Integrating Experimentation and Instrumentation in Upper-Division Physics

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Motivation

- Knowledge and understanding of measurement and instrumentation is essential for any physicist
- At KSU, all B.S. physics majors take:
  - *Modern Physics Lab (MPL)* in 1st semester of soph. year,
  - *Advanced Physics Lab (APL)* in 2nd semester of soph. year
  - *Physical Measurements and Instrumentation (PMI)* in their junior or senior year

Can we integrate these learning experiences?

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Capstone Project Goals

1. Continuity of education over these three courses,
2. Re-learning of important concepts in modern physics, and
3. Application of newly learned material of electronic measurement and instrumentation in a laboratory environment.

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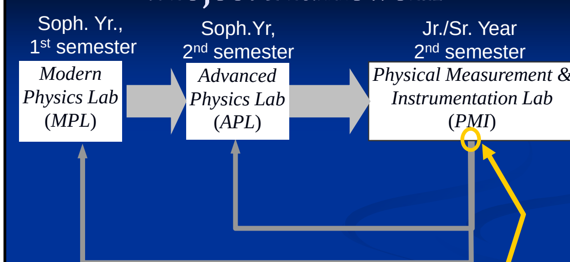
Project Framework



Students revisit experiments in *MPL* and *APL* and design electronic instrumentation and analysis software using LabVIEW™.

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Capstone Project List

- **Photoelectric Effect**
- **Franck-Hertz Experiment**
- **Speed of Light**

MPL

- **X-Ray Spectroscopy**
- **Saturated Absorption**
- **Mössbauer Effect**

APL

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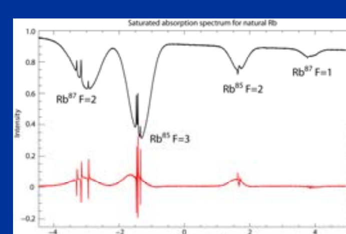
Saturated Absorption: Overview

- When a beam of photons is passed through a vapor, photons whose energy matches transition energies from the ground state to excited states in the atoms of the vapor will be resonantly scattered.
- By measuring the apparent absorption in the beam as a function of photon energy one can thus determine the excited level structure of the absorbing vapor atoms.



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Saturated Absorption: *APL* Experiment

- In *Advanced Physics lab* students use the absorption of light from a tunable diode laser to explore the energy levels of Rubidium.
- By measuring the absorption versus laser frequency they observe four broad absorption peaks
- By employing standard sub-Doppler techniques, further resolve those peaks to reveal the hyperfine structure.

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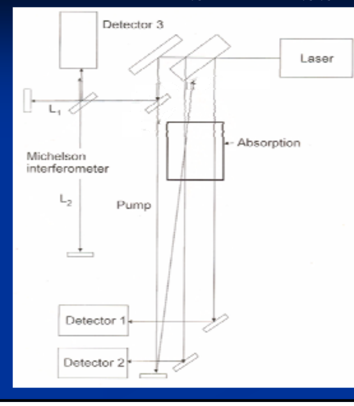
Saturated Absorption: Apparatus



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Saturated Absorption : Capstone Goals

Physics Goals

- Understanding saturation spectroscopy in Rubidium.
- Understanding the physical mechanism behind the reduction in absorption.
- Understanding the physical principles underlying a Michelson interferometer.

Instrumentation Goals

- Learning to write a LabVIEW™ program to control the diode laser and collect interferometer and absorption photodetector voltages.
- Learning to write a LabVIEW™ program to acquire and import data acquired by computer into an Excel-compatible spreadsheet for further analysis.

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Saturated Absorption

LabVIEW Program Demo

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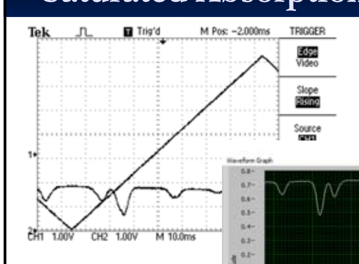
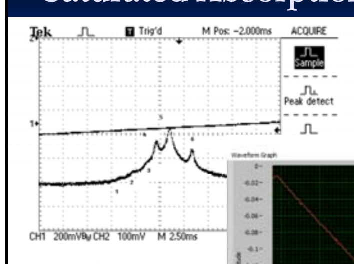
Saturated Absorption: Ground State



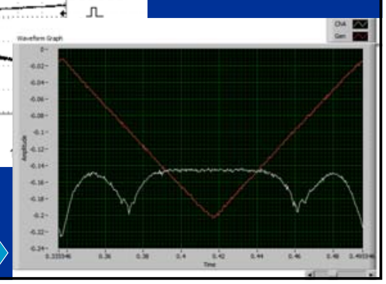
Digital Oscilloscope (APL)

LabVIEW Program (PMI - Capstone)

Saturated Absorption: Excited State



Digital Oscilloscope (APL)

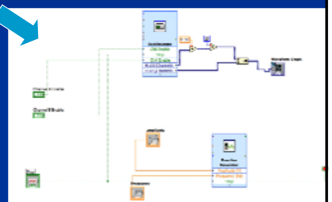


LabVIEW Program (PMI - Capstone)

Saturated Absorption : Conclusion

After completing this project, students would have

- Written a LabVIEW™ program to control the diode laser and collect interferometer and absorption photodetector voltages.
- Written a LabVIEW™ program to acquire and import data acquired by computer into an Excel-compatible spreadsheet for further analysis.



