Current

- U.S. Naval Academy
- 338 acres of land
- 4,500 Midshipmen
- > 500 Faculty and Staff

1845

- Fort Severn
- Nine acres of land
- 50 Midshipmen
- 7 professors (3 civilian, 4 officers)

Undergraduate Student Research

Svetlana Avramov-Zamurović

Professor, United States Naval Academy

avramov@usna.edu

http://www.usna.edu/Users/weapsys/avramov

- Research presentations on Student Conferences

- S. Avramov, "**The Problems in Construction of Spherical Block Codes in Spherical Coordinates", 1986.**

- S. Avramov, "Design of one semi-iterative algorithm for finding equilibrium state of the great techno-economical system and comparison with already existing iterative algorithm,1985.

- ✓ Graduated from University of Novi Sad, Serbia 1986.
- ✓ College of Technical Sciences
- ✓ Undergraduate Major: Electrical Engineering
- ✓ Concentration: Electronics and Communication Systems

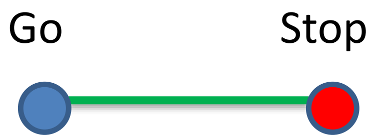
Min- Max Coding

Binary code

Generate code words so that minimal distance between two code words is maximized => allows communication in the presence of the highest noise level

TWO Code words

Go **0** Stop **1**

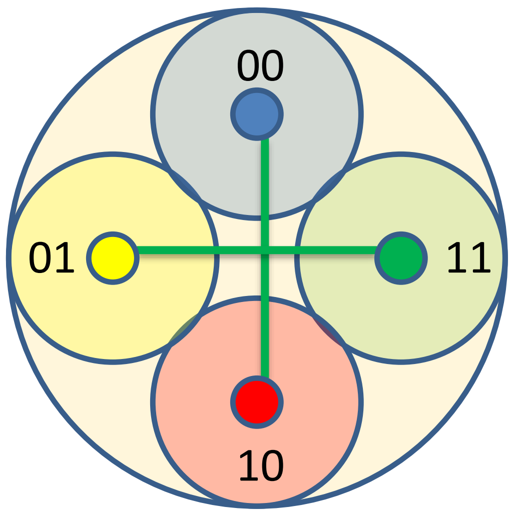


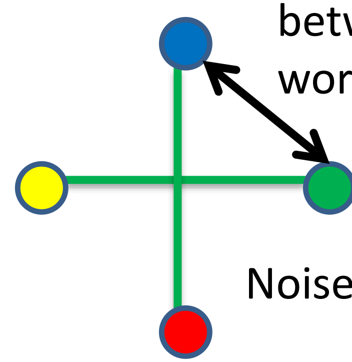
0 => -10 V **1** => 10V

Minimal distance between the code words 20 V Noise max < 10V

FOUR code words

Code meaning	Code words
Yes	**00**
No	**01**
Maybe	**10**
Hmm	**11**



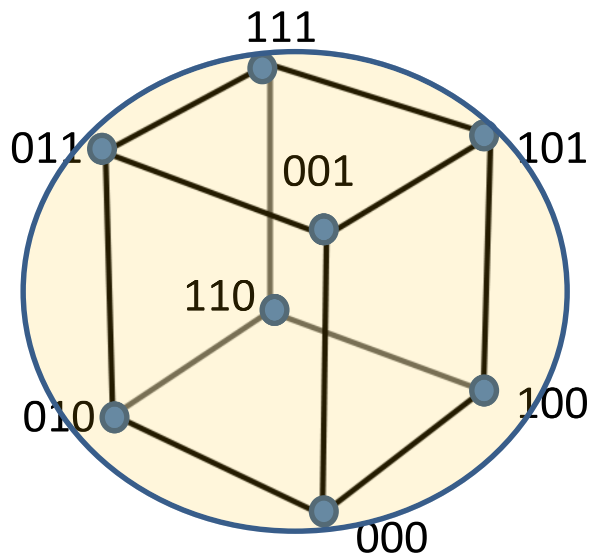


Minimal distance between the code words $10\sqrt{2}$ = 14.1V

Noise max < 7.05 V

Signal radius10 V

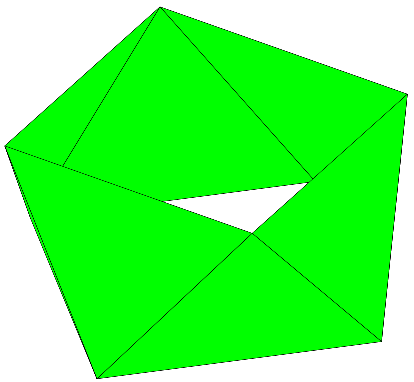
Nose signal can be anywhere in the shaded circle and it will NOT change the meaning of the transmitted code word.



CUBE Eight Code word 0 0 1 => (-10/$\sqrt{3}$ -5.7 5.7)

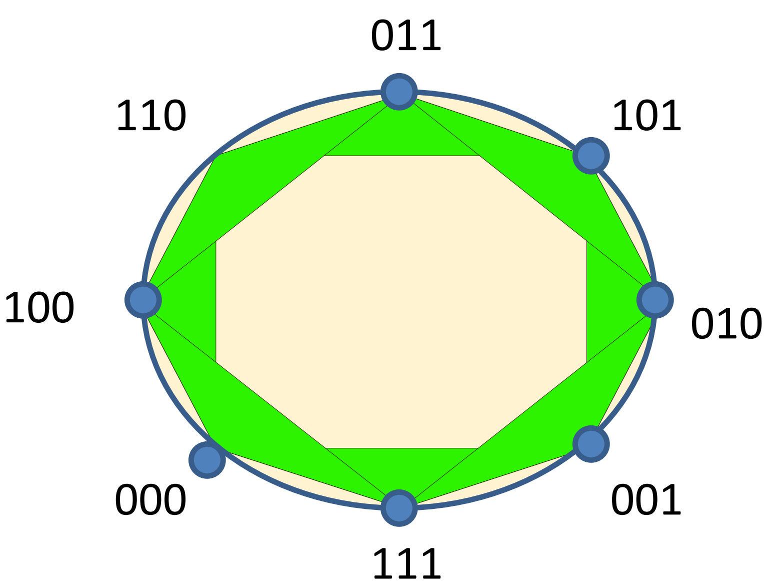
Minimal distance between the code words 11.5 V

Noise max < = 5.75 V



Signal radius 10 V

ARCHIMEDES CUBE



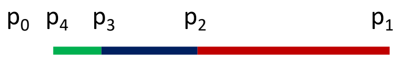
ARCHIMEDES 0 0 1 => (10/$\sqrt{3}$ 5.7 -5.7)

Minimal distance between the code words 14.7 V

Noise max < = 7.35 V

Greek Philosopher : **Zeno of Elea**

For anyone (*S*) to traverse the finite distance across a stadium from p_0 to p_1 within a limited amount of time, *S* must first reach the point half way between p_0 and p_1, namely p_2.



Before *S* reaches p_2, *S* must first reach the point half way between p_0 and p_2, namely p_3. Again, before *S* reaches p_3, *S* must first reach the point half way between p_0 and p_3, namely p_4. There is a half way point again to be reached between p_0 and p_4. In fact, there is always another half way point that must be reached before reaching any given half way point, so that the number of half way points that must be reached between any p_n and any p_{n-1} is unlimited. But it is impossible for *S* to reach an unlimited number of half way points within a limited amount of time. Therefore, it is impossible for *S* to traverse the stadium or, indeed, for *S* to move at all; in general, it is impossible to move from one place to another.

