Note:

Due to file size limitations, a high-resolution version of this document can be downloaded by clicking *here*.

Contents

1 Introduction

I completed **five laboratory courses** during my undergraduate studies, taken in chronological order: *University physics experiments 1*、*Electromagnetic Experiments of General Physics*、*General Physics Comprehensive Experiment*、*Modern Physics experiments 1* and *Advanced Physics Experiments*，Among them *Modern Physics experiments 1* and *Advanced Physics Experiments* fall under the category of Advanced Physics Experiments，esigned specifically for physics majors. These courses are more demanding: students must independently prepare the experimental background, underlying principles, and instrument structure *prior to the lab session*; conduct the experiment collaboratively within a small group; and, subsequently, present a comprehensive analysis to the instructor covering the principles, procedures, data, proposed improvements, and assigned reflection questions. To succeed, students must master every aspect of the experiment and articulate the material through a clear, logical slide presentation, thereby significantly enhancing their skills in experimental operation, analytical thinking, comprehension of physical principles, and formal academic reporting. The contact hours for each course are listed in the table below：

Table 1: Laboratory courses, their types, workloads, and modes of documentation.

<table>
<tr><th>Types</th><th>Courses</th><th>Total workload
(In class+out of class)
(hours)</th><th>Documentation</th></tr>
<tr><td rowspan="3">General Physics Experiment</td><td>University physics experiments 1</td><td>96 (48+48)</td><td>written report on course official website</td></tr>
<tr><td>Electromagnetic Experiments of General Physics</td><td>128 (64+64)</td><td rowspan="2">written report by hand</td></tr>
<tr><td>General Physics Comprehensive Experiment</td><td>128 (64+64)</td></tr>
<tr><td rowspan="2">Advanced Physics Experiments</td><td>Modern Physics experiments 1</td><td>128 (64+64)</td><td rowspan="2">Presentation to the course instructo</td></tr>
<tr><td>Advanced Physics Experiments</td><td>128 (64+64)</td></tr>
</table>

Table 2: Laboratory courses and some of their Information

Courses	Numbers	Conducting Method	Documentation method
University physics experiments 1	12	Group work (2 students), hands-on experimental work	Real-time data recording & post-experiment analysis & formal reporting (written report)
Electromagnetic Experiments of General Physics	14		
General Physics Comprehensive Experiment	13		
Modern Physics experiments 1	13	Group work (1/2/3 students *), hands-on experimental work	Real-time data recording & post-experiment analysis & formal reporting (presentation)
Advanced Physics Experiments	12	Group work (1/2/3 students **), hands-on experimental work	

* This course consists of 13 sessions, of which 3 are conducted individually, 7 are conducted in pairs, and 2 are conducted in groups of three.

** This course consists of 12 sessions, of which 5 are conducted individually, 5 are conducted in pairs, and 2 are conducted in groups of three.

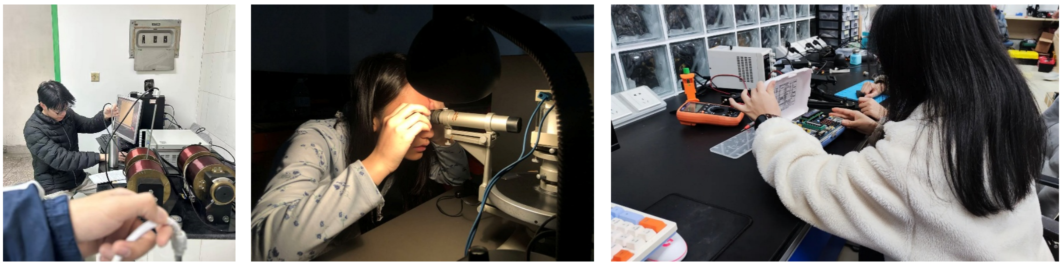
It is worth noting that the actual time commitment for Modern Physics Experiments I and Advanced Physics Experiments is far greater than what is indicated in the official Module Description. The significantly more complex experimental principles necessitate more time for theoretical preparation compared with standard laboratory classes. Furthermore, the sophisticated and intricate instrumentation and the correspondingly demanding operational procedures substantially increase both the preparation time and the duration of the lab sessions; indeed, some experiments span two full weeks to complete. Moreover, the post-lab workload is heavily weighted: data-processing alone is considerably heavier, with certain experiments requiring 6 or more hours of data handling. Concurrently, since these modules are designed exclusively for physics majors, each experiment culminates in a formal slide presentation to the instructor. As a result, the actual total workload conclusively exceeds 128 hours, significantly surpassing the typical time commitment of standard laboratory courses.

The following sections provide detailed descriptions of each course—including experimental themes and assessment methods—and conclude with a representative sample report. Additional information can be found in the uploaded course syllabi.

