Senior Laboratory

PHYC 493L, Spring 2019

Webpage: http://physics.unm.edu/Courses/Becerra/Phys493LSp19/

Lectures: Mondays, 12:00-11:50 am, P&A room 184

Lab Sessions: Room 116

- Monday and Wednesday 8:00-10:50

Instructor: Francisco Elohim Becerra
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Office: P&A, room 19

Teaching Assistant: Xuefeng Li
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Office: P&A

Office hours: arrange meeting with instructor or TA via email.

Senior Lab 493L

- **Description**

  Lab course: experiments in particle physics and atomic molecular and optics (AMO) for advanced undergraduates. Students will perform experiments related to:

  - Quantization and Wave-particle duality
  - Nuclear decay, lifetime measurements, and particle physics
  - Photon and coincidence counting
  - Atomic structure and laser physics
  - Interferometry and metrology

- **Goals**

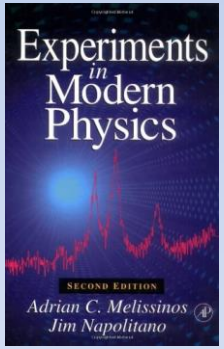
  - Obtain experience of an advanced physics laboratory
  - Verify fundamental concepts in quantum mechanics
  - Learn how to document, present and communicate your work
  - Learn technical skills in experimental physics

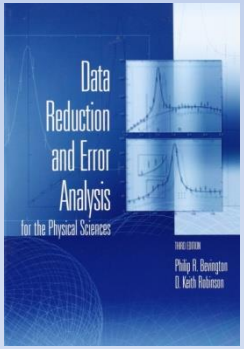
Course Materials

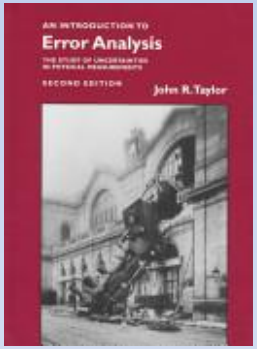
- **Textbook**

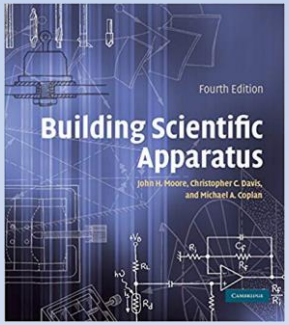
There are many good books. See website for references

- *"Experiments in Modern Physics"* A. C. Melissinos and J. Napolitano.
- *"Data Reduction and Error Analysis for the Physical Sciences"* P. R. Bevington
- *"Building Scientific Apparatus 4th Edition"* John H. Moore, Christopher C. Davis, Michael A. Coplan









- **Other resources**
  - Books, journal articles, Web , etc. (See class page for additional references)

Senior Lab 493L

- **Course Structure**
  - Lectures only for student presentations at the end
  - Two lab session per week: 4 experimental modules (7 sessions each)
  - **3 experimental modules** from 6 available
  - **1 module** for machine shop
  - **Lab notebook** (electronic with google docs)
  - **3 formal reports + 1 for machine chop**
  - **Oral Presentation**

Grading

Lab Notebook	10%
3 Formal Reports (20% each) Performance and report	60%
Machine shop mod. with report 10% Final quiz 10%	20%
Oral Presentation	10%
Total	**100%**

Machine shop module

- **7 sessions. Total 21 hours**
- **Topics: Elementary machine shop skills**
  - Milling machine, Lathe, belt sander
  - Create basic multi-view orthographic 2D engineering prints
  - Drawing standards and nomenclature
  - Fabrication
  - Learn how to work with machine equipment, shop safety and critical shop skills.

Evaluation based on
-Performance, technical drawing and report
-Final quiz

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Experimental modules

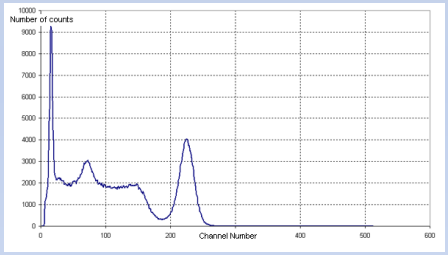
- 7 sessions. Total 21 hours each

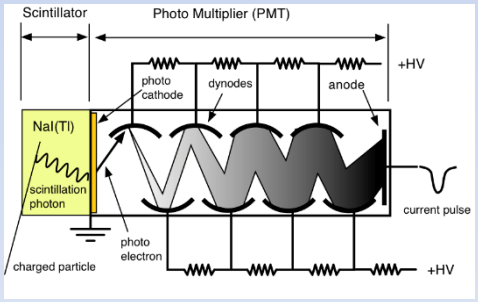
- Nuclear physics
- Wave meter
- Single photon interference
- Doppler velocimetry
- Lock-in amplifier
- Saturated Absorption Spectroscopy