NASA Zeno Experiment

Find the critical point of inert gas Xenon

At just right volume, pressure and temperature Xenon's state is 'both' gaseous and liquid

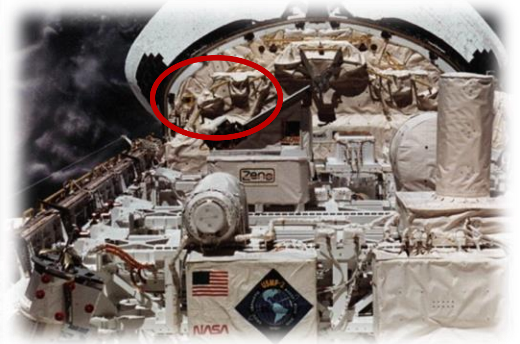
Xenon was put in a container so the volume and pressure were fixed. We changed temperature in ½ steps to find the critical point

I constructed inductive voltage divider that had resolution of 1 part per billion in order to calibrate a bridge that changed the temperature in 1 μK steps

PhD thesis

NASA STS 62 1994

Mission: USMP-2; OAST-2
Space Shuttle: Columbia
Launch Weight: 4,519,319 pounds
Launched: March 4, 1994; 8:53:01 a.m. EST
Landing Site: Kennedy Space Center, Florida
Landing: March 18, 1994 at 8:10 a.m. EST
Mission Duration: 13 days, 23 hours,
Orbit Altitude: 163 nautical miles
Miles Traveled: 5.8 million



THE CRITICAL FLUID LIGHT SCATTERING EXPERIMENT ZENO

Study of the properties of xenon at its critical point, taking subtle optical measurements in the region surrounding it.

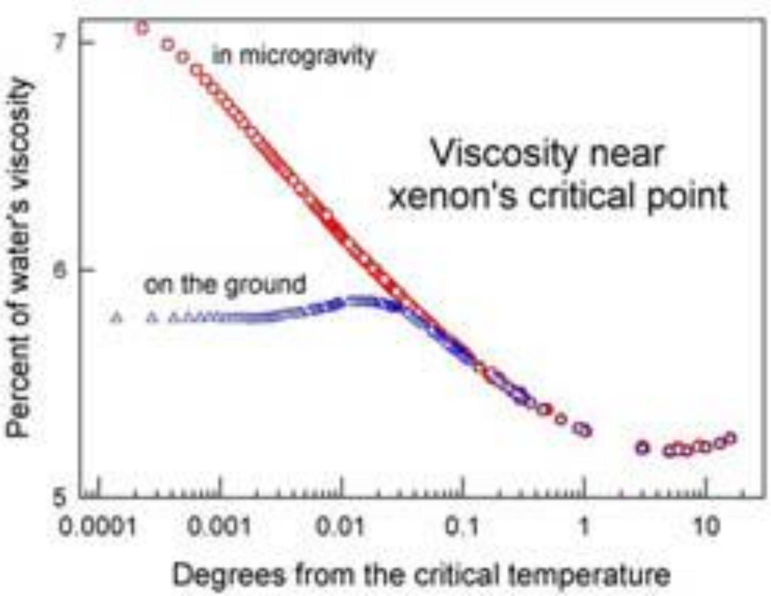
A fluid's "critical point" occurs at a condition of temperature and pressure where the fluid is simultaneously a gas and a liquid.

By understanding how matter behaves at the critical point, scientists hope to learn phase changes in fluids and changes in the composition and magnetic properties of solids.

http://www.youtube.com/watch?v=7HnZgM542Go&feature=youtu.be

NASA STS 85 1997

Mission: CRISTA-SPAS-02
Space Shuttle: Discovery
Launched: August 7, 1997, 10:41:00 a.m. EDT
Landing Site: Kennedy Space Center, Florida
Landing: August 19, 1997, 7:07:59 a.m. EDT
Mission Duration: 11 days, 19 hours, 18 minutes, 47 seconds
Orbit Altitude: 173 statute miles
Miles Traveled: 4.7 million



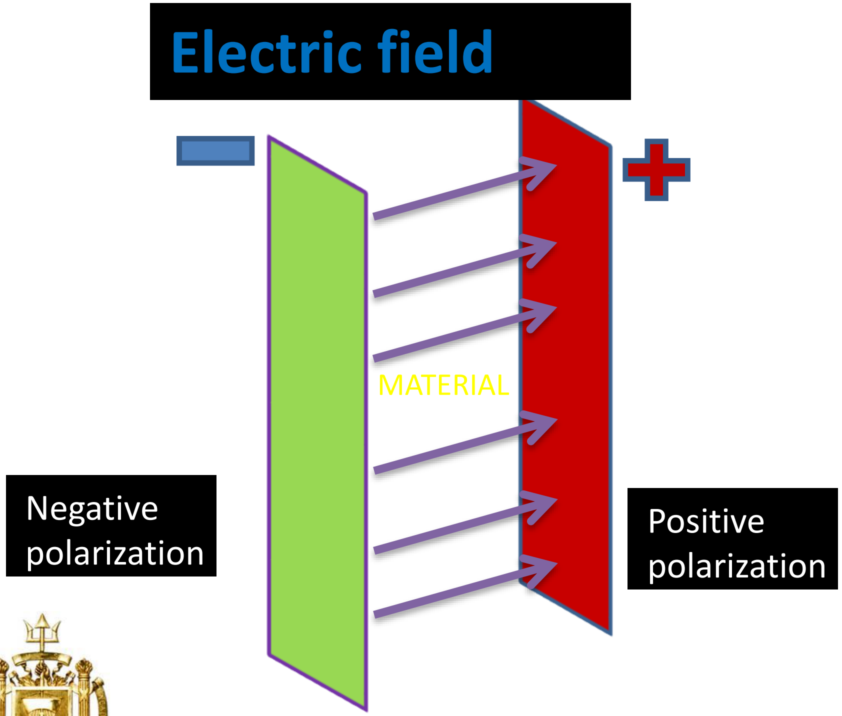
CVX-2 - Critical Viscosity of Xenon - was a science experiment to measure the viscosity (slipperiness) of Xenon at its critical point (the temperature and pressure where a substance is both a liquid and a gas at the same time.) Here's the very technical status reports the team released during the mission.

Sensing the distance and material properties by using capacitive sensors

Current work

Parallel Plate Capacitor

- The conducting plates have the same area and the distance between them is constant.

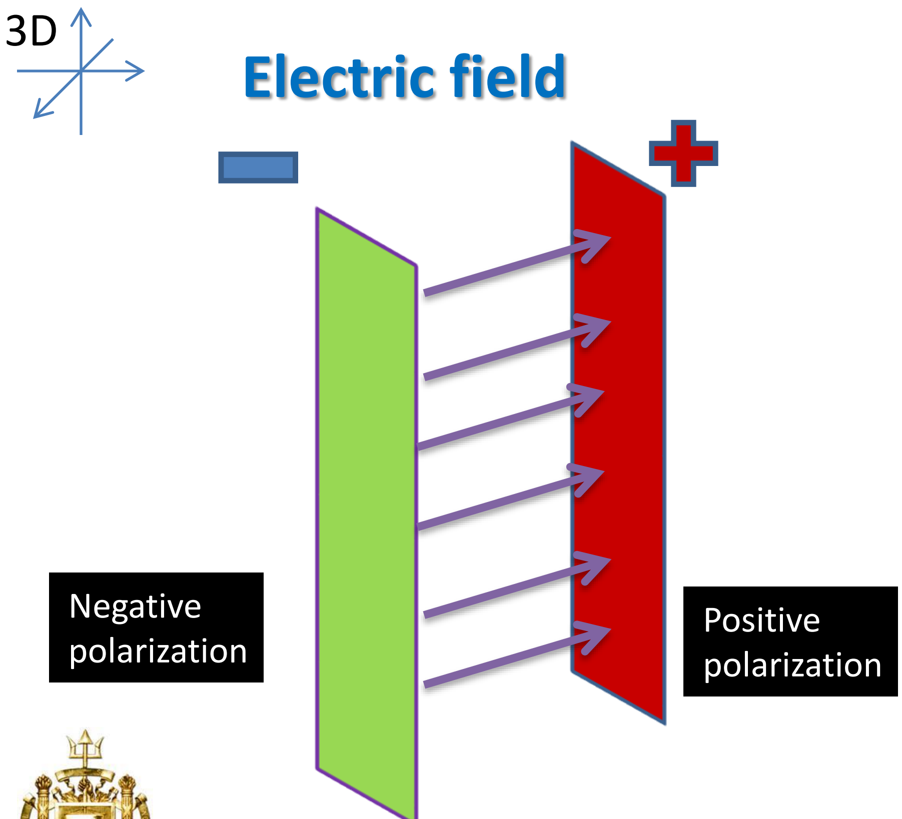


- The potential creates the electric field. The electrical field lines are parallel between the plates.
- This geometry of the plates and the material between the plates determine the capacitance.
- The capacitance is measured very precisely using alternating current and measuring the impendence between the plates.
- The material between the plates contributes to the loss of the capacitor.

