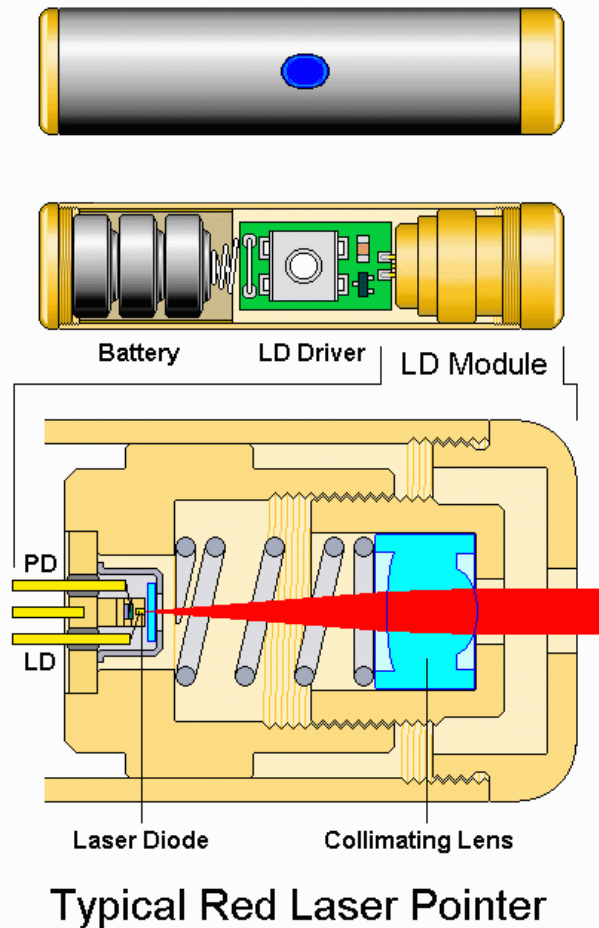
Pumping is the process of delivering energy to the lasing material to create a population inversion. The most common forms of energy delivery are:

- Electricity
- Light

Laser Light is:

- **Coherent.** Different parts of the laser beam are related to each other in phase. These phase relationships are maintained over long enough time so that interference effects may be seen or recorded photographically. This coherence property is what makes holograms possible.
 1. Spatial Coherence
 2. Temporal Coherence
- **Monochromatic.** Laser light consists of essentially one wavelength, having its origin in stimulated emission from one set of atomic energy levels.
- **Typically Highly Collimated.** Because of bouncing back between mirrored ends of a laser cavity, those paths which sustain amplification must pass between the mirrors many times and be very nearly perpendicular to the mirrors. As a result, laser beams are very narrow and do not spread very much.

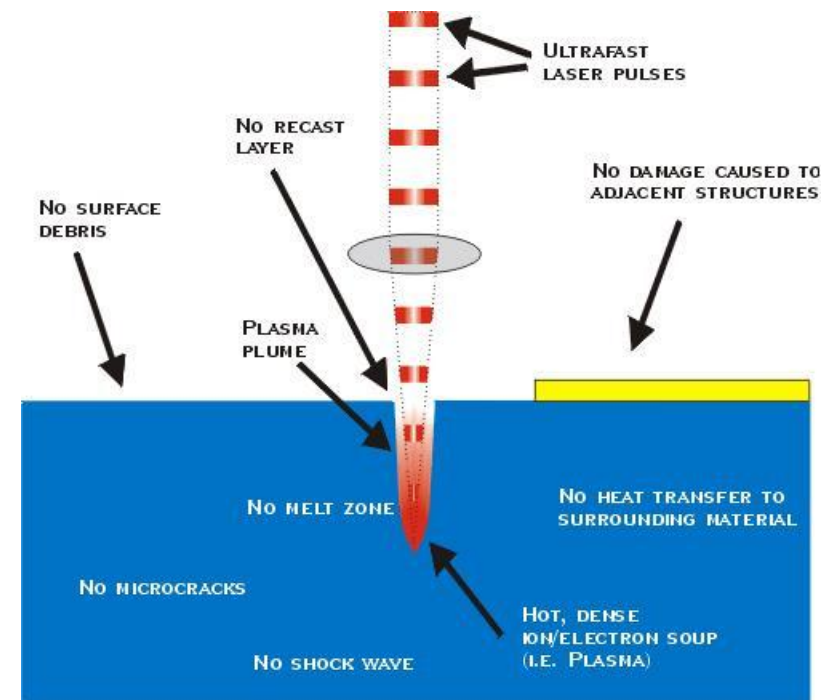
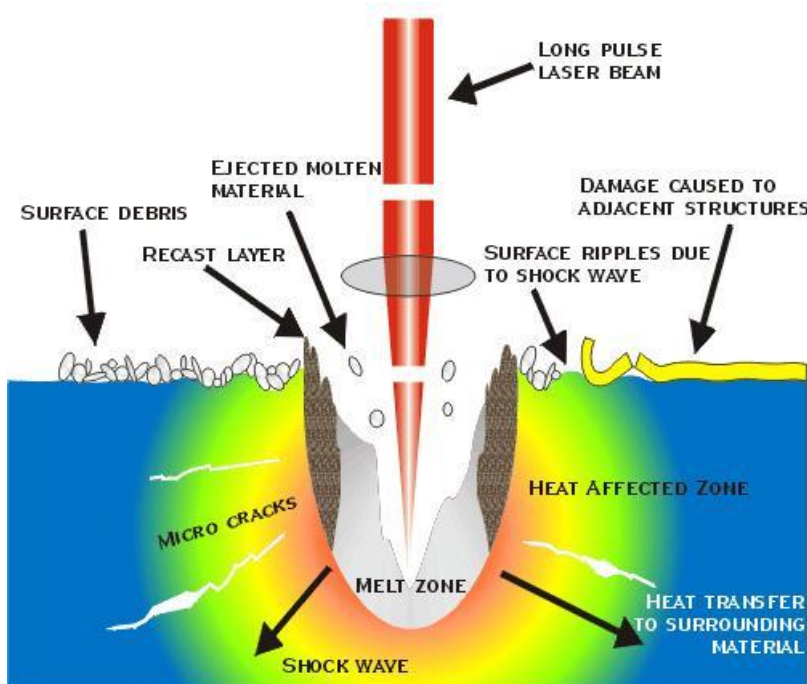
The Inner Workings of a Laser Pointer



The typical output power is less than 1 mW

Ultrashort Pulse Drilling

Material is ablated by squeezing energy into an ultrashort time span to superheat and liberate the surface material before heat transfer negatively affects the surrounding material



How Short is Ultrashort?