Nuclear physics

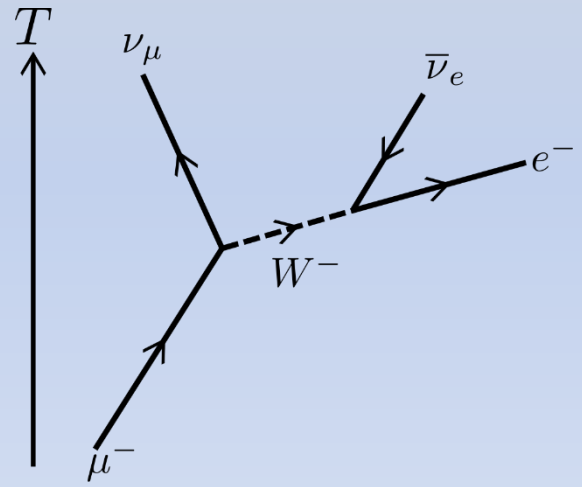
- **Spectroscopy of gamma rays from radioactive material**
- **Muon decay**

Gamma ray spectroscopy





Muon decay: Weak interactions



The muon a constituent of cosmic-ray particle "showers". 1936 Carl D. A. and S. Neddermeyer.

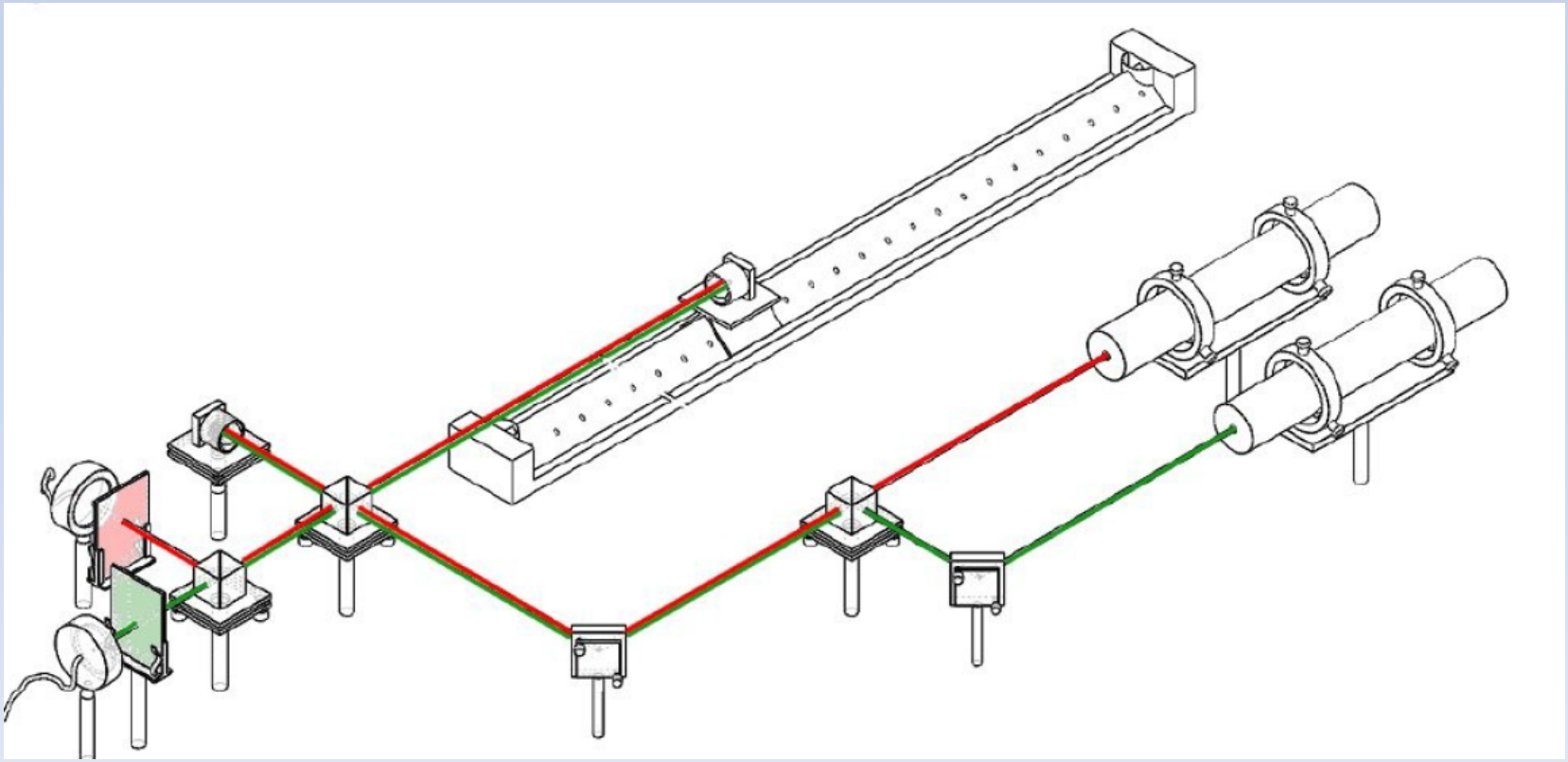
$$\mu^+ \longrightarrow e^+ \ \nu_e \ \bar{\nu}_\mu$$