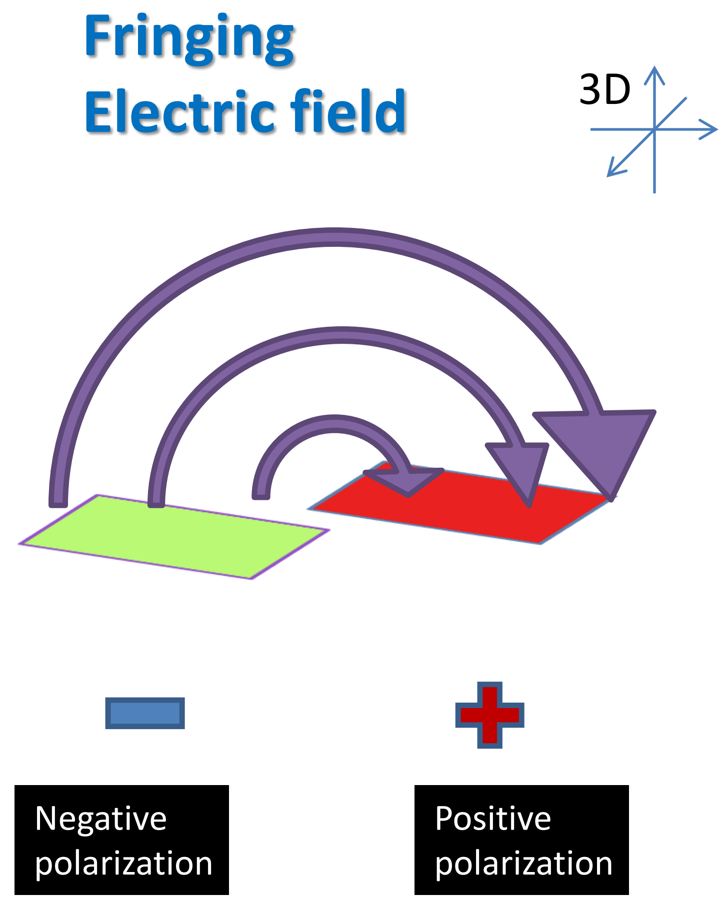
$$\text{Capacitance} = \text{Dielectric constant of the material beteen the plates} \frac{\text{Area of the plate}}{\text{Distance between the plates}}$$

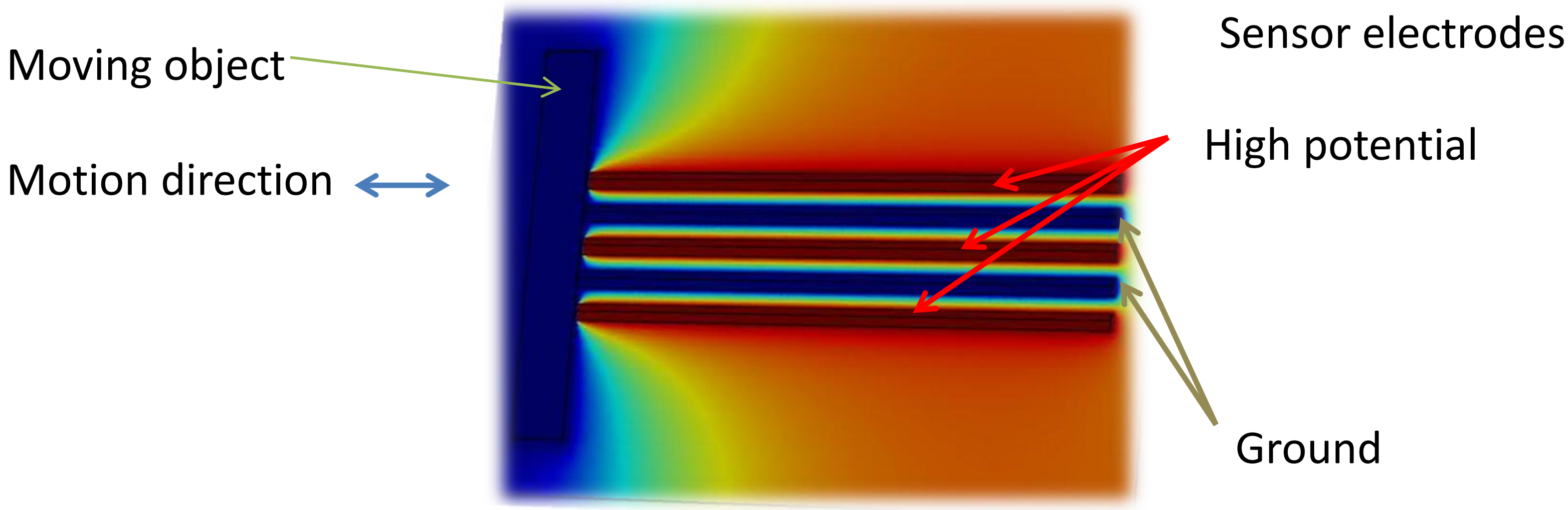
$$C = \varepsilon \frac{A}{d}$$

PARALLEL plate capacitor



PLANAR capacitor



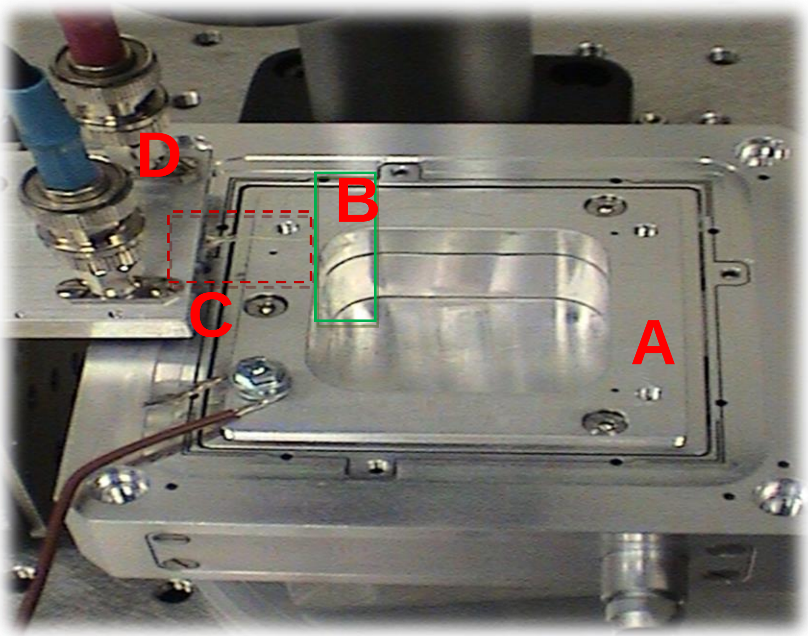


In-line Displacement Sensor Concept design

- Capacitance measured between pillars constructed from Teflon isolated wire oriented orthogonally to the moving object

Displacement Sensor for Detecting Sub-micrometer Motion

Experimental set up

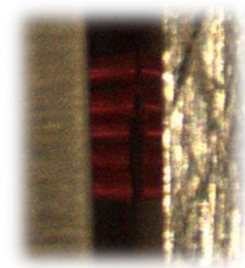


Moving object

Sensor electrodes

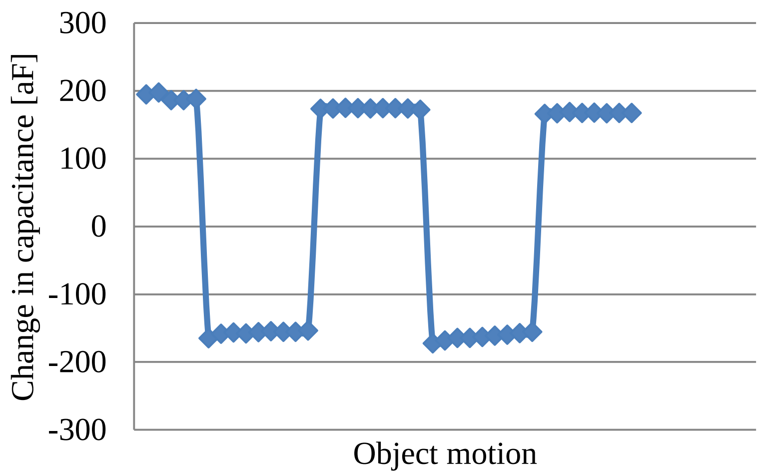
A - Moving platform.
B - Object (needle) attached to the platform (labeled with a solid green box).
C - Sensor placed on the stationary surface (labeled with a dashed red box).
D - Capacitance bridge coaxial connection.

