Institute of Applied Physics
Friedrich-Schiller-Universität Jena

Experimental Optics

Introductory lecture (2014/2015)

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Goals of the course

- Experimental experience
- Team work experience
- Learn to write a scientific report

Contact:

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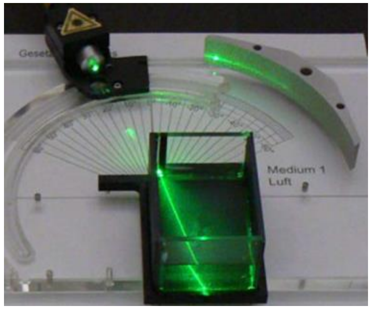
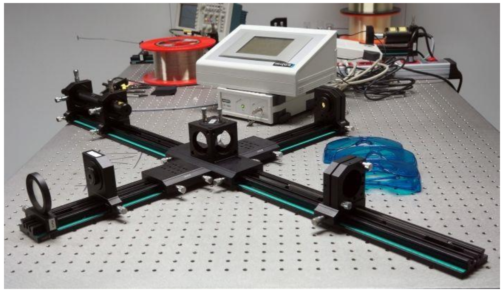
coordinator: Roland Ackermann, Tel: +49 3641 9-47821,
E-Mail: Roland.Ackermann@uni-jena.de

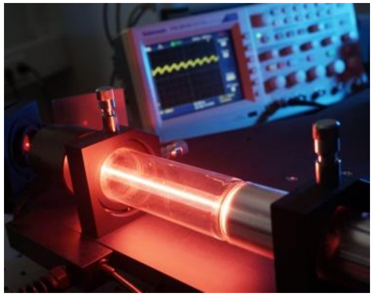
Teaching assistants (TAs) for labs: TBA

Program

- 8 experiments are scheduled
  - **6th (or 13th) January 2016: „Fundamentals“**
  - **Main part: 22rd February – 15th March**
  - **1st part: „Basics of optics“**
    - Fabry-Perot Interferometer
    - Michelson Interferometer
    - Spectroscopy
  - **2nd part: „Basics of lasers“**
    - He:Ne laser
    - Laser gyroscope
    - Nd:YAG-laser

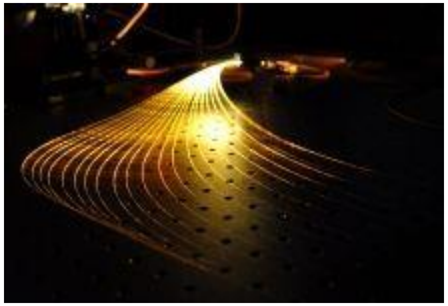






program

- 3rd part „laser applications“
  - Choice of two experiments:
    - Optical-Time-Domain-Reflectometry (OTDR)
    - Adaptive Optics
    - Optical Tweezers