Prefix	Value
milli-	10^{-3}
micro-	10^{-6}
nano-	10^{-9}
pico-	10^{-12}
femto-	10^{-15}
atto-	10^{-18}

One attosecond (one billionth of a billionth of a second) is the approximate time that it takes light to travel the diameter of an atom

In 200 femtoseconds, light can barely travel the thickness of a strand of hair (60 micrometers)

Power = (Energy)/(Time Duration)

1 Watt = (1 Joule)/(1 Second)

A laser pointer is a Continuous Wave (CW) laser.

If it has an output of 1milliWatt

for 1 second, the energy is 1milliJoule.

For example, we will use 0.242 milliJoules

If we compress that energy into a pulse that is 200 femtoseconds we get a laser pointer with a power of...

1.21 GigaWatts!

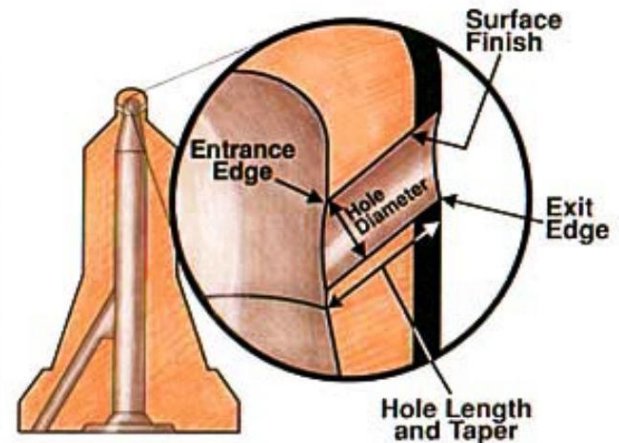
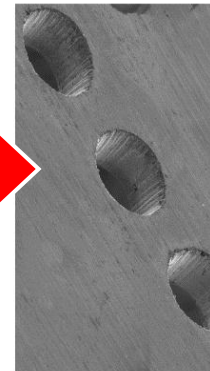


Ultra-Short Pulse Laser Machining

Improved Performance and Lower Pollution



5-ton diesel truck



Benefits

- ❑ Precise machining with negligible heat affects
- ❑ Higher reliability and improved performance
- ❑ Lower pollution

Femtosecond laser-drilled holes
Improved Fuel Injection

Fun with Lasers...

(Courtesy of Ben Hall at PSU's ARL)



[Laser Bending Video](http://youtu.be/HUM1tAszhjQ)

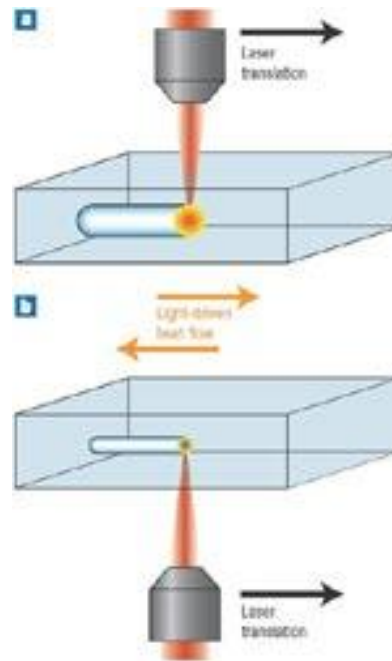
<http://youtu.be/HUM1tAszhjQ>

[And some laser music!](http://youtu.be/9hUHD9EGMQE)

<http://youtu.be/9hUHD9EGMQE>

Laser Writing Inside Materials

- Unfocused lasers can be transmitted through transparent materials
- If the laser is focused, it will only interact with the material over a fluence threshold (high energy density)
- The material will be damaged at the focus with the highest fluence.
- Moving the focus within the material will shape the damage zone.