5E In-line sensor Sensitivity at 0.5 μm Close Proximity



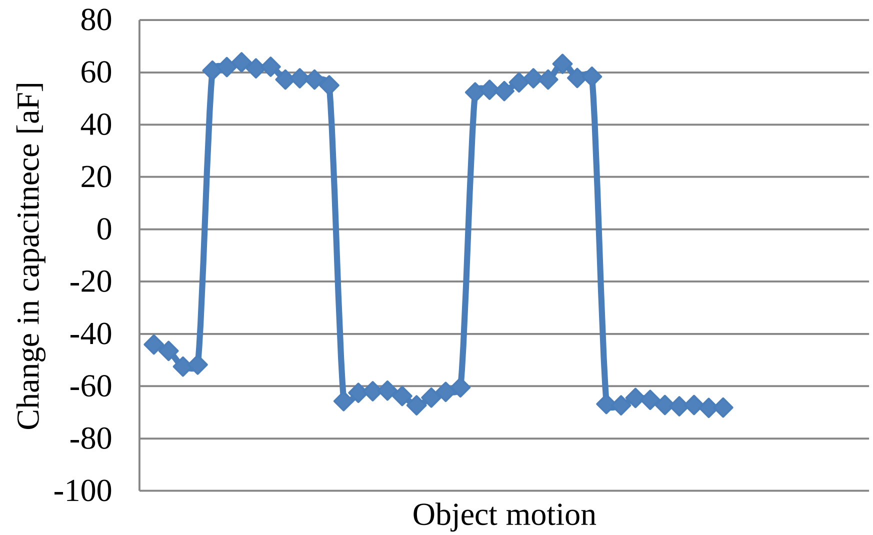
Sensor : 5 in-line electrodes, wire diameter 254 μm
Moving Object : Tungsten plate

Sensitivity 100 aF/ μm



Moving range 4 μm.

Sensitivity 600 aF/ μm



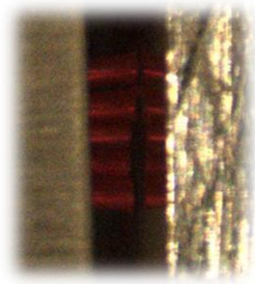
Moving range 0.2 μm.

Practical y resolution is 10 nm at the distance of 0.5 μm

Minimal gap between the sensor and the moving object ~ 0.5 μm

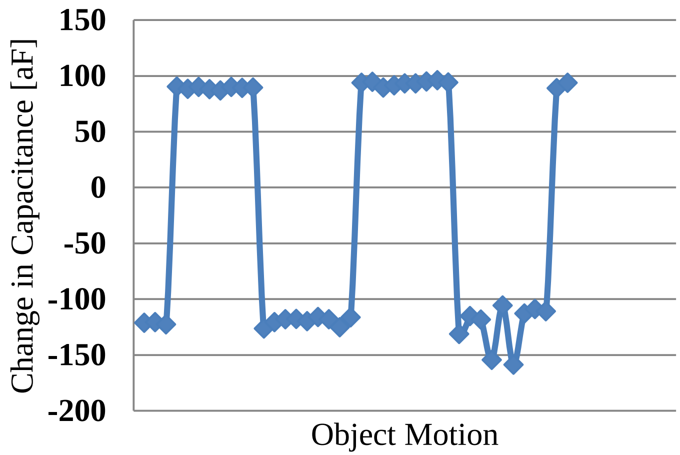
Capacitance bridge drive 15 V Measured dissipation ~2 μ rad
Capacitance resolution ~0.5 aF

5E In-line sensor Sensitivity at 30 µm



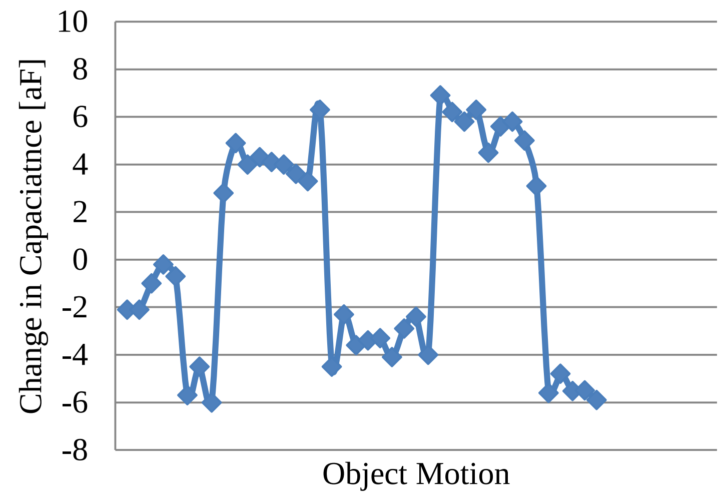
Sensor : 5 in-line electrodes, wire diameter 254 µm
Moving Object : Tungsten plate

Sensitivity 50 aF/ µm



Moving range of 4 µm.

Sensitivity 8 aF/ µm



Moving range of 1 µm.

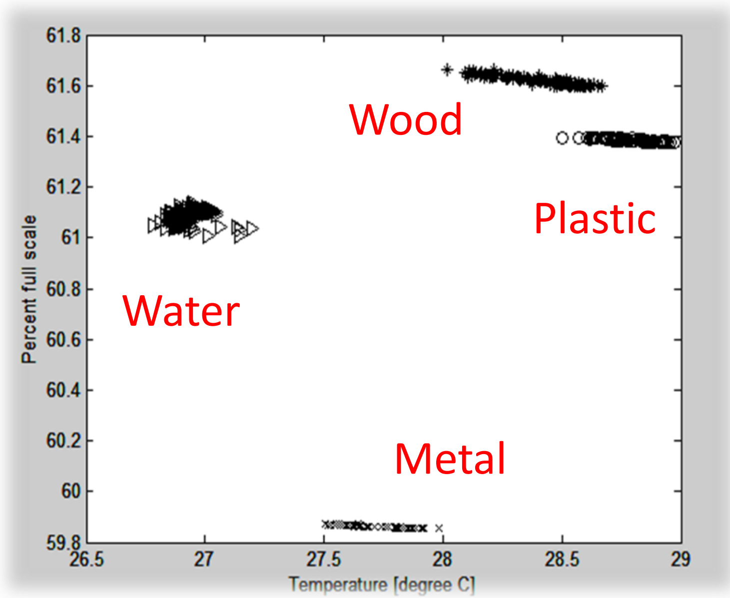
Practical y Resolution is 500 nm at the Distance of 30 µm

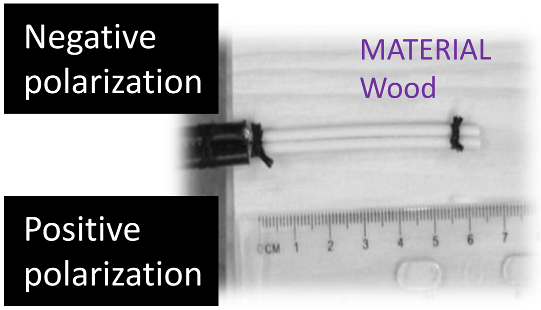
Average gap between the sensor and the moving object ~ 30 µm

