Senior Laboratory

PHYC 493L, Spring 2020

Classes: Mondays, 8:00-11:50 am
Wednesdays, 8:00-10:50 am
Location: PAIS 1417

Instructor: Tara Drake
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Office: PAIS 2234 and CHTM 118B

Teaching Assistant: Xuefeng Li
Email: xuefengli@unm.edu

Office Hours: arrange meeting with instructor or TA via email

Senior Lab 493L

Overview

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

- Develop independent problem-solving and laboratory skills
- Learn/practice effective technical writing and oral presentation skills

Senior Lab 493L

Course Structure

- Work in teams of 2 (or 3 if necessary)
- Two lab session per week: 4 experimental modules (7 sessions each)
- **3 experimental modules** from 5 available
- **1 module** for machine shop
- **Oral Presentation** on one experimental module

Experimental modules

3 + 1 modules required

7 sessions per experiment

Report due 1 week after

- **Machine Shop (mandatory)**
- **Nuclear physics**
- **Wavemeter**
- **Single photon interference**
- **Doppler velocimetry**
- **Saturated Absorption Spectroscopy**

Machine shop module

- **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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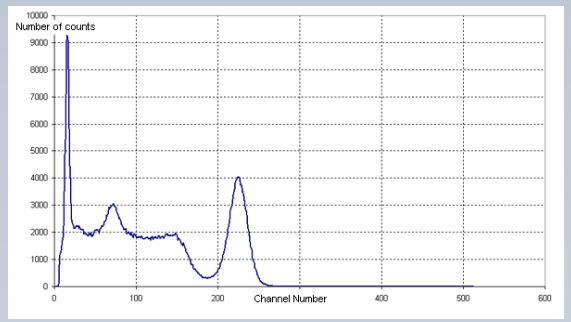
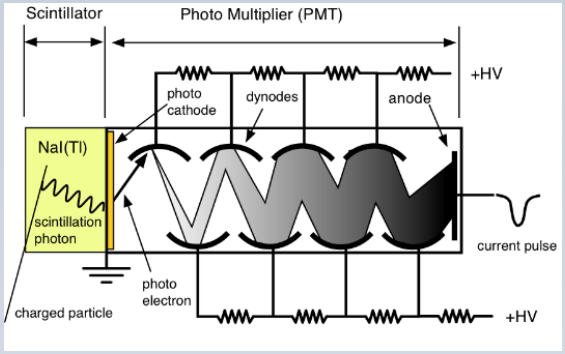
Nuclear physics

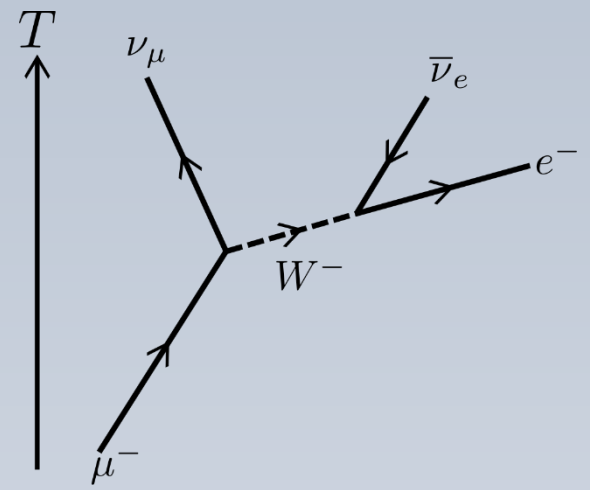
- **Spectroscopy of gamma rays from radioactive material**
- **Muon decay**