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Franck Hertz : Overview

- This experiment demonstrates the quantization of energy levels of isolated atoms.
- Capstone Project: Students use NI ELVIS™ and LabVIEW™ programming to record and analyze data.

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Frank Hertz : Capstone Goals

Physics Goals

- Understanding the reasons for quantization of energy levels of gas atoms.
- Understanding how to detect and compute these levels from a measurement of tube current.

Instrumentation Goals

- Learning how analog-to-digital conversion can be used in order for a computer to read and control analog voltages to control an experiment.
- Learning to write a LabVIEW™ program to read in the amplified tube current.

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Frank Hertz

LabVIEW Program Demo

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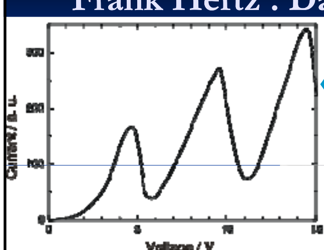
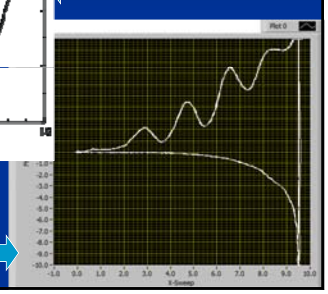
Frank Hertz : Data Collection



Theoretical Result



Experiment (PMI - Capstone)

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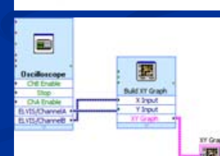
Frank Hertz : Conclusions

After completing this project, students would have

- Learned how analog-to-digital conversion can be used to read and control analog voltages:
  - They will use NI ELVIS interfaced with a computer to read and control experiment
- Learned to write a LabVIEW™ program to read in the amplified tube current.



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Speed of Light : Capstone Goals

Physics Goals

- Understand how to measure the speed of light.
- Understand the essential role of uncertainty in the measurement.

Instrumentation Goals

- Design a high-speed timing circuit.
- Write a Lab-VIEW™ program to record a series of timing interval measurements and calculate statistics on the resulting data.
- Assess the uncertainty in their instrumentation and therefore in the final measurement of the speed of light.

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Speed of Light: Overview

- Measure the speed of light directly with a pulsed nitrogen laser.
- The students measure the difference in arrival time between the two pulses on the photodetector, which are separated in time by about 100 ns.

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Speed of Sound

Resolution needed to measure speed of Light exceeds our capabilities, so speed of sound

- Same principle and similar process as Speed of Light
- Two Microphones are placed on different places with a distance D.
- Sound signal is produced very close to one Microphone and thus distance D to another one.
- Measure the time difference between two sound signal.

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Photoelectric Effect : Capstone Goals

Physics Goals

- Understanding the quantization of electromagnetic radiation.
- Understanding the photoelectric effect and how it is evidence of the quantization of electromagnetic radiation

Instrumentation Goals

- Understanding how to use an ADC to send and measure voltages to an experiment.
- Learning to write a LabVIEW™ program for the automation of an experiment.

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Mössbauer Effect: Capstone Goals

Physics Goals

- Understanding the principles underlying the Mössbauer effect.
- Understanding how the Mössbauer effect can be used to observe Zeeman splitting of nuclear states and to measure the magnetic field seen at the site of the nucleus in natural iron.

Instrumentation Goals

- Understanding how analog-to-digital conversion can be used in order for a computer to read and control analog voltages to control an experiment.
- Learning how to design a simple amplifier for the measurement of small voltages.
- Learning how to write a LabVIEW™ program to perform statistical calculations from the data from the multi-channel analyzer.

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X-Ray Spectrometer : Capstone Goals

Physics Goals

- Understanding the principles of x-ray production.
- Understanding the principles of x-ray diffraction.

Instrumentation Goals

- Learning the operation of stepper motors and the hardware that controls them.
- Learning to write a LabVIEW™ program that will control a stepper motor.

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Future Work

- Develop assessments to evaluate student learning after completing these capstone projects.
- Introduce two more important experiments into the APL course and their PMI capstone projects
  - Teach Spin™ NMR
  - Magneto Optical Trap (MOT).