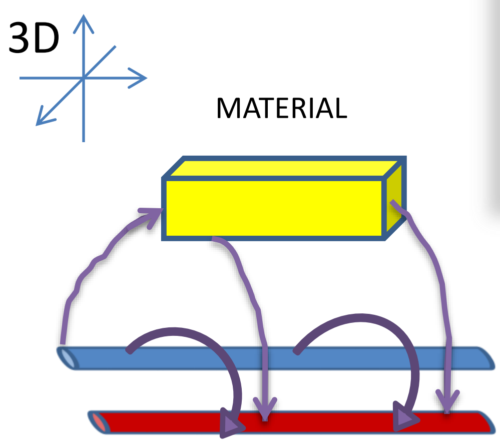
Capacitance bridge drive 15 V Measured dissipation ~2 µ rad
Capacitance resolution ~0.5 aF

Planar Capacitance Sensor Application
Material Properties Classification through Sensing
MIDN Dadds, Robotics

- Capacitance change for a variety of objects is very small.
- For reliable distinction between materials measurements have to be accurate within tens parts per million
- Measurement Uncertainty is obtained from 30 data sets each having 100 samples







Proximity of Material to Sensor: 0.5 inch

Property Classification Through Sensing

MIDN Nicholas A. Dadds, Weapons and Systems Engineering

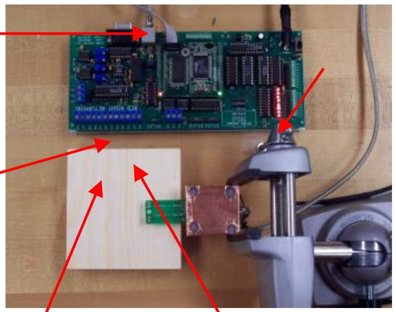
Advisor: Dr. Svetlana Avramov-Zamurovic Co-Advisor: Dr. Kenneth A. Knowles

http://go-systems.blogspot.com/2008/10/reach-out-and-touch-something.html

Capacitive Sensor Setup

Rabbit 2000

IC Cable

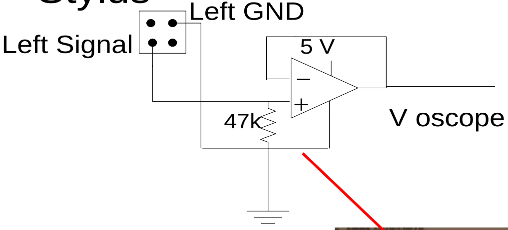


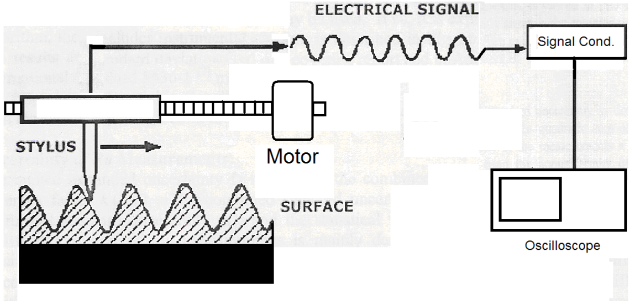
Sensor

Material

AD7746Converts capacitive reading to digital info for Rabbit

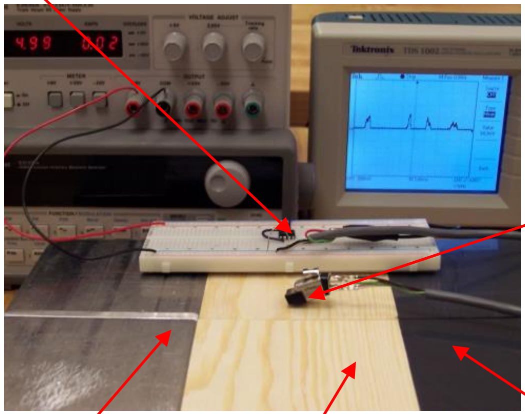
Signal Conditioning Circuit





Roughness Sensor

Stanton 400.V3

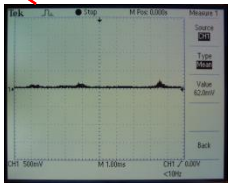


Material Type Classification Based on Capacitance

Material	Mean Capacitance [% Full Scale]	Relative Uncertainty [ppm]
Air	0.59597	7
Wood	0.59931	7
PVC	0.59705	7
Aluminum	0.5732	50

Aluminum Roughness Profile

Wood Roughness Profile



PVC Roughness Profile

Evaluation of Static Random Access Memory (SRAM) Chip Based Ultra Low Power Neutron Detection system

Professor Martin E. Nelson – Mechanical Engineering
Professor Svetlana Avramov-Zamurovic – Weapons Systems Engineering
CAPT Charles B. Cameron – Electrical Engineering
Professor James F. Ziegler – Physics

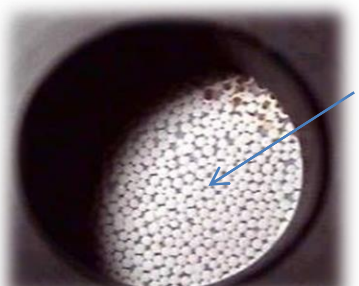
MIDN Kayla J. Sax

Objective

Evaluate memory chips for sensitivity to neutrons, comparing them to conventional detection systems, in an effort to establish their potential for general scientific use.

Conventional Neutron Detection Systems

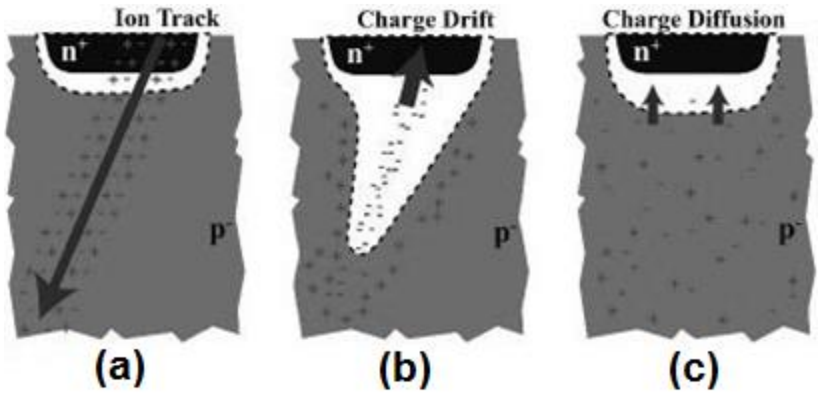
Non-powered
- Thermoluminescent dosimeter (TLD)
- Foil activation detector
- Bubble detector
- Track-etch detector