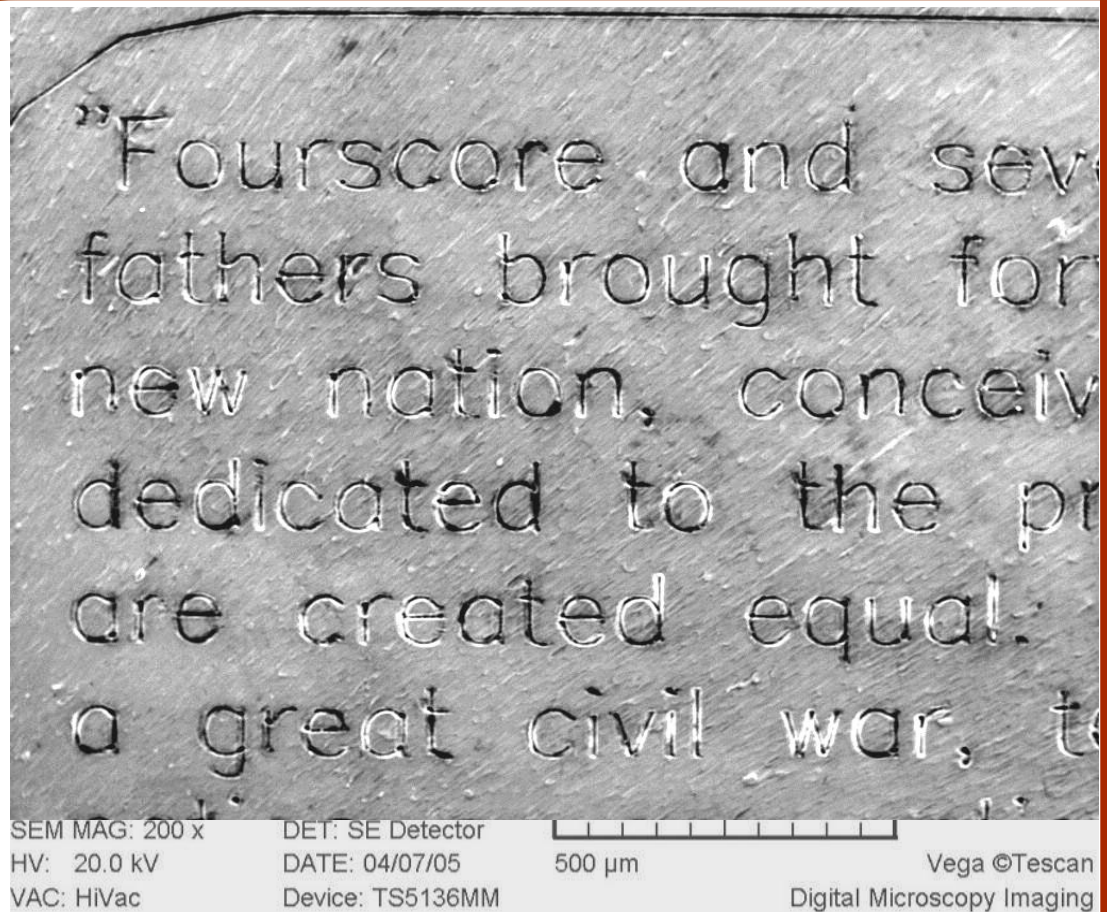


How Small Can We Laser Etch?

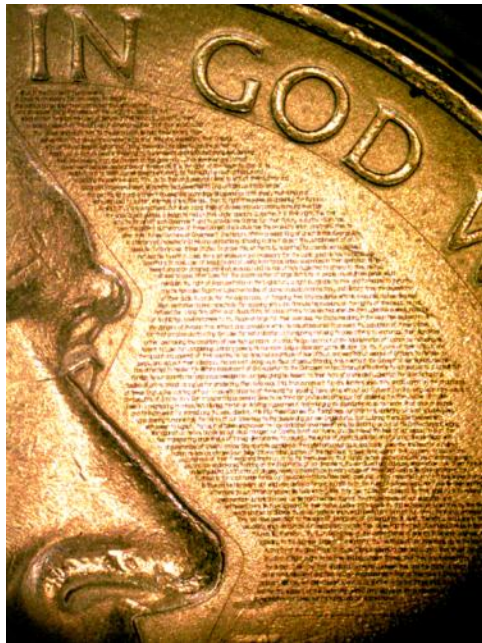
The Gettysburg Address etched on a Lincoln Penny



The Gettysburg Address contains 267 words (1189 characters) and is compressed into an area measuring less than 4mm (3/16 inch) by 6mm (1/4 inch). The height of each letter is 1/10 of a millimeter tall (four-thousandths of an inch),



Laser micromachining the Declaration of Independence on a Jefferson nickel



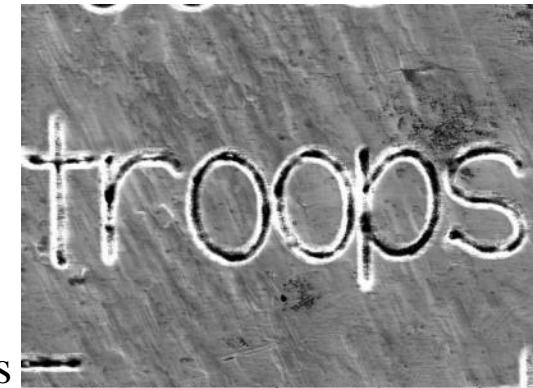
The Declaration of Independence contains:
6,716 Characters
1,327 Words

The program to etch the nickel was:
4,427 pages in size 10 font
252,298 lines of code.

Still enough room left to add the signatures of the founding fathers below the text.



SEM MAG: 700 x
HV: 20.0 kV
VAC: HiVac
DET: SE Detector
DATE: 08/08/07
Device: TS5136MM
200 um
Vega ©Tescan
Penn State Electro-Optics Center



SEM MAG: 1.27 kx
HV: 20.0 kV
VAC: HiVac
DET: SE Detector
DATE: 08/08/07
Device: TS5136MM
100 um
Vega ©Tescan
Penn State Electro-Optics Center