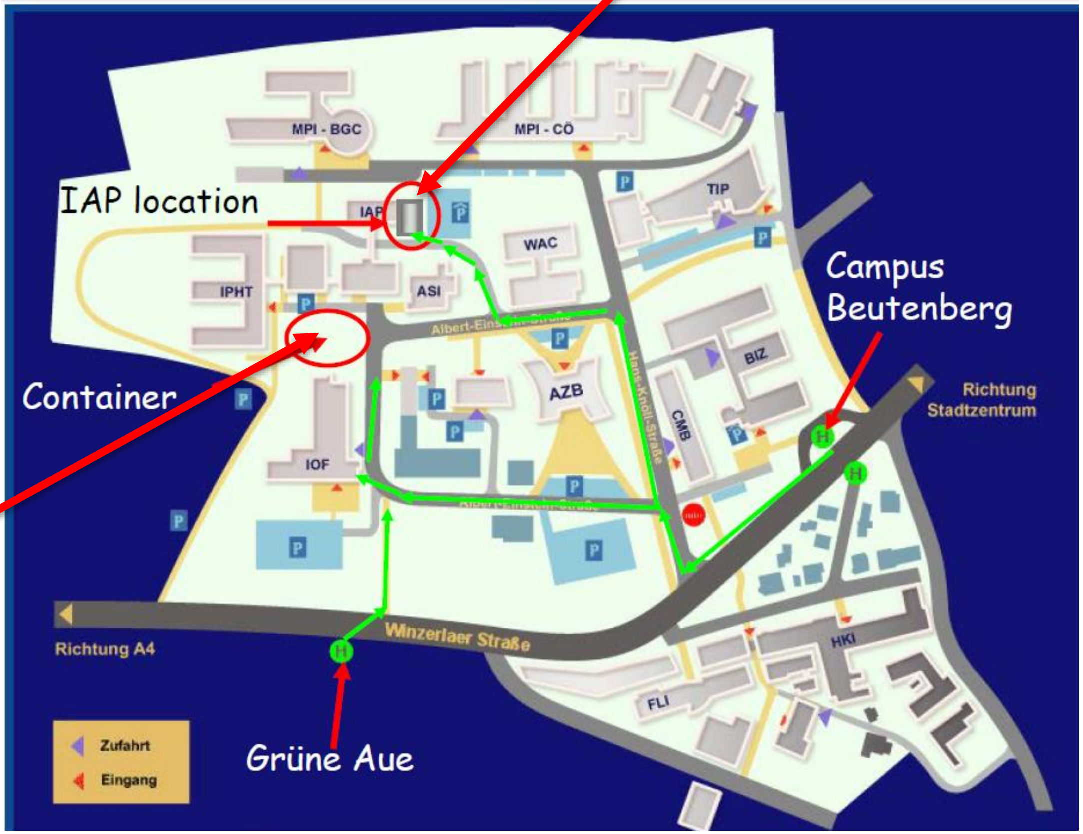
- Experiments are perfomed
  - every other day, i. e.
    - 1st day: experiment
    - 2nd day: homework (lab report, lab preparation)
    - …
  - in groups of 2 students

Site of the Course: Beutenberg Campus

- Buses: 10, 11, 12 ,13, bus stop: „Beutenberg Campus“
- „Fudamentals“ **(1/6/15 & 1/13/15)**
    - Institute of Applied Physics

      Albert-Einstein-Straße 15

      seminar room
- **Main course (2/22/15 – 3/15/15)**
    - **Albert-Einstein-Straße 9**
    - ‚container‘



Tasks for each lab

- **Homework: Lab preparation**
  - **carefully read the manual for your experiment**
  - **consult the cited literature**

  ⇨ **Be prepared to answer the „Preliminary Questions“ provided in section A of each manual**
- **The lab**
  - **Preliminary talk before each lab (~ 15 minutes)**
    - **Be ready to answer the „Preliminary Questions“!**
    - **Provide the necessary knowledge to perform the lab!**

    ⇨ **Succesful talk is a prerequisite for the experiment**
  - **Each Lab session (‚hands-on‘) ~ 4 hours**
  - **You receive an averaged grade for the talk and lab session**

Tasks for each lab

- The lab report
  - Each group writes a common report of (handwritten or computer)
  - Basic structure:

  0. Title page: Download from asp website

Experimental Optics

Abbe School of Photonics

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07743 Jena, Germany
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Lab Title:

Group number	
Student name(s)	
Name of TA	
Date of Lab	
Date of Final Report return	

Tasks for each lab

- The lab report
  1. Introduction
     - Provide a short introduction to the topic
     - E. g. sample report „Sound velocity measurements using ultra ound“ on (will be found on asp website)

1 Introduction

Sound travels through an elastic medium as a wave. It's velocity dependents on the temperature and the properties of the material the sound is traveling through. There exist various possibilities for measurements of the velocity of sound.

The aim of this project was to measure the velocity of sound waves in three different gases (air, argon and nitrogen) as a function of its physical parameters using at least two different methods. Then, with the results, the degrees of freedom of the gas molecules were to be determined.

Tasks for each lab

2. Theory

2 Theory

2.1 The Velocity of Sound

A sound wave is a longitudinal wave, the molecules of air are moving in the same direction as the wave itself. Sound passes through a media by compressing and expanding the distance between the atoms, transmitting energy between them. The velocity of sound through the media depends on the stiffness of the bonds between the particles and their weight.