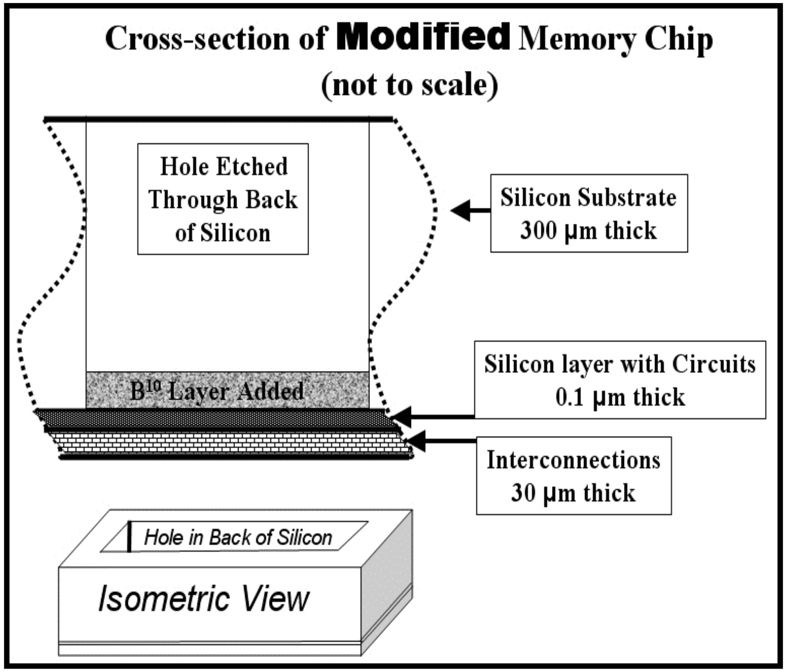
Lithium Fluoride Crystals

Powered
- BF_3 proportional counter
- ^3He proportional counter

SOFT ERROR PHENOMENON AND SINGLE EVENT UPSETS

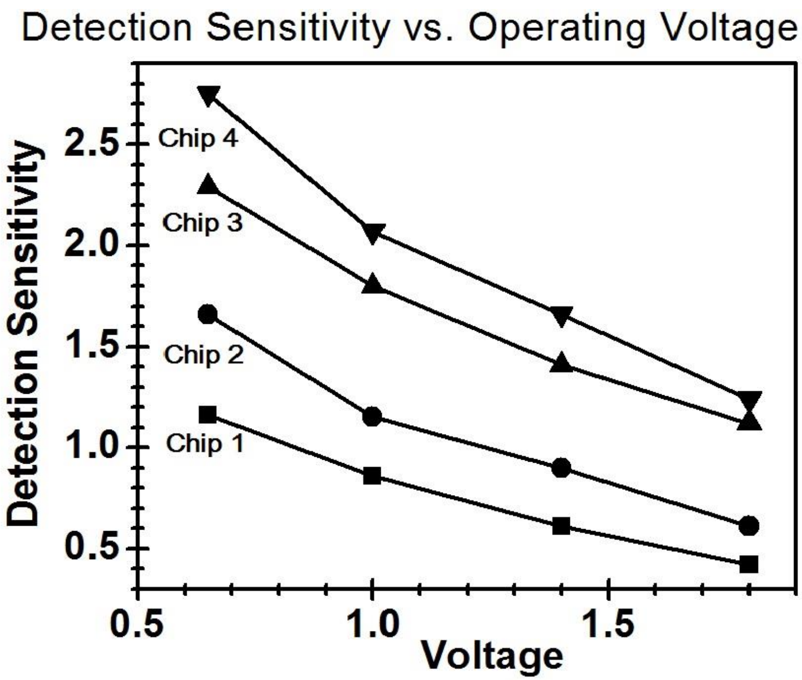


Pictorial representation of a single event upset. In (a), an ionizing particle traverses through a sensitive device well, producing a dense radial distribution of electron-hole pairs. Next, in (b), the non-equilibrium charge distribution creates a funnel-shaped potential distortion, furthering the effects of charge collection by drift. Finally, as shown in (c), the funnel collapses, and diffusion dominates the collection process until all the excess carriers have been collected, recombined, or diffused away. If the cumulative charge collected in this process exceeds the critical charge required for an SEU, a bit-flip occurs, indicating the presence of radiation.



Cross-sectional view of SRAM with added ^{10}B layer next to the active SRAM circuits (not to scale). Thicknesses are approximate values.

SRAM sensitivity



Sensitivity, S_{SRAM}, is a number of soft error upsets observed per number of neutrons that bombarded aperture normalized but he area of the aperture.

SRAM Chip	Aperture Area [cm2]	^{10}B Thickness [µm]
Control Chip	0.216	Not Applicable
^{10}B Chip #1	0.216	1.4 ± 0.1
^{10}B Chip #2	0.216	1.7 ± 0.1
^{10}B Chip #3	0.216	2.0 ± 0.5
^{10}B Chip #4	0.420	1.0 ± 0.5

Sensitivity, S_{SRAM}, of ^{10}B Chips#1– #4 at various core operating voltages. Sensitivity is shown in units of 1E-5, i.e. a value of 1=.001%. ^{10}B Chip #4 was the most sensitive at every core operating voltage tested.

Conclusion

- Smaller ^{10}B thickness but larger aperture area can result in increased sensitivity

Comparison of comerically available ^{3}He detector and SRAM ^{10}B chip operating at 0.65V

	COTS ^{3}He System	Modified SRAM
Thermal Neutron Sensitivity (S)	1.7×10^{-1}	2.75×10^{-5}
R/W Current Requirement [mA]	1200	0.6
Sleep-Mode Power Requirement	~5V / 400 mA	< 1V / ~ 0.001mA
Estimated Operating Time on Battery	< 3 days	years

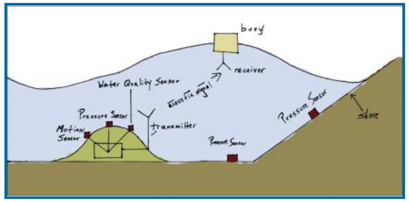
- Modified SRAM was placed in a radiation field next to a subcritical reactor (water-shielded PuBe) at USNA
- Thermal neutron flux of 0.4 n/cm^2 sec, a flux approximately equal to that found at a distance of 10 ft from 5 kg of a combination of weapons grade and reactor grade plutonium material.
- One memory upset every 12 hours. A control test lasting 92 hours in an adjacent room at the USNA with no radioisotope source resulted in no detected memory upsets.
- When integrated over a typical maritime voyage, the modified SRAMs are capable of detecting SNM being transported in cargo containers.

Tsunami Warning System

Joseph, Song and Professor Avramov-Zamurovic

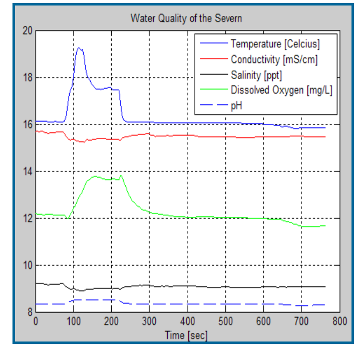
Weapons and Systems Engineering

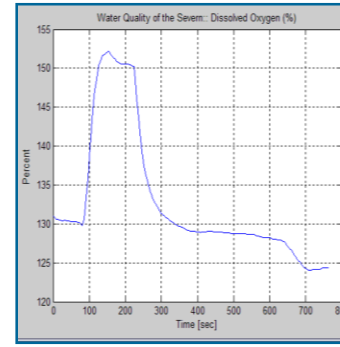
Tsunami Phenomenon

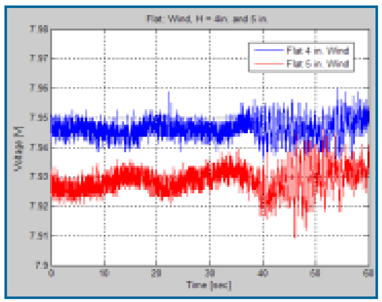


Tsunami Warning System

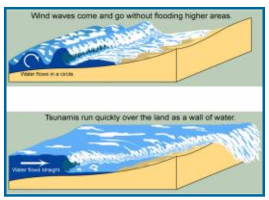
Results: Water Quality



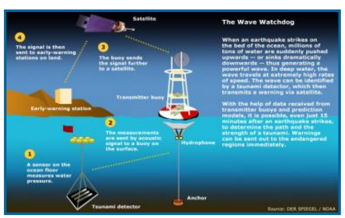


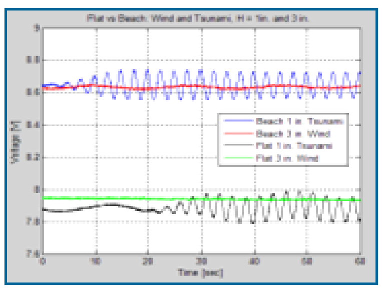


Flat:
Wind 4 in.
and 5 in.