School of Engineering Mathematics and Science at RMU



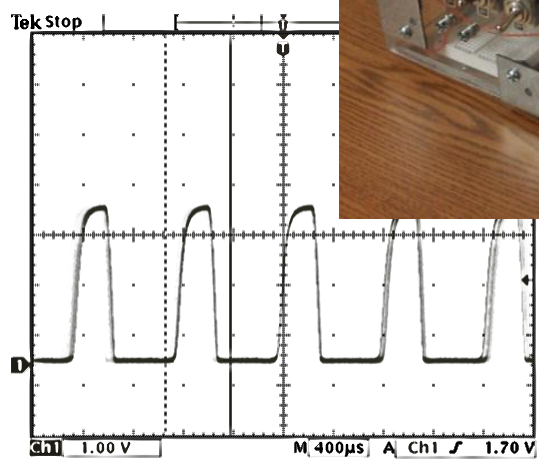
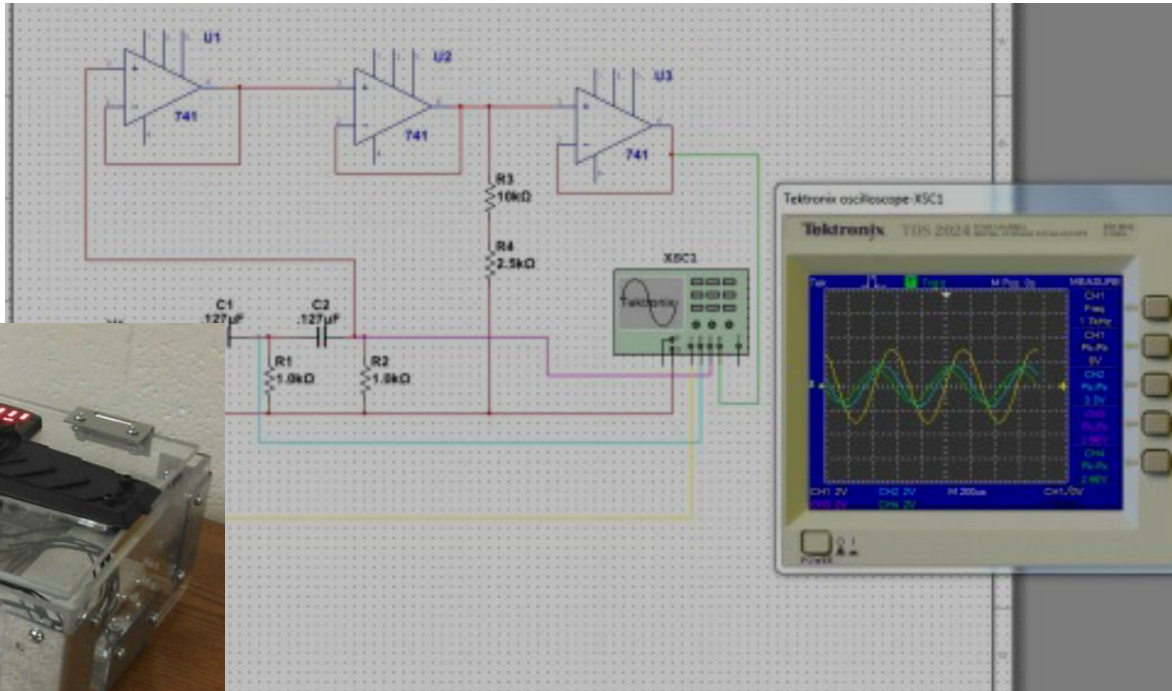
- Private School with small class sizes (typically 20 or less)
- Engineering degrees with concentrations in Mechanical, Biomedical, Software and Industrial Engineering, Masters in Engineering Management
- Science/Math Majors in Biology, Environmental Science, Mathematics and Actuarial Science
- Planning on Launching a Mechatronics Minor in 2014
- Minor in Alternative Energy and Sustainability

Mechatronics

- Mechatronics is a new term that covers three areas of engineering:
 - Mechanical Engineering
 - Software Engineering
 - Electrical Engineering
- Multidisciplinary approach to robotics and automation



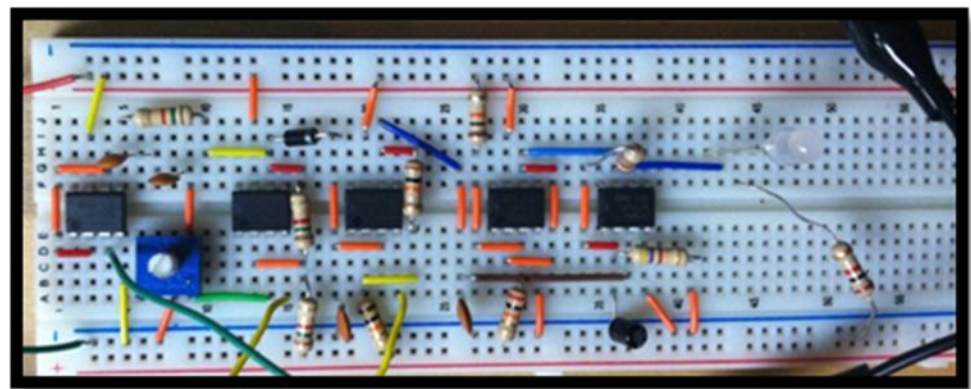
Neural Interface



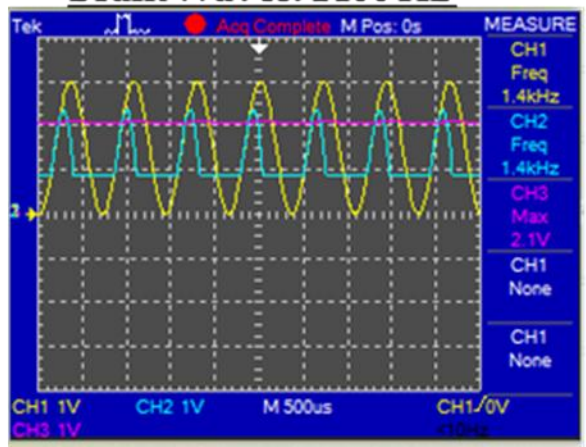
Frequency Ranges for Encoder Output



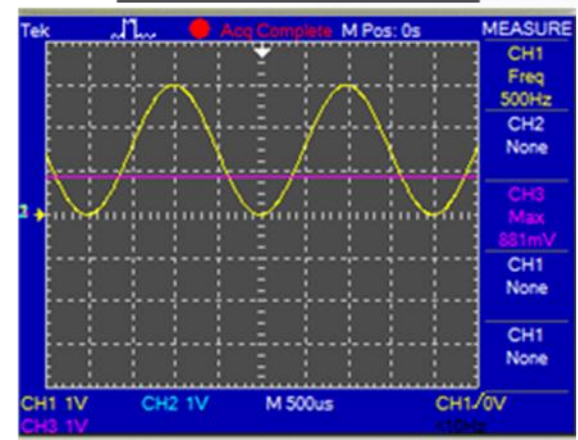
Neural Interface



Brain Waves: 1400 Hz



Brain Waves: 500 Hz



Yellow: Frequency generated by game
Blue: Frequency after high pass filter
Pink: DC voltage after AC-DC Converter

Neural Interface

- Exploring mental control of more advanced devices
- Using Arduino controller to read signals from EEG headsets and trigger other devices
- Exploring control of Lego Mindstorm based robots via Bluetooth



Artificial Finger Project

What is the Problem?