From the equations of conservation of mass and momentum, under assumption of adiabatic condition, it can be deduced that the velocity of sound c_s is given by [1]

$$c_s = \sqrt{\gamma \frac{p}{\rho}}, \tag{1}$$

where p is the pressure, ρ is the density and γ is the adiabatic index. The adiabatic index is the ratio of specific heats of a gas at a constant pressure to a gas at a constant volume ($\gamma = C_p/C_v$, [1]).

- **Provide the theoretical background which is required to perform the experiment and to evaluate the results.**

Tasks for each lab

2. Theory

2 Theory

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- **Introduce relevant equations**

Tasks for each lab

2. Theory

2 Theory

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- **Explain all quantities**

Tasks for each lab

2. Theory

2 Theory

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- **Use citations**

Tasks for each lab

- **The lab report**

3. **Experimental Setup**

   - **Explain the experimental techniques used in your experiment**
   - **A sketch is highly recommended, e. g.**

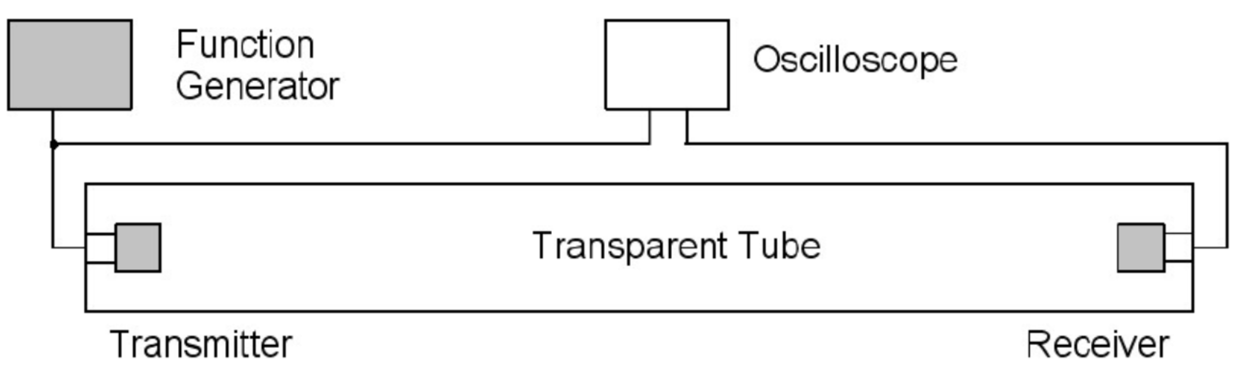

Figure 1: Experimental setup.

   - **Use figure captions and refer to them!**

Tasks for each lab

- **The lab report**

  4. **Results**

     - **Show the original results of your experiment**

	Δt (ms)	c_s (m/s) Measurement	Literature [4]
Air	2.81±0.02	331 ± 3	343
Argon	2.99±0.02	311 ± 3	318
Nitrogen	2.76±0.02	337 ± 3	334

Table 1: Results for the velocity of sound at room temperature using the method of time delay (error calculation see appendix A).

Tasks for each lab

- The lab report

4. Results

- Show the **original** results of your experiment

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	Δt (ms)	Measurement	Literature [4]
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Table 1: Results for the velocity of sound at room temperature using the method of time delay (error calculation see appendix A).

- Provide a suitable error calculation
  - Show only relevant digits
  - Basic law for propagation of error: $\Delta f = \left|\frac{\partial f}{\partial x}\right| \Delta x + \left|\frac{\partial f}{\partial y}\right| \Delta y + \ldots$
  - Lab specific issues will be discussed with your TA