$$\mu^- \longrightarrow e^- \ \bar{\nu}_e \ \nu_\mu$$

Wavemeter

- **Using a known reference laser**
- **Measure the wavelength of a second laser bis interference**

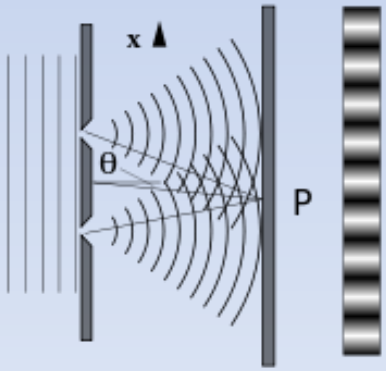
Beam alignment; interferometry; stability; calibration and nonlinear effects correction for frequency metrology

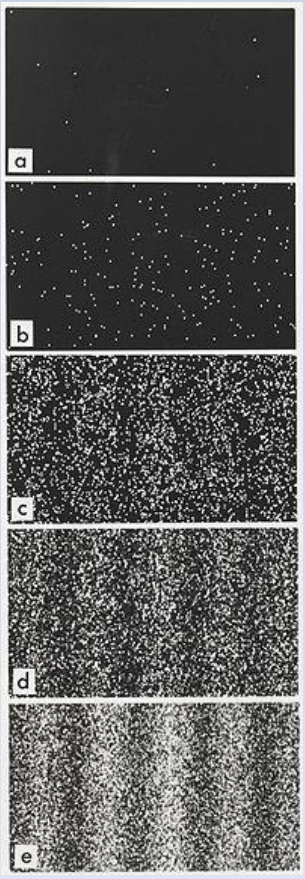


Single photon interference

Concepts:

- Wave particle duality
- Photon flux
- Calibration
- Photon counting
- Diffraction of particles





Doppler velocimetry

- **Interference and light shifts**

Concepts:

- Optical arrangement
- Interferometry
- Optical pathlength calculations
- Frequency mod. detection techniques

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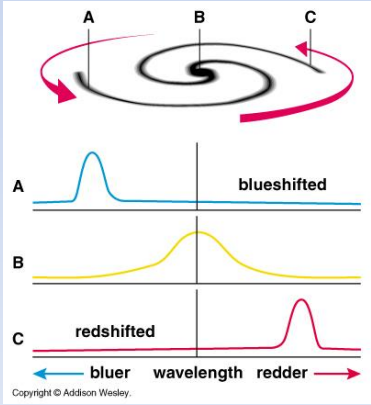
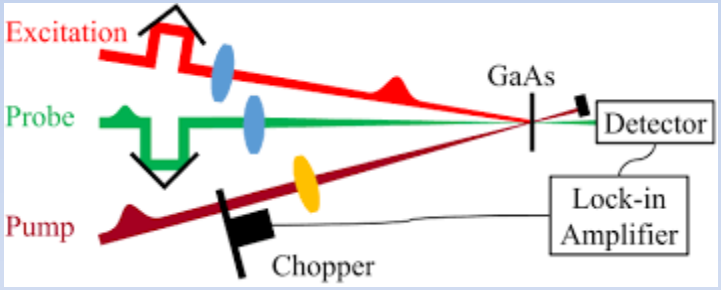


Lock-in Amplifier

- **Detection of ultra weak signals << background**
- **Develop experiment to implement locking detection**

Lock in amplification is a coherent detection technique that is very useful in experimental physics.