- Prosthetic hands cannot operate touch screens
- Most gloves inhibit touch screen use
- Many different types of touchscreens are made

Engineering Investigation

- What types of touchscreens can we identify
- Test common materials on each
- Design new materials to be universal activator



Artificial Finger Project

Building prototypes to effect capacitance fields through insulating material.

Student designed app for testing accuracy of touching targets. Comparing:

- Normal fingers
- Finger with Band-aid
- Glove with conductive fingertip
- Stylus
- Prototype prostheses

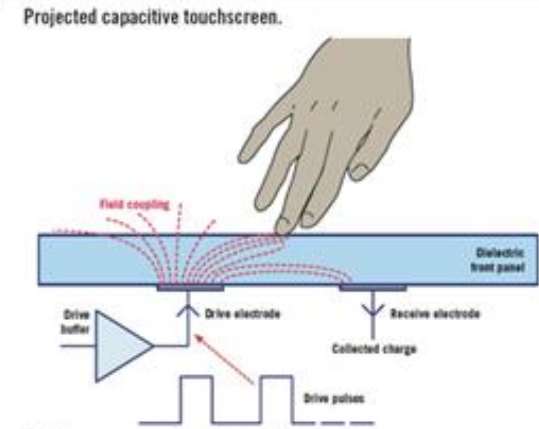
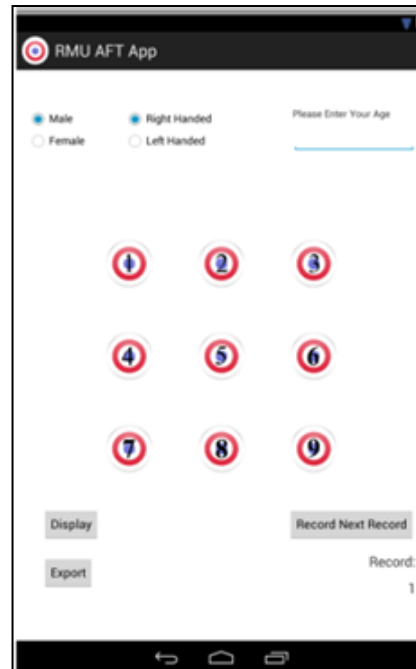
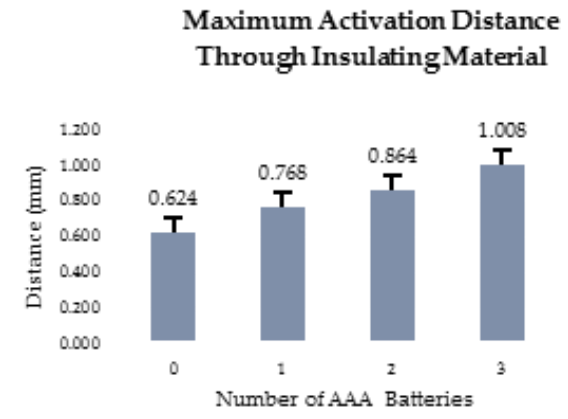
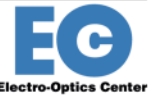


Figure 1
Picture courtesy of <http://www.embedded.com/>





Designing a Low-Cost Otoscope for Developing Countries Using a Non- traditional Power Source

**Sarah Robb, Derrick Wells, Josh Leipheimer,
Nicole Stone, & Devon Cesario**



Faculty Advisors:

Dr. Ben Campbell

Dr. Won Joo



Engineering World Health (EWH)

EWH is a dynamic global organization serving engineering students, healthcare professionals communities around the world and, most importantly, patients in need.

- Training Programs
- Student Chapters
 - Kit Building
 - Summer Institute
 - Design Competition



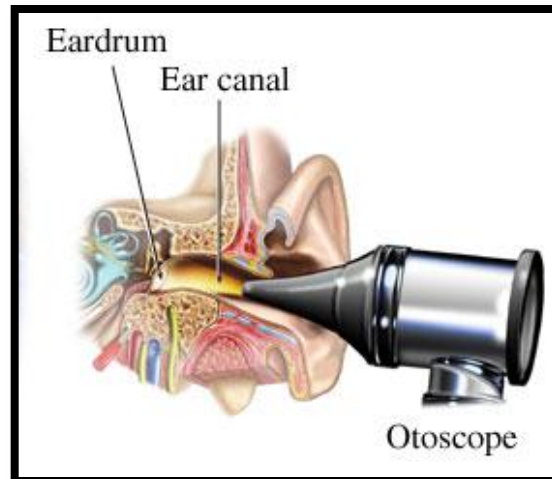
Engineering World Health: Projects that Matter



BME Device: Otoscopes



- Magnifies and illuminates
- Used to diagnose and view disorders of the...
 - Ear
 - Eyes
 - Throat
 - Nose



Specific Need/Potential Market

In many developing countries...