2 Conduct, Documentation, and Report of Experiment

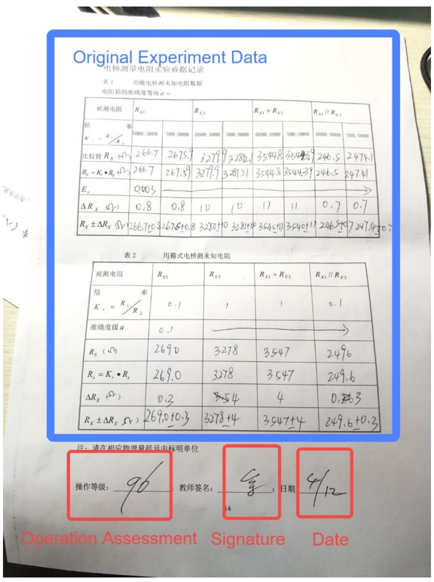
2.1 Experiments Conduct

1. Students independently complete the pre-class preparation and submit a preview report.
2. At the beginning of the lab session, the instructor explains the experimental procedures, principle of the experiment, and safety requirements based on the handout.
3. Students work collaboratively with group members to carry out the experiment.



Photos from the actual experimental procedure.

2.2 Documentation



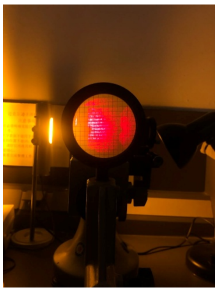
The image on the left shows an example of a standard documentation sheet.

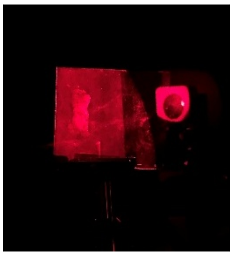
I. Students record the experimental setup, key parameters (such as voltage, time, and angle), the observation methods, and the measured values for each step along with their estimated uncertainties.

II. After completing the experiment, the documentation is submitted to the instructor for review. Once the records are confirmed to be accurate, the instructor will enter the operation score for this session, sign the sheet, and note the date.

2.3 Report

2.3.1 General Physics Experiment





(General Physics Experiment — group-based laboratory work with individually written reports.)

Experiments of this general nature often require elaborate procedural execution, involving tasks such as setting up optical paths, precise alignment, measuring diffraction rings, taking oscilloscope readings, or producing holographic plates. In contrast, the underlying physical principles are usually straightforward, and the data processing and conclusion-drawing are relatively direct.

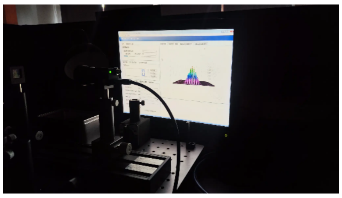
The evaluation focuses primarily on (1) whether you have correctly executed the experimental operations and measurements, and (2) whether you have completed the experiment in a thorough and meticulous and accurate manner

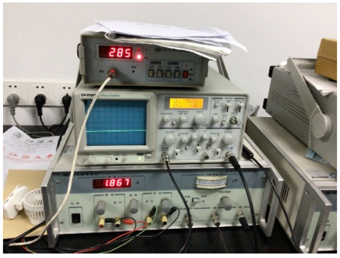
2.3.1.1 Written report

- **Submission timing:** A printed written report is submitted at the next lab session.
- **Required structure of the written report:**

1. **Pre-lab Preparation**– summary of the preparatory work completed before experiment.
2. **Experimental Procedure**–description of how the experiment was conducted.
3. **Results** – presentation of the measured data and key observations.
4. **Data Analysis** – processing of the raw data and fitting results.
   The report must specify the software used for data fitting, such as MATLAB (scripts, version, and key functions) and Origin (plotting/fitting settings). All fitting plots should be generated on the computer, printed out, and included in the report.
5. **Analysis and Discussion** of the fitting results.
6. **Conclusions** and any assigned post-lab questions.
7. The report is normally submitted together with the **documentation sheet**, which serves as proof of participation in the experiment.

2.3.2 Advanced Physics Experiment





The Advanced Physics Experiments utilize modern and complex instrumentation. While the equipment operation may be mechanically simple, the instruments have a steep learning curve and require a deep understanding of their design and the underlying physical principles. Consequently, the standards for data analysis and the depth of conclusions are significantly higher, requiring more extensive model derivations, careful error-propagation analysis, and a discussion of instrument response.

All Advanced experiments are conducted collaboratively in groups (2–3 students). However, beginning with Advanced 2, the final presentations transition to an individual format, even as the experimental work remains collaborative.

2.3.2.1 Pre-lab (completion of the pre-lab report)

I. The pre-lab report consists of answering the preparatory questions provided in the lab handout.

II. Students must upload an electronic version of the pre-lab report to the university's designated website before the deadline, which is normally the day before the experiment or as required by the course.