Observation of Nondegenerate Two-Photon Gain in GaAs. PhysRevLett.117.073602

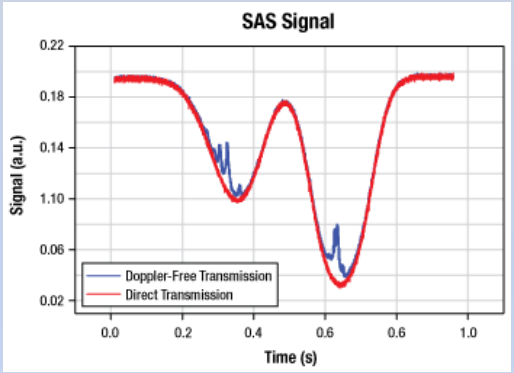
ROBERT H. DICKE

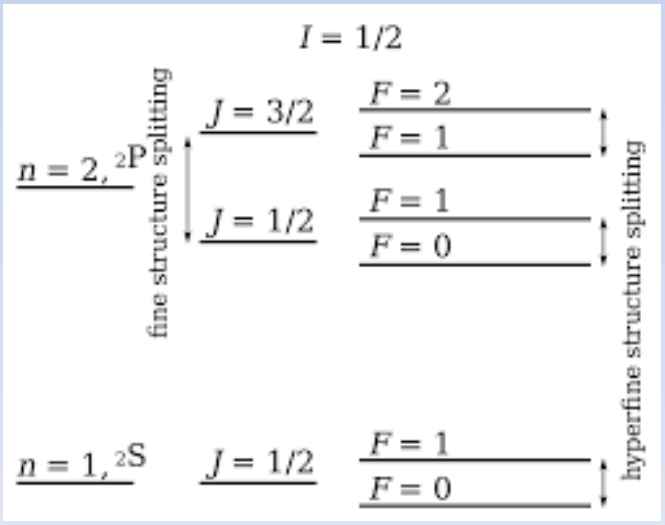
Saturated Absorption Spectroscopy

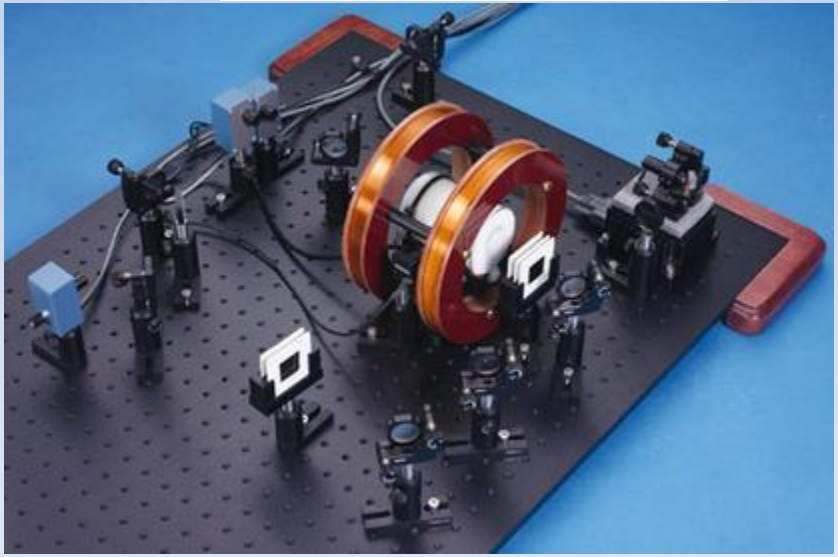
- **Sensitive laser absorption spectroscopy in Rb atoms**

Concepts:

- **External cavity diode laser**
- **Atomic quantization**
- **Sin-orbit coupling**
- **Hyperfine interactions in atoms**
- **Interferometry as a frequency reference**







Lab Notebook

- **Each student develop an Electronic Lab Notebook (google docs)**
  - One google doc for experimental module
  - Use figures, photons, pictures, detailed descriptions of setup, etc.
  - Include important information such as experimental parameters, etc.
- **For each experiment (see guide in class website for specific details)**
  - **Brief description** of objectives and physics behind the experiment
  - **Description of experimental procedure** and techniques, diagrams and plots.
  - **Data collection, and analysis.** Include graphs
  - **Estimated uncertainties**
  - **Results with uncertainties** with units.
  - **References** to books, articles and links

Instructor periodically looks through notebooks unannounced.