- Electricity is unavailable/unreliable
- Healthcare is inaccessible/unavailable/expensive

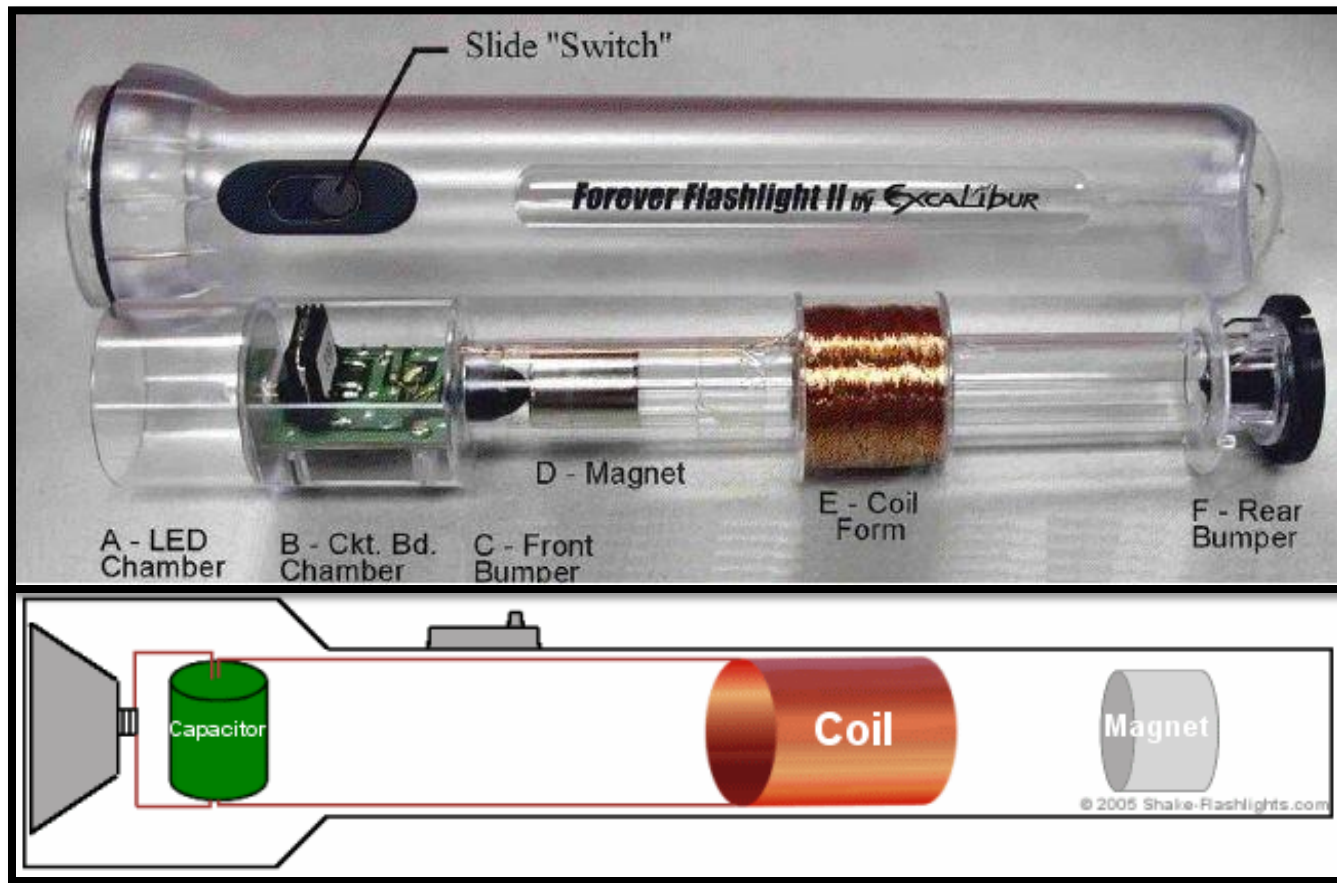
Africa (1 billion)