Gamma ray spectroscopy





Muon decay: Weak interactions



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

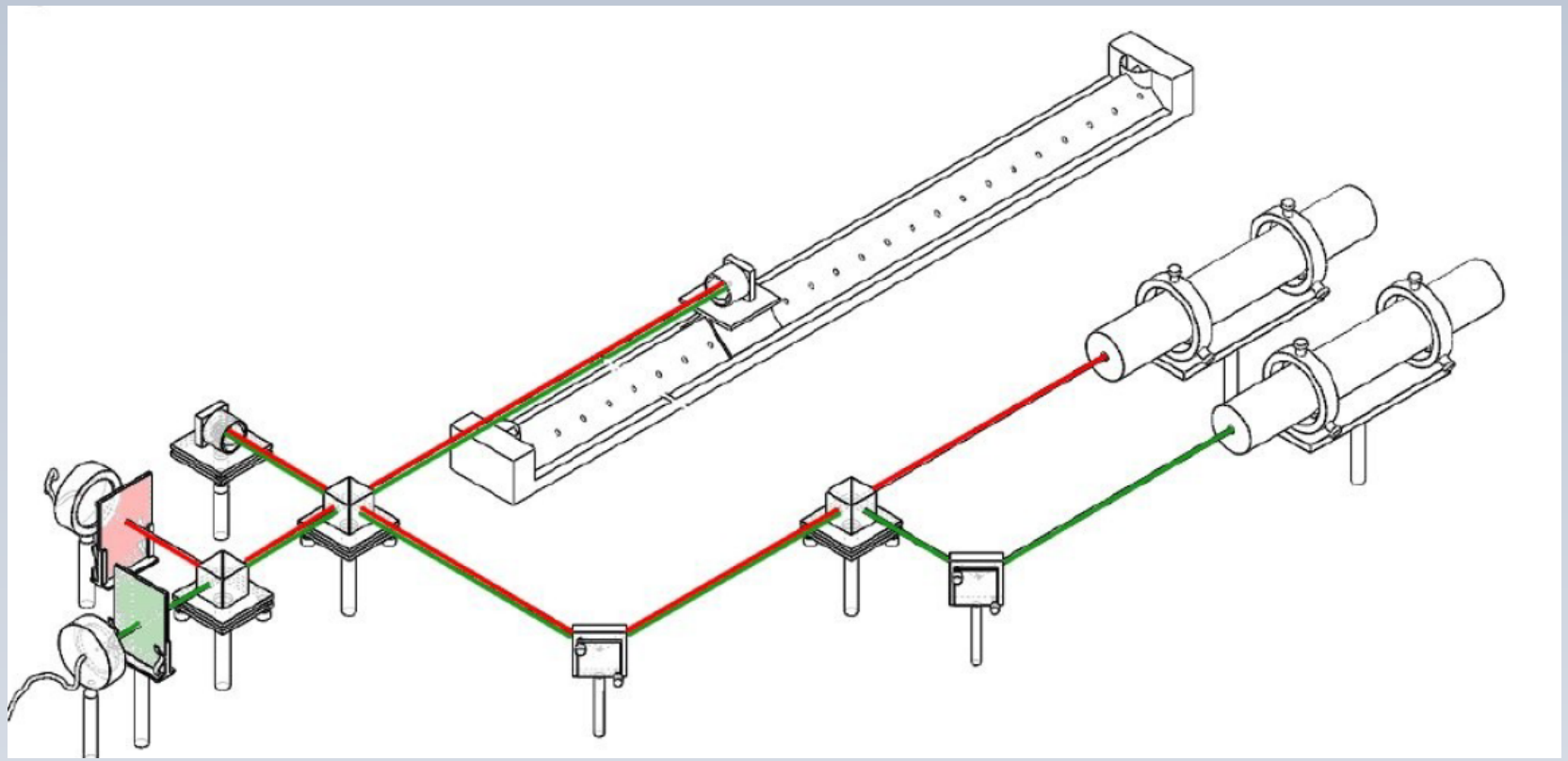
$$\mu^+ \longrightarrow e^+ \ \nu_e \ \bar{\nu}_\mu$$

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

Wavemeter

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

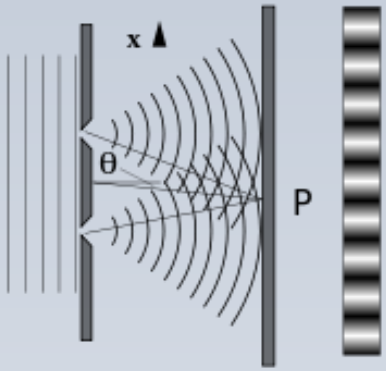
Beam alignment; interferometry; stability; calibration and nonlinear effects correction for frequency metrology