Graded on completeness and clarity of information.

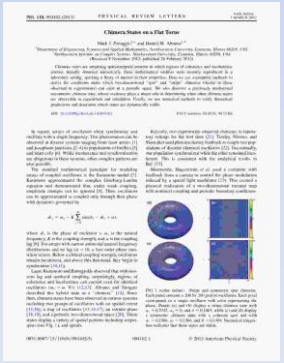
Formal Reports

Formal reports are based on experiments that you performed.

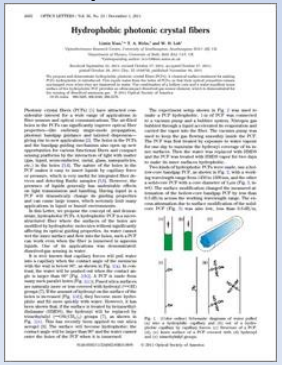
Should follow the style of a scientific journal (Typed, one or two columns)

- **Main sections (see guide in class website for specific details)**
  - **Abstract**: concise description of methods and results.
  - **Introduction**: motivation, background and summary of experiment
  - **Methods**: description of experimental methods and calibrations
  - **Data**: present the data, use plots or/and tables
  - **Results and data analysis**: describe how the data analysis was done and present your results with errors
  - **Discussion**
  - **Conclusion**
  - **References**
  - **Appendix if necessary**

Phys. Rev. Lett.



Opt. Lett.



- **Purpose**
  - Gain familiarity with formal writing style of scientific journals

Oral Presentation

15-minute Oral Presentation based on an experiment. It will be followed by questions (about 5 minutes) from students, TA and instructor.

- **Suggested outline**
  - Motivation
  - Theoretical background
  - Brief description of the experiment
  - Brief description of data collection process
  - Results and discussion with error analysis
  - Application of the physics learned in technology /fundamental research
  - Conclusion
- **Purpose**
  - Strengthen your communication skills
  - Think how to present your results to a broad audience and defend your ideas

Grading

Tentative schedule (subject to revision)

Date	Description
02/18 (M)	1st Formal Report (via email 5pm)
03/20 (W)	2 nd Formal Report (via email 5pm)
04/15 (M)	3 rd Formal Report (via email 5pm)
05/08 (W)	4 th Formal Report (via email 5pm)

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***Late work policy*:** *Late work within 3 days after the deadline is accepted for 75% credit.*
Late work within 1 week after the deadline is accepted for 50% credit.
No credit is given after that.

Oral presentations at the end of the semester

Please check course website for updates

Lab Safety

- **Footwear**.- Closed-toed shoes with a covered heal (tennis shoes, leather shoes, etc.)
- **Electrical**.- Some experiments use HV supplies. Look for damaged cables or faulty connections.
- **No food or drinks**.- Do not eat or drink in the laboratory. Any spill can cause irreversible damage to equipment and can cause an accident when working with or near HV equipment.
- **Broken or nonworking equipment**.- Report any nonfunctioning equipment to the lab instructor or the TA.
- **Secure rooms**.- Close the door behind you when you leave or you go out of the laboratory for a short period of time (some experiments use HV and or radioactive materials).

Lab Safety

- **Broken glass**.- Do not deposit chipped or broken glass in normal trash containers. Use a glass bin.
- **No loose ends**.- Tie your shoelaces and long hair must be tied back.
- **House keeping**.- Clean up and make sure everything is safe before you leave. Keep your work area in order. Do not block passages or exits with cables or equipment.
- **Report any accident or concern to the instructor or TA**
- **Before doing an experiment**.- Talk to the instructor or TA about the safety concerns of each experiment and any special instructions for working with sensitive equipment.
- **Laser-based experiments**.- Read specifications. Use laser-safety glasses.
- **Use caution when handling radioactive material**.

Machine shop module

- **7 sessions. Total 21 hours**

- **Topics: Elementary machine shop skills**
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