- 2.3 healthcare professionals per 1,000 people

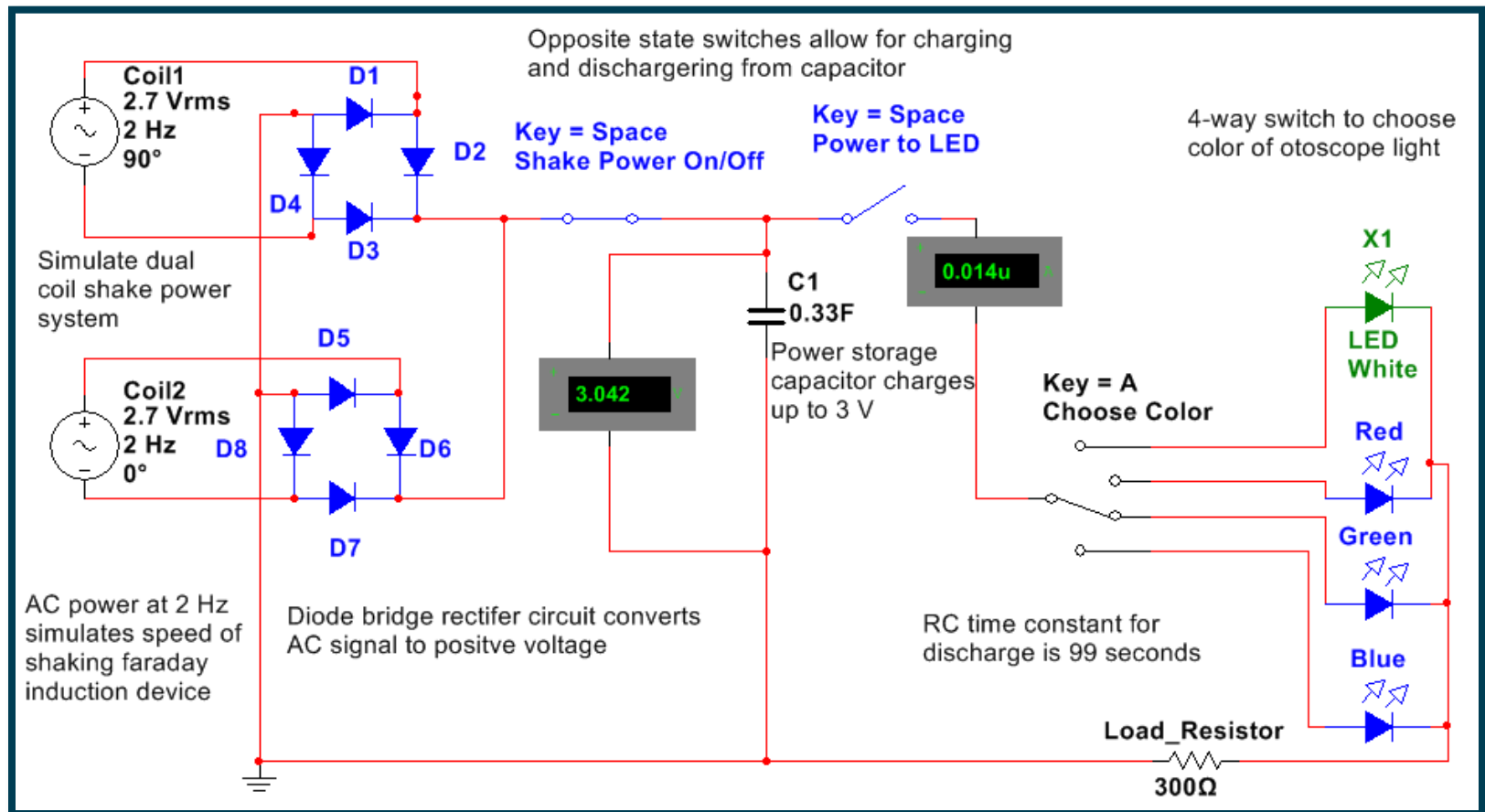
US (314 million)