Tasks for each lab

- **The lab report**

  1. **Results**

     - **Generally, provide a plot of your data**

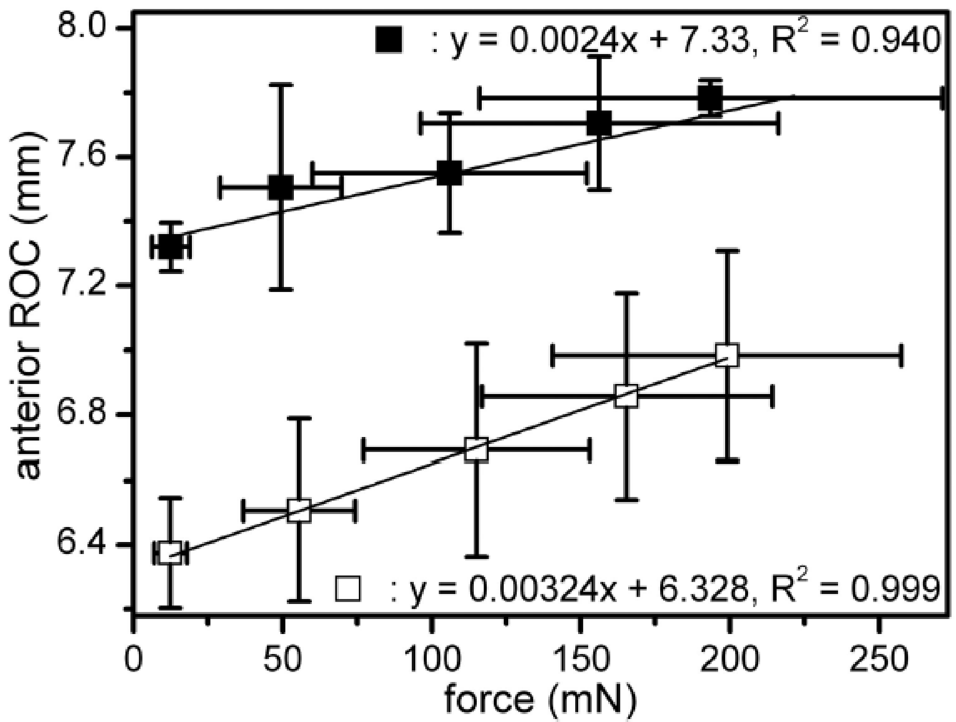

FIGURE 7.
Anterior ROC as a function of the applied force for young and old (n = 3) lenses.

Tasks for each lab

- **The lab report**
  1. **Results**
     - **Provide a figure caption and refer to it!**

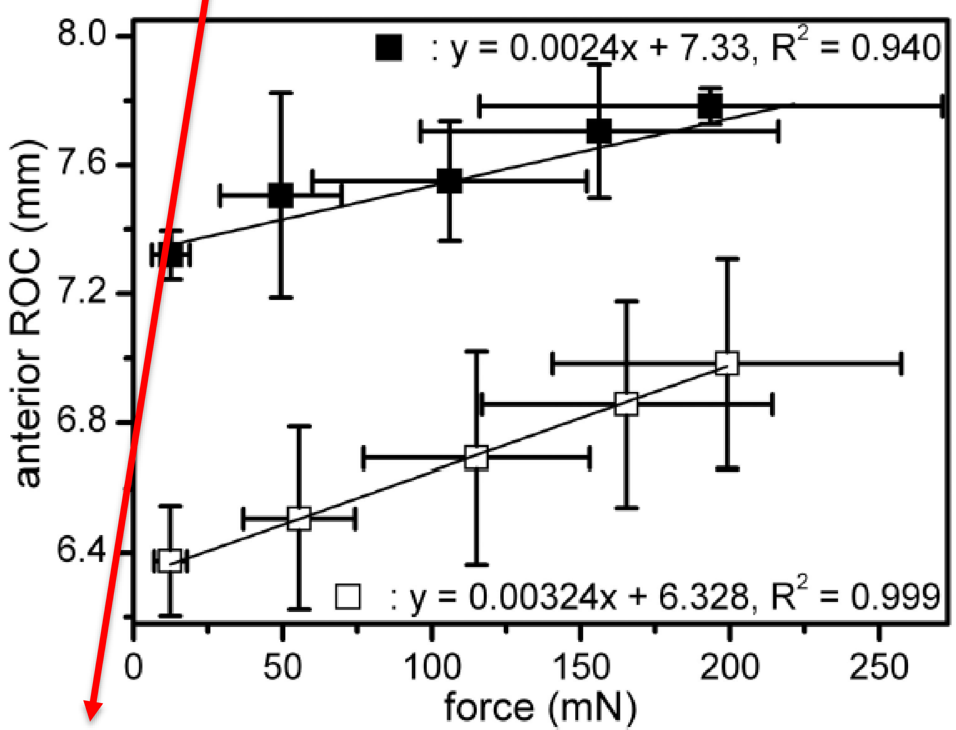

FIGURE 7.
Anterior ROC as a function of the applied force for young and old (n = 3) lenses.