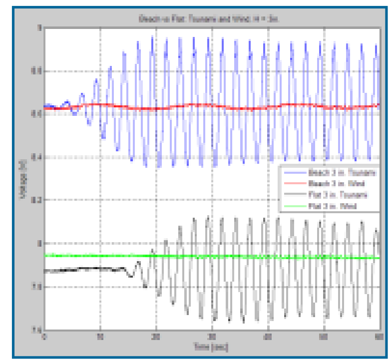


DART System





Realistic Experiment: Wind 3 in. compared to Tsunami 1 in. Beach and Flat Comparisons

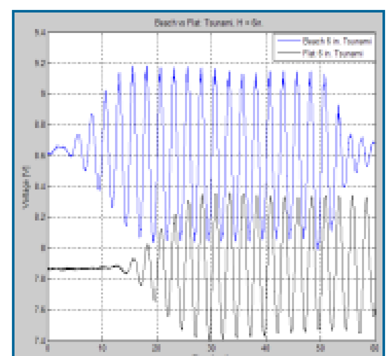


Beach vs. Flat Comparison 1 inch and 3 inches

Hydro Lab

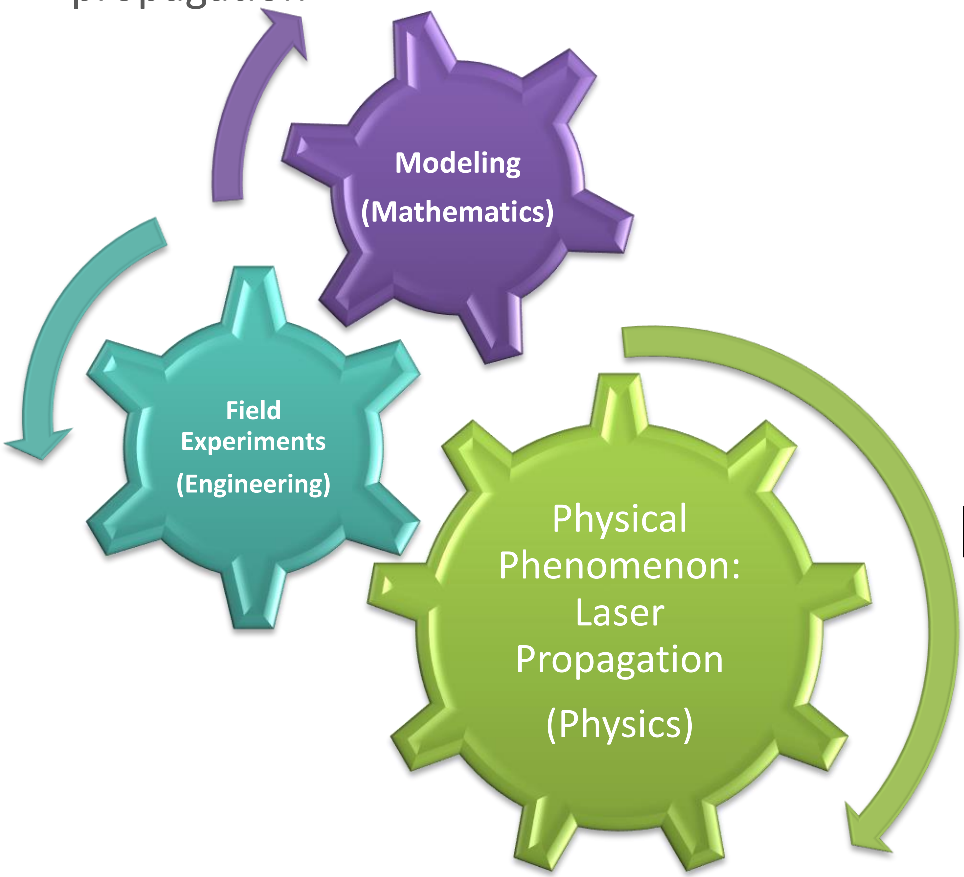
120 ft long,
8ft long,
5ft deep has beach

Results: Beach Compared to Flat, Level Floor



Beach vs. Flat Comparison 6 inches, Tsunami Only

Field experiments: True environmental changes along the entire path are occurring simultaneously, influencing laser light propagation



Field Experiments

Laser Beam Propagation In Maritime Environment

Olga Korotkova, Physics Department, University of Miami, FL

Svetlana Avramov-Zamurovic, Weapons and Systems Department, USNA

Charles Nelson Electrical and Computer Engineering Department, USNA

Reza Malek-Madani, Director of Research, Mathematics Department, USNA

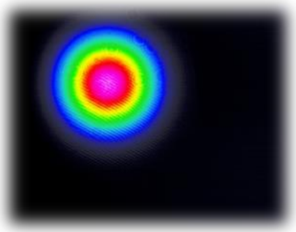
Analysis of Gaussian Beam Distribution Qualities of a Helium-Neon Laser

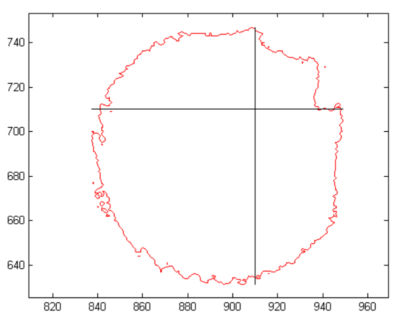
MIDN Steven T. Hallgren, MIDN Thorys J. Stensrud

The intensity and physical size of the emitted Gaussian laser beam is expected to vary over the path of propagation according to factors determined by the construction of the laser and environmental components.

The beam passes through an absolute minimum of size and intensity as opposed to expanding uniformly over the entire path.

Photograph of Gaussian beam profile

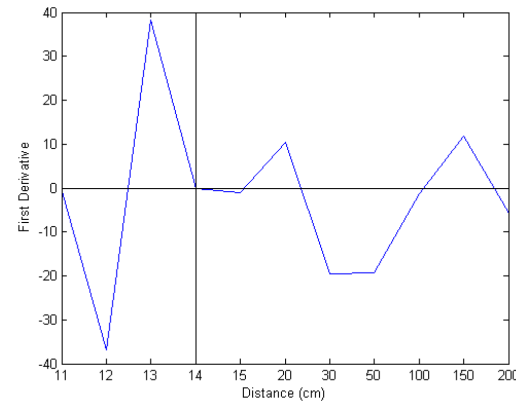




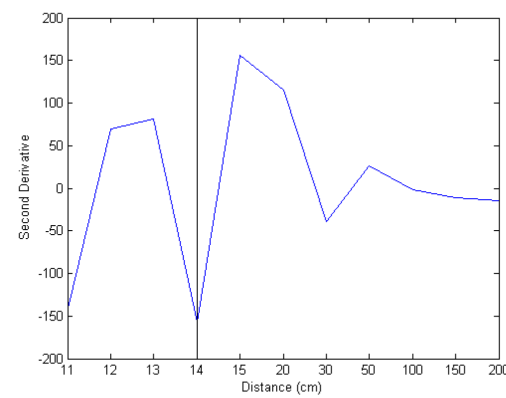
Gaussian beam contour at 14 cm distance from the laser

Beam waist is manifested as a physically smaller spot radius.

Differential calculus predicts that the beam equation at the waist will have a first derivative equal to zero and a second derivative equal to some maximum curvature.



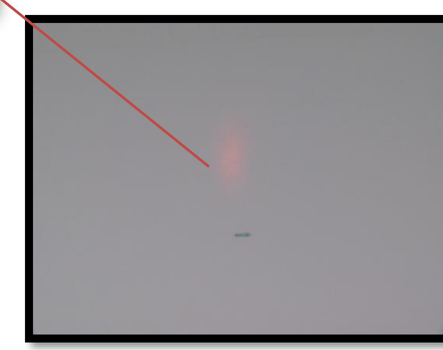
First derivative data averaged over all diameters. Note the near-zero value at 14cm.



Second derivative data averaged over all diameters. Note the absolute minimum value at 14cm.

College Creek Test

College Creek site with 400 m long laser link. Experiment 18 June 2010. Source is low power (4 mW) red He-Ne laser with an expander, creating 1 cm wide Gaussian beam. Target is a white board. Light intensities amplitude range of 255 was measured. Sequencing 30 frames per second three minutes of data collected. Pixel size was effectively measuring 0.3 mm^2 . Spacial coherence radius for our Gaussian beam is on the order of 1 cm.