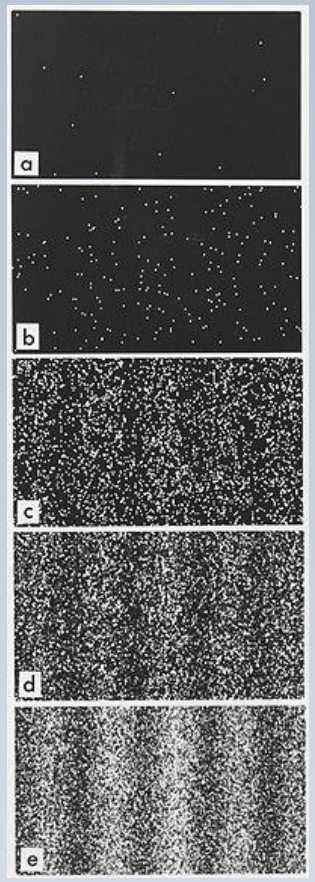


Single photon interference

Concepts:

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



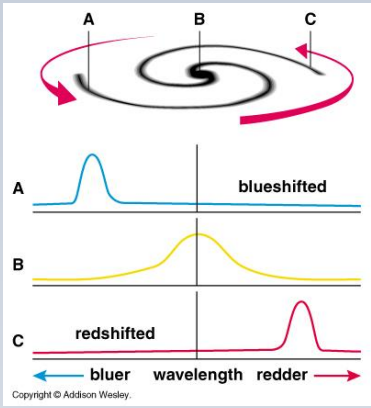


Doppler velocimetry

- **Interference and light shifts**

  Concepts:

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

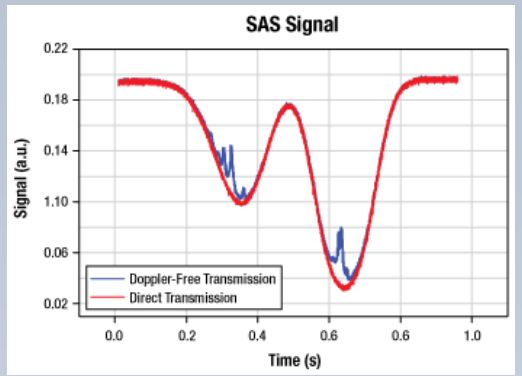


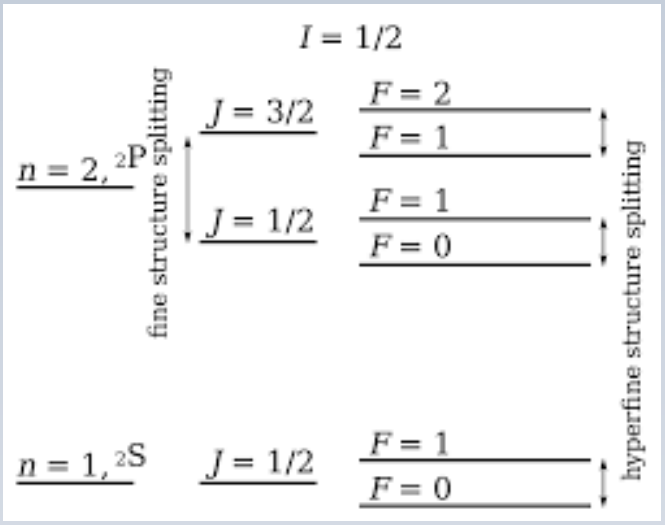
Saturated Absorption Spectroscopy

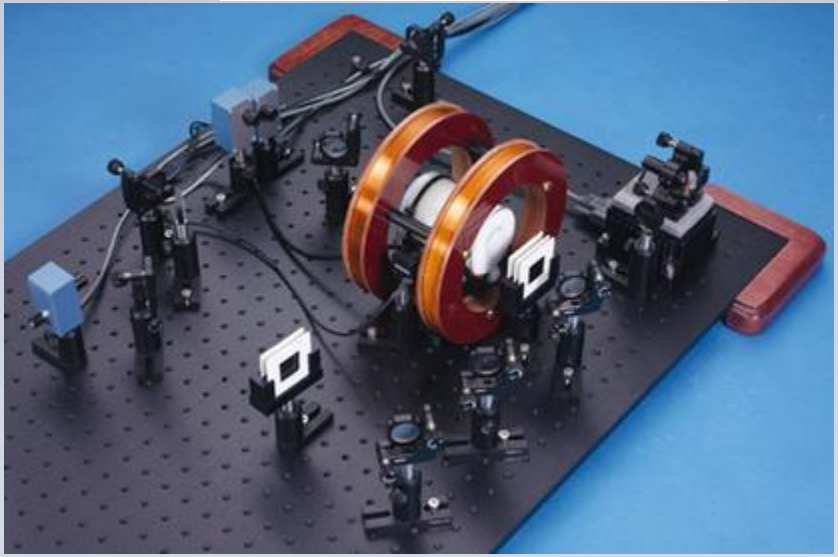
- **Sensitive laser absorption spectroscopy in Rb atoms**

Concepts:

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







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Introductions

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Special Circumstances

Class Participation

Students must attend each lab session unless explicitly excused by the instructor.