Tasks for each lab

- **The lab report**
  1. **Results**
     - **Provide axis labels and units!**

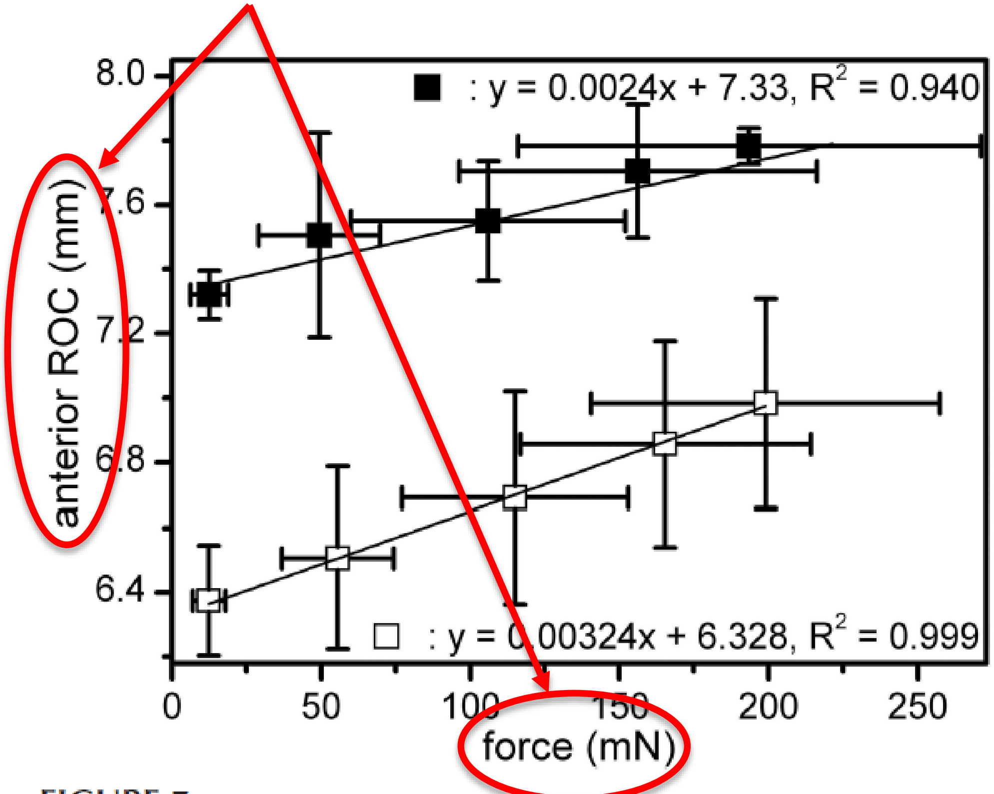

FIGURE 7.
Anterior ROC as a function of the applied force for young and old (n = 3) lenses.

Tasks for each lab

- The lab report
  1. Results
     - Provide error bars!