- 24 healthcare professionals per 1,000 people

Inspiration



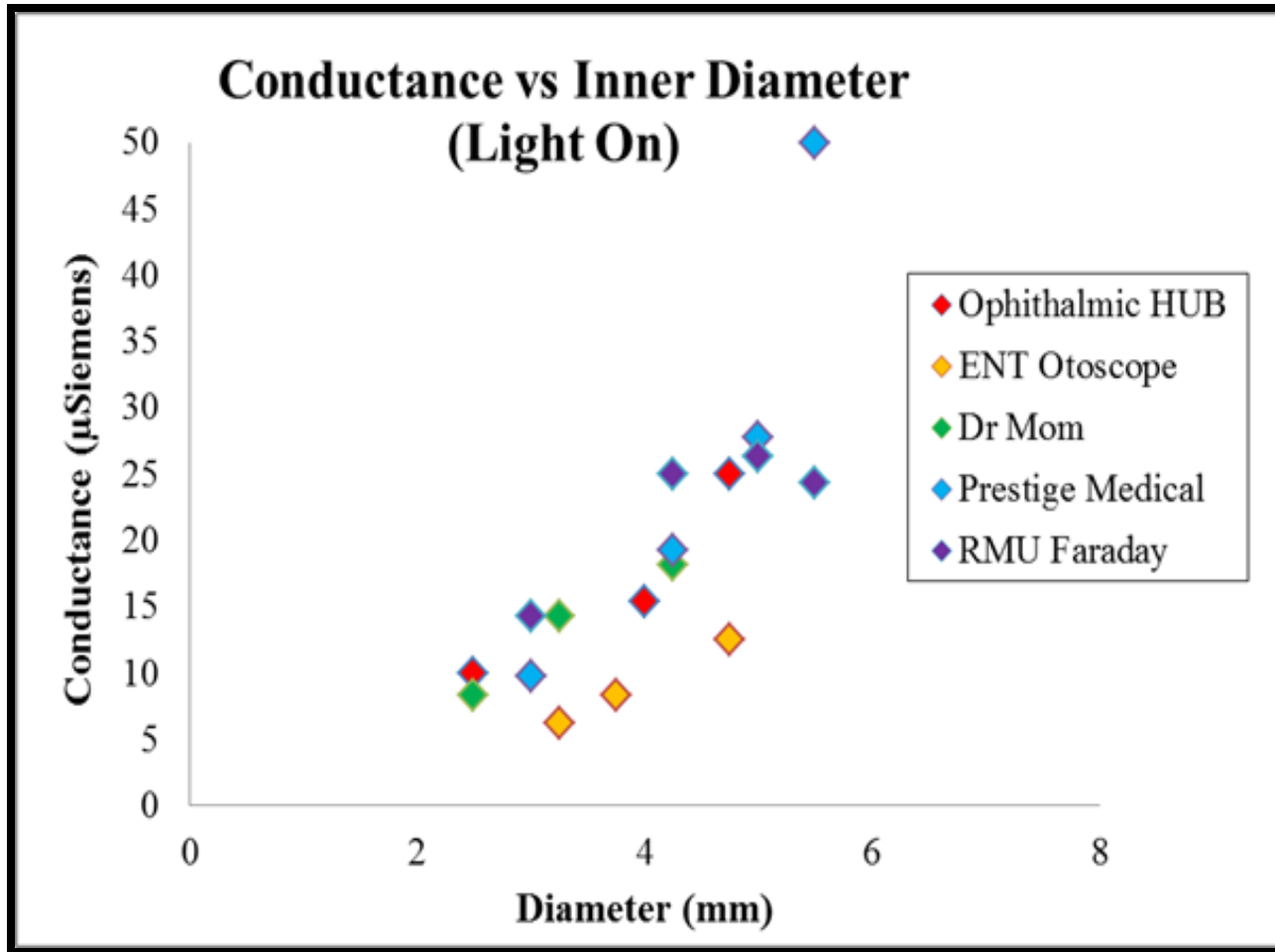
Circuit



Prototype

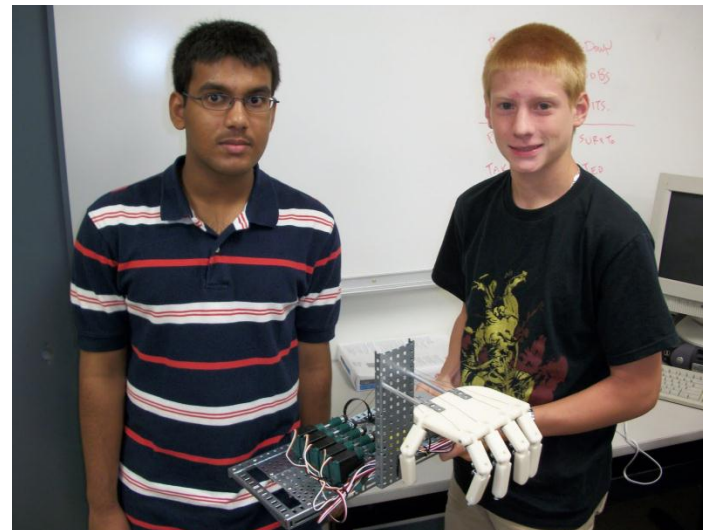


Comparison to Commercial Products



RMU Summer Camps

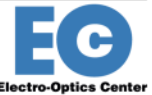
- Electro-Optics Summer Camp
- Animatronics Summer Camp
- Zombie Apocalypse Summer Camp



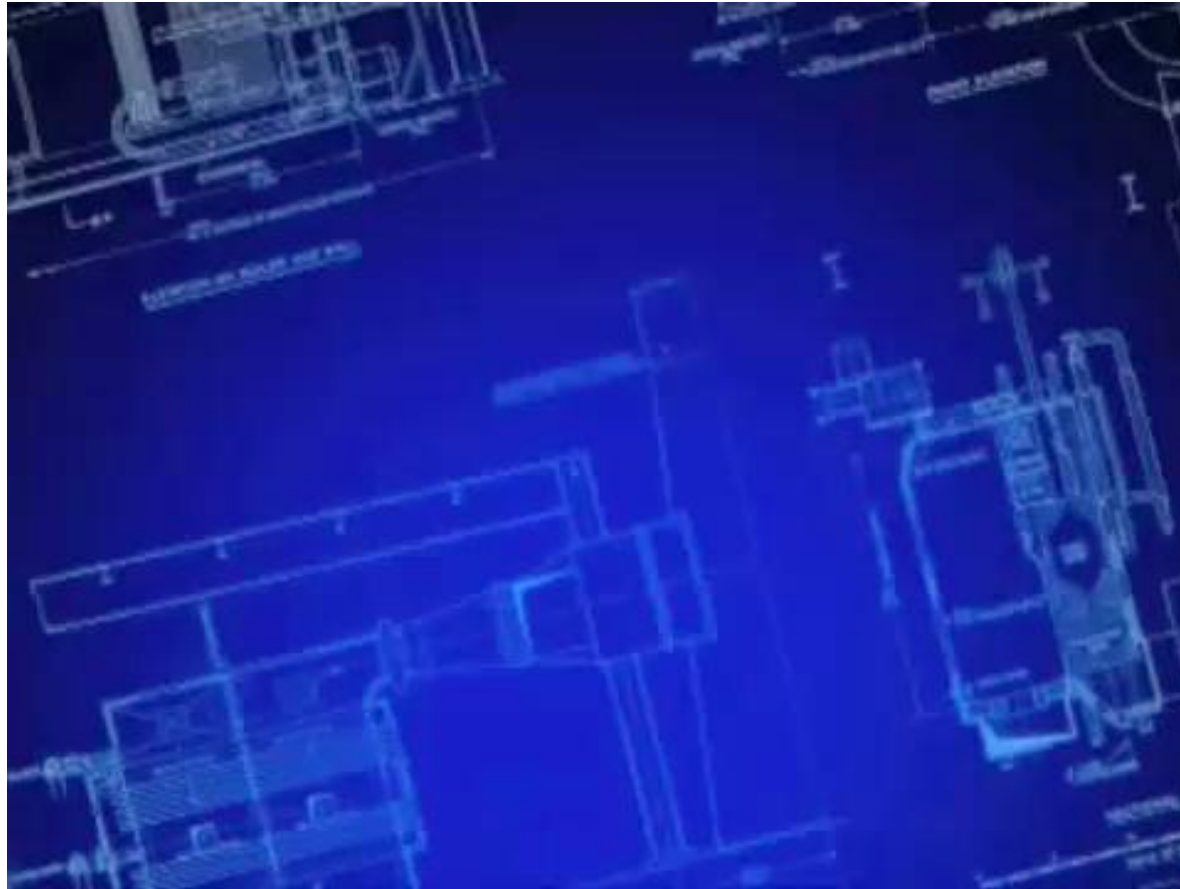
RMU Research

- RMU Engineering Learning Factory





The Learning Factory



<http://youtu.be/k92vIAvnFz0>

PGSS at Carnegie Mellon

The Pennsylvania Governor's School for the Sciences

www.pgss.mcs.cmu.edu



- 5 week intensive residential summer program
- Study advanced topics in Biology, Chemistry, Computer Science, Mathematics and Physics
- Choose from electives and a lab in those subjects
- Complete an original research project in a team
- Free program for rising seniors, applications due Jan 31th of Junior year (no late applications accepted)

Questions?

Email:

campbellb@rmu.edu

Website:

<https://sites.google.com/a/rmu.edu/campbellb/>