Students will work in teams of 2. Rotation of teammates at the completion of each experiment is encouraged (and may be changed to compulsory). Students are expected to share responsibilities in an equitable fashion, and each student is expected to develop a complete, independent understanding of the work.

Participation is important, especially when all work is done in groups, and unexcused absences will affect your class participation grade. Before approaching instructor, please negotiate with your teammate(s) how work will be shared.

Lab notebooks will count towards participation.

Lab Notebook

- **Each student develop an Electronic Lab Notebook (google docs)**
- Students are expected to bring a laptop to each class.
- At the beginning of every experiment, each team will begin a Google Doc to serve the joint lab notebook for that experiment, and share it with **drakete@unm.edu** and **xuefengli@unm.edu**.
- The lab notebook should be detailed, clear, complete, and updated every class. You will be graded on the completeness and clarity of your notes-- **using your lab notebook, a third party should be able to reproduce your work**.
- Specific style and format is less important than completeness:
  - Use figures, photos, drawings, detailed descriptions of setup, etc.
  - Include important information such as experimental parameters, etc.
- The instructors will periodically look at your lab notebook; this will count towards your class participation grade.

Lab Reports

Each student produces a separate formal report based on experiment.
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**
- **Purpose**
  - Gain familiarity with formal writing style of scientific journals

Phys. Rev. Lett.


PHYSICAL REVIEW LETTERS

Chimera States on a Flat Torus

Opt. Lett.


Hydrophobic photonic crystal fibers

→ Document with guidelines available on class website.

Oral Presentation

20-minute Oral Presentation based on an in-class experiment. It will be followed by questions (about 10 minutes) from students, TA and instructor.

- **Purpose**
  - Strengthen your communication and presentation skills
  - Think how to present your results to a broad audience
  - Learn how to respond to questions and defend your ideas
- **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

Topics and teams must be proposed to instructor in advance (tbd). **Practice talks with instructor are highly encouraged.**

Grading

Tentative schedule (subject to revision)

Date	Description
02/19 (W)	1st Lab Report due
03/23 (M)	2nd Lab Report due
04/15 (W)	3rd Lab Report due
05/11 (M)	4th Lab Report due
05/06 (W)	Oral Presentations

Class Participation + Lab Notebook	10%
3 Formal Reports (20% each)	60%
Machine shop mod. With report 10% Final quiz 10%	20%
Oral Presentation	10%
Total	**100%**

Late work policy: *Late reports will be marked down one full letter grade for each class that passes after report is due.*

In some cases, it may be possible to resubmit a report with revisions for more credit.

Please check course website for updates (on physics.unm.edu soon)

Lab Safety

- **Footwear**.- Closed-toed shoes with a low, covered heal.
- **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 room**.- Close the door behind you when you leave or you go out of the laboratory for a short period of time.

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.
- **Use caution when handling radioactive material**. In most cases, only instructor or TA will handle.

Laser Safety

- **Training:** Complete laser safety training module on https://learningcentral.health.unm.edu/, "Laser Safety Training, UNM PandA", and send me evidence of completion.
- **Read laser specifications.**
- **Use laser-safety glasses.** (Provided with each laser experiment—get help to find some if not.)
- **Practice care, communication, and common sense:**
  - Most laser accidents occur during alignment, and many NOT to those aligning.
  - When laser is on, curtains are closed. (Otherwise, communicate to the room, distribute eyewear, and hang notes on doors.)
  - Remove jewelry and watches on hands, hanging necklaces, and anything else potentially reflective. Keep cell phones off lab tables and away from beam paths.

Today

- Complete laser safety training (learning central)
- Choose your partner
- Choose your experiment
  - One group goes to machine shop
- Three groups in lab: Share a google doc lab notebook with TA and myself

- First: quick snack in SPS office