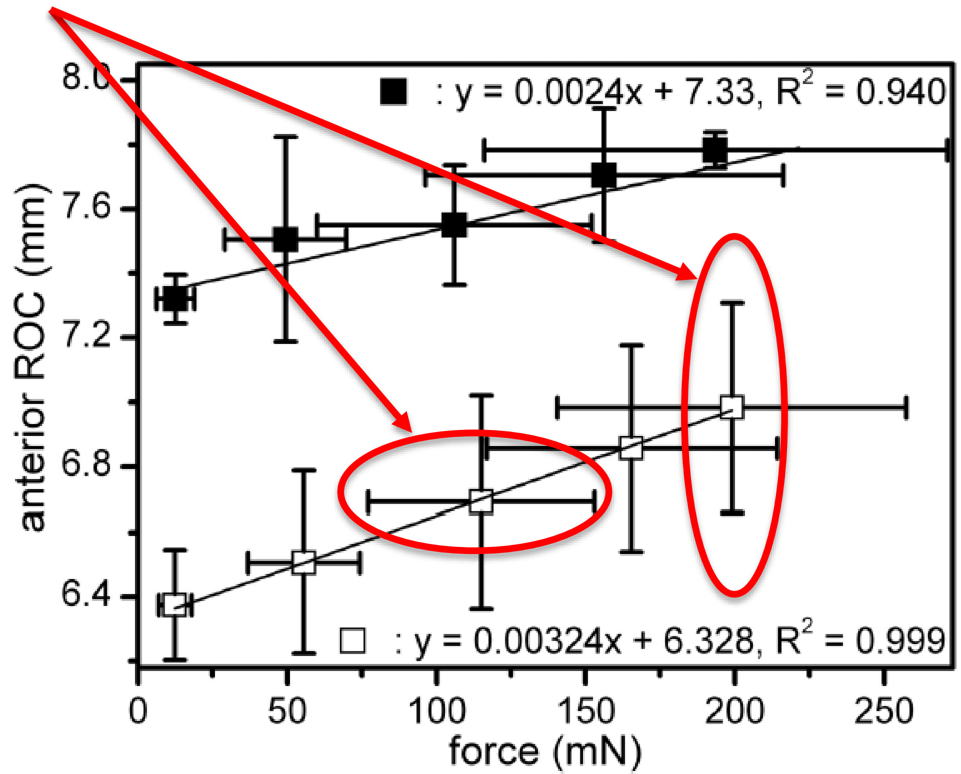

FIGURE 7.
Anterior ROC as a function of the applied force for young and old (n = 3) lenses.

Tasks for each lab

- **The lab report**

  1. **Results**

     - **Provide fit data (if applicable)!**

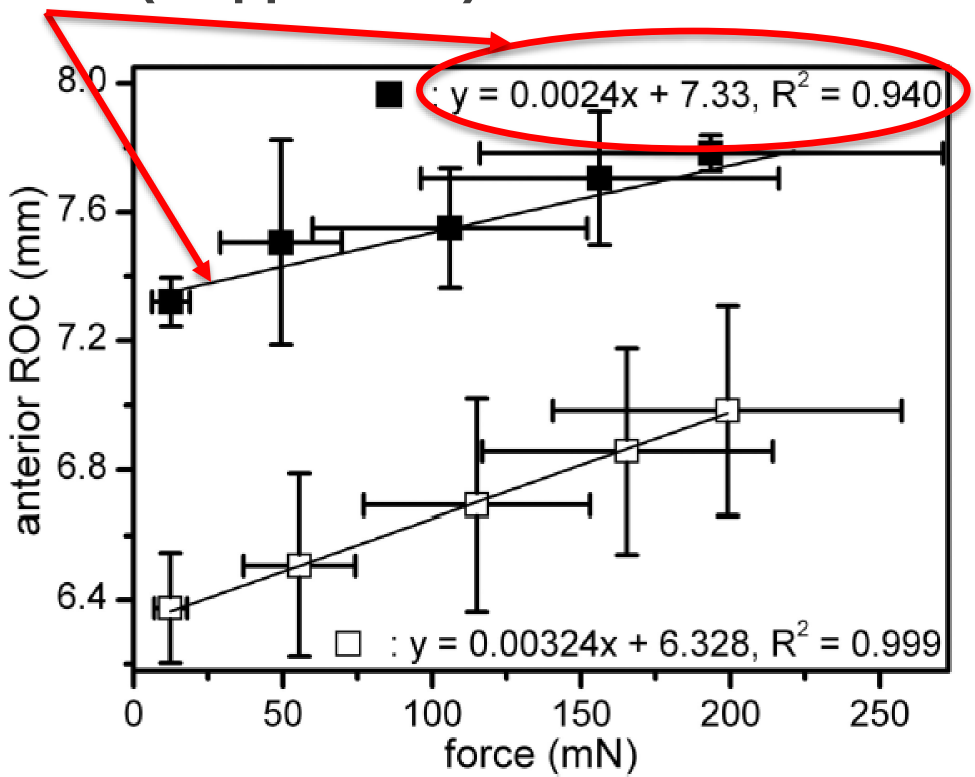

FIGURE 7.
Anterior ROC as a function of the applied force for young and old (n = 3) lenses.