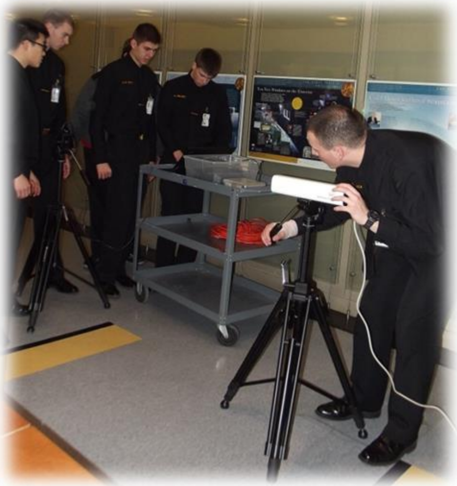


Weather conditions at Hospital Point on June18, 2010							
Time	Temp	Humidity	Sea Level Pressure	Wind Dir	Wind Speed	Gust Speed	Conditions:
9:54 AM	73.0 °F	57%	30.13 in	North	none	none	Clear
10:54 AM	75.0 °F	53%	30.13 in	none	none	none	Clear

Classes with Field Experiments

- Introduction to Laser Research
- Mathematics of Light
- Directed energy: naval applications of lasers

- Control Systems and their Applications to Weapons
- Control systems modeling and simulation
- Modern control systems



Discussion

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SHARPSHOOTER

Andrew Sharp

Prof. Avramov-Zamurovic

Problem Statement

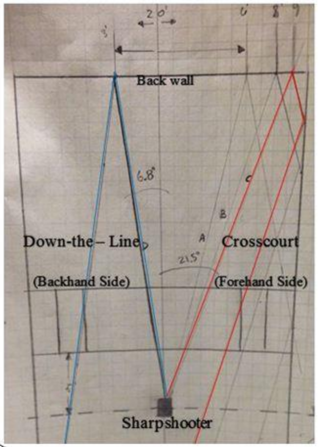
- The effectiveness of "solo practice" is not trivial, but it is inherently limited by the player's current level of skill.
- The Sharpshooter is meant to provide realistic simulation of specific racquetball shots in order to allow a player to improve his game without the help of a coach or a competitor with whom to practice.

Similar Devices

- JUGS pitching machines
  - Baseball, football, tennis, cricket, field hockey, etc.
- Squash Cannon

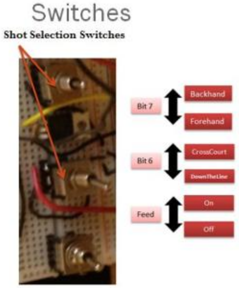
Device	Launch Velocity
JUGS Machine	90mph
Squash Cannon	>100 mph
Sharpshooter	**60 mph**

Aim Angle Determination



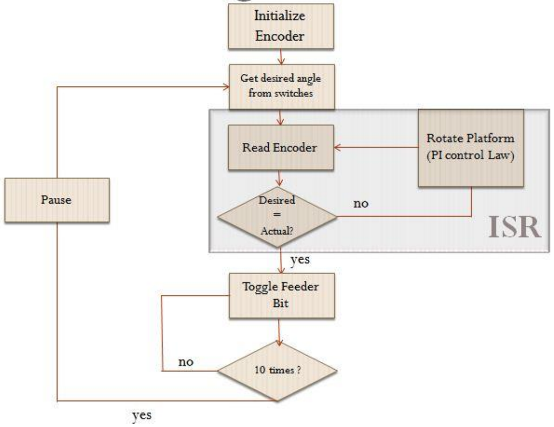
- Red line indicates flight path of crosscourt forehand shot (21.5° CW)
- Blue line indicates flight path of backhand down the line shot (6.8 ° CCW)

Switches



- Switches connect to digital input/output port on Rabbit
- Position of switches determines shot produced

Software Design Phase

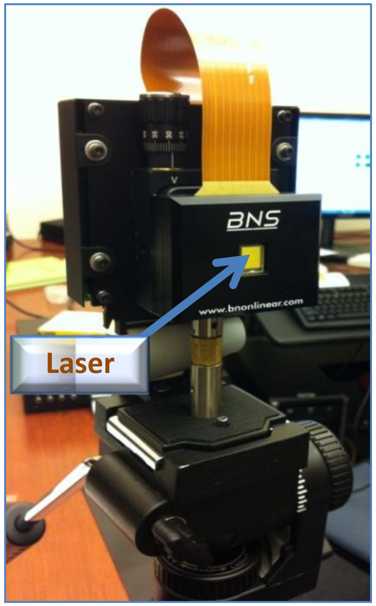


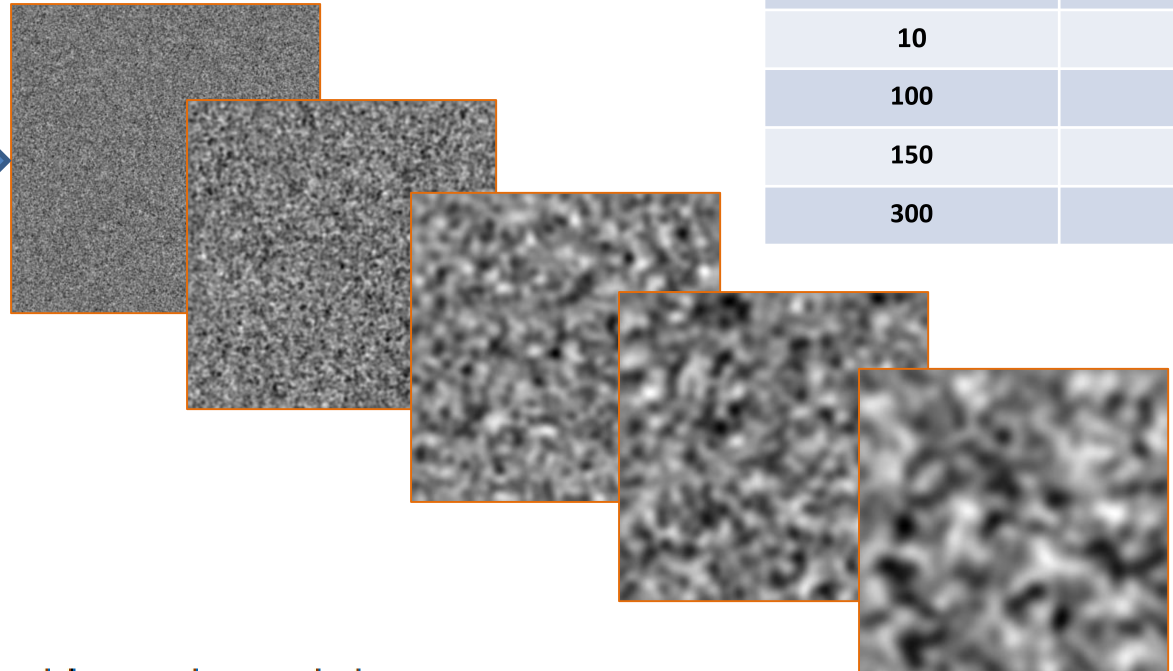
Performance Metrics Achieved (ES402)

Objective	Metric
Accuracy / Precision	On average, 5 of 10 balls go where they're supposed to go.
Power (muzzle velocity)	60mph
Rate of Fire	5 shots / 50 seconds
User Friendly	No manual required (min accetpable: 2 page pamphlet manual required)
Functional Versatility	Capable of six different shots (min acceptable: 4 different shots)
Safe	No accidents at all (min acceptable: 1 fatal accident)
Quiet	Very loud, irritatingly so.

SLM – Phase Screens

$(\text{Gamma\_phi})^2$	~Speckle Size (mm)
1	0.02
10	0.06
100	0.2
150	0.24
300	0.34

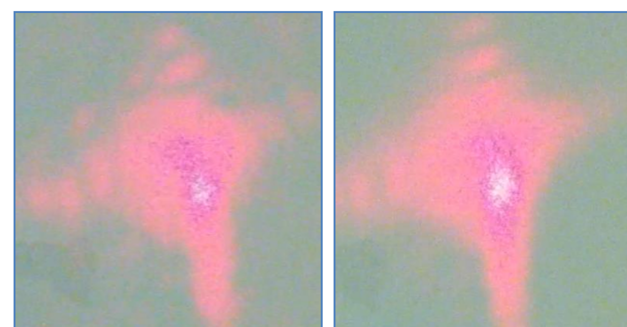




$$R_\varphi(\rho) - \; random\ function\ with\ Gaussian\ statistics, zero\ mean$$

$$f_\varphi(\rho) = \exp\left(-\frac{\rho^2}{\gamma_\varphi^2}\right), window\ function$$

$$g_\varphi(\rho) = \int f_\varphi(\rho - \rho')R_\varphi(\rho')d^2\rho', convolution\ integral$$



T. Shirai, O. Korotkova, E.Wolf, "A method of generating electromagnetic Gaussian Schell-model beams," *J. Opt. A: Pure Appl. Opt. 7 (2005) 232-237*