Example — Pre-lab Preparation

1. Responding to the preparatory questions

二、预习要求及问题 **Q&A (from the Handout)**

1. 电子自旋共振研究的对象是什么？
2. 材料 g 值的大小和ΔH的宽窄，反映什么微观现象和微观过程？
3. 弄清楚本微波测量系统中各元件及各种测量仪器的使用方法。
4. 了解反射式谐振腔的谐振特性。

Translation

1. What is the principal object of study in Electron Spin Resonance (ESR) spectroscopy?
2. What specific microscopic phenomena and processes are reflected by the magnitude of the material's g-factor and the linewidth ΔH of the ESR signal?
3. Ensure a comprehensive understanding of the operational procedures for each component and every piece of measurement equipment within this specific microwave detection system.
4. Acquire knowledge regarding the specific resonance characteristics of a reflection-type microwave resonant cavity.

image: list of sample pre-lab questions

2. Submitting the pre-lab report

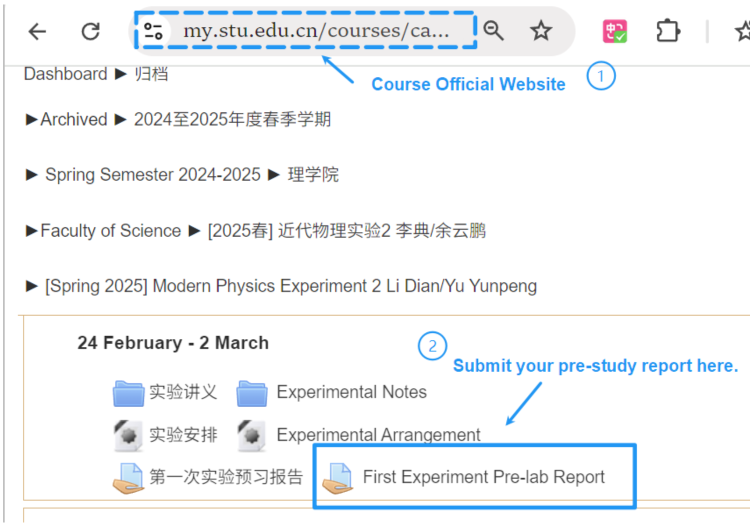


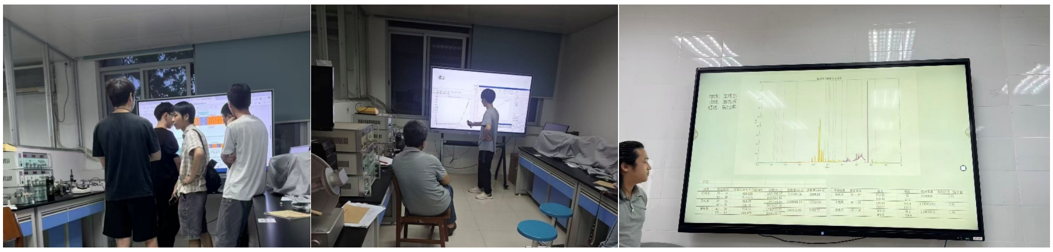
image: how the submission page looks

2.3.2.2 Post-lab deliverable — PPT + Presentation:

1. **Title slide-**title of the experiment, presenter, group members, and date
2. **Experimental Principles** — a clear explanation of the underlying physics.
3. **Experimental Setup & Procedure** — schematic of the apparatus and the main procedural steps.
4. **Documentation** — instructor-verified data sheets, oscilloscope screenshots, and other records used for data checking.
5. **Data Fitting**— organization of raw data and fitting results (methods, parameters, residuals, and uncertainty analysis).
   It is recommended to specify the software used, such as MATLAB (scripts, version, key functions) and Origin (plotting/fitting settings), and to attach the main scripts or sample commands.
6. **Analysis and Discussion** of the fitting results.
7. **Conclusions**
8. **Questions / Reflections** — assigned questions in Handout or personal reflections on the experiment,

Presentation:

Students deliver a presentation detailing their experimental work and findings. The instructor will evaluate the students’ performance based on criteria.

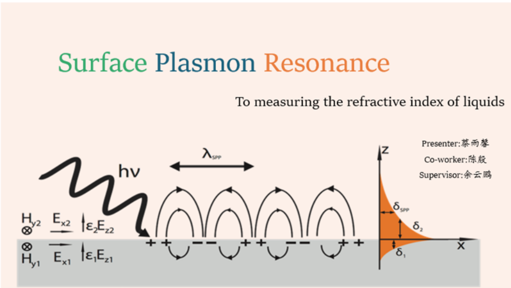


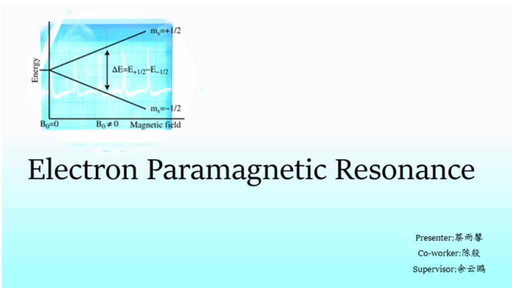
The image on the left shows part of the discussion during our presentation; the images in the center and on the right are from the main presentation itself.