Tasks for each lab

- The lab report

4. Results
    - This section is the most important of your report!
    - Try to refer to equations which are introduced in the ‚Theory‘-section
    - Carefully check that you have addressed all tasks of the manual
5. Discussion
    - Show that you have understood the experiment:
        - Judge the quality of your data, discuss limitations of the setup
    - Discuss possible problems or mistakes you made during your measurement
    - Compare you measurements with the literature!

Tasks for each lab

- **The lab report**

  6. Conclusions

  - **Provide a short summary of your results!**

5 Conclusion

In this project the velocity of sound in air, argon and nitrogen was to be analyzed in a transparent tube. The velocity was determined as a function of pressure for the three different gases by using a time delay measurement. The results of the velocity of sound are in air $c_{s,air} = (331 \pm 3)$ m/s, in argon $c_{s,Ar} = (337 \pm 3)$ m/s and in nitrogen $c_{s,N_2} = (311 \pm 3)$ m/s. In agreement with the theory the velocity of sound is not dependent on the pressure.
The velocity of sound in air was also detected with the aid of the resonance detection technique. Thereby standing waves and resonance were produced in the tube. The result $c_{s,air} = (315 \pm 20)$ m/s agrees not with the value found in the literature. The error was relatively large caused by background noise and the fact that it was not possible to find the

Tasks for each lab

- The lab report

6. Conclusions

- Provide a short summary of your results!
- Discuss possible problems and/or improvements of your measurement!

5 Conclusion

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Tasks for each lab

- **The lab report**

  7. References

  - **Provide a list with references that you refer to**
    - **References from journals:**

      [number of first appearance] Name of the authors (year) "Title of their article", Journal with Volume and Page number
    - **Books:**

      [number of …] Name of the authors (year) "Title of their book", Publisher
    - **Websites:**

      [number of … Name of the authors (year) "Title of the article/manual/database entry", full webadress, date,

Tasks for each lab

- **The lab report**

7. References

- **Provide a list with references that you refer to**
  - **Example:**

3. Blum M, Kunert KS, Riehemann S, Ackermann R, Dick M (2008) Presbyopietherapie mit Femtosekundenlaser. Ophthalmo-Chirurgie 20:40–43
4. Reggiani Mello GH, Krueger RR (2011) Femtosecond laser photo-disruption of the crystalline lens for restoring accommodation. Int Ophthalmol Clin Spring 51(2):87–95
5. Ripken T, Oberheide U, Fromm M, Schumacher S, Gerten G, Lubatschowski H (2008) fs-Laser induced elasticity changes to improve presbyopic lens accommodation. Graefes Arch Clin Exp Ophthalmol 246(6):897–906

Tasks for each lab

- The lab report
  - Do not copy+paste anything from the web, the manual, books or reports of former students into your report, i. e:
    - graphs, images, experimental sketches, text passages
    - most of the sources are copyright protected
  - Try to focus on facts that are relevant for your report
    - E. g. do not write general introductions to the research area

Rules

- Grades
  - You receive a **grade** for
    - the **experimental part** (preliminary talk, lab) and the **report**
    - The final grade for each lab is the average of both.
    - The **final grade** for the module is the **average of all labs** rounded to valid values (1.0, 1.3, 1.7 …)
  - A lab is graded as **5.0** („insufficient“) and you will not be allowed to perform the lab in case of
    - **being absent** without certificate of illness
    - **being late** for more than 15 minutes
    - **Poor lab preparation**
    - **Persistently breaking of rules** during the lab session

Rules

- <u>Grades</u>
  - a **report** is graded as **„5.0“** **(„insufficient“) in case of being** **unacceptable, that is**
    - **the report appears to be evident plagiarism.**
    - **a major part of the report is copied from the other sources even with appropriate references**
    - **content of the report evidently shows that author do not understand the subject and/or did not achieve the goals of the lab**
    - **the report is not submitted in time**
- **in case of a lab graded as „5“, the student has to do another lab**
- **in case of a report graded as „5“ the students have to provide a revised version**
- **In case of a 2nd lab or report graded as „5.0“, the module is graded as failed.**

Last but not Least

Next dates: "Fundamentals" at seminar room IAP, Albert-Einstein-Straße 15, 07745 Jena at 1 p.m. (s. t.) on

6th January 2016 for groups G1 - G10

13th January 2016 for groups G11 - G20

Please, team up in groups of 2 students and fill in your names in the lists!