Example Slides

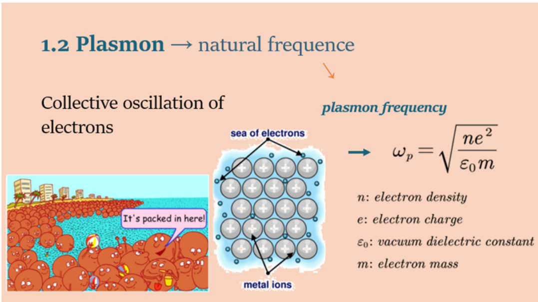
(Selected excerpts from my own presentation slides, provided for style reference only)

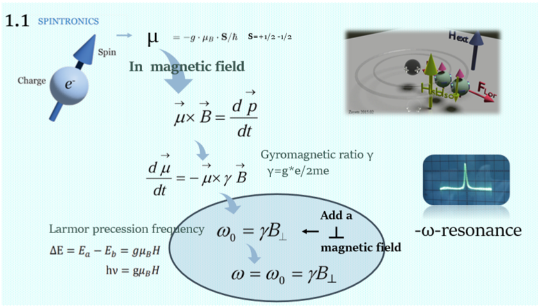
1. Title slide



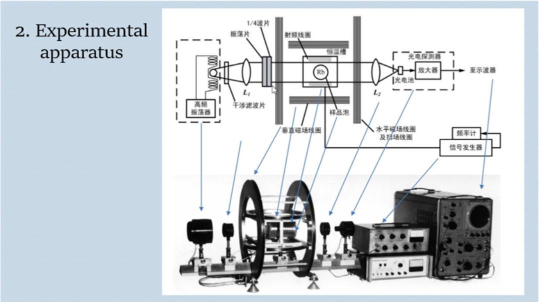


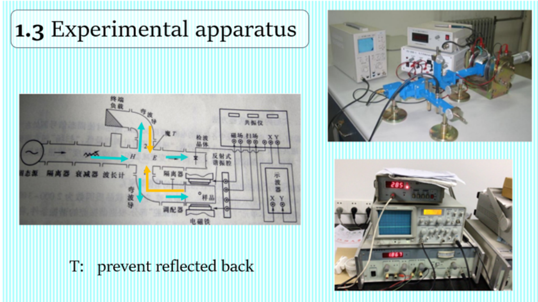
2. Schematic of the physical principle





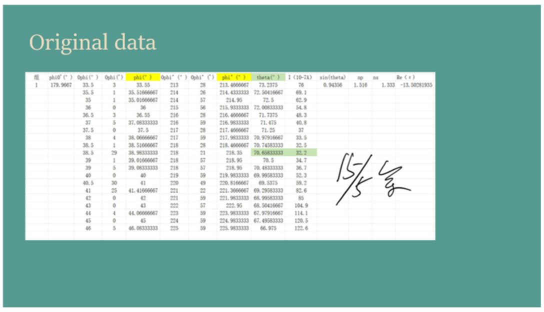
3. Diagram of the apparatus / experimental layout

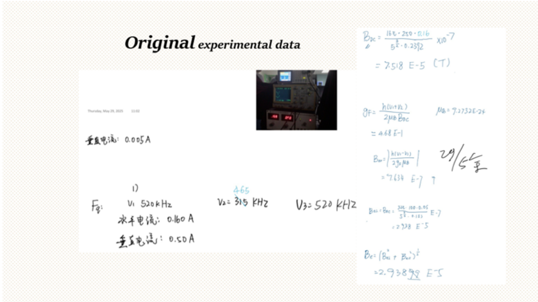




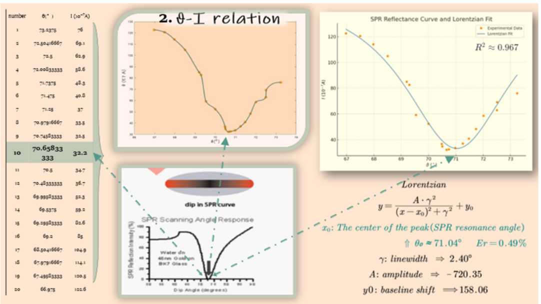
4. Raw data, data fitting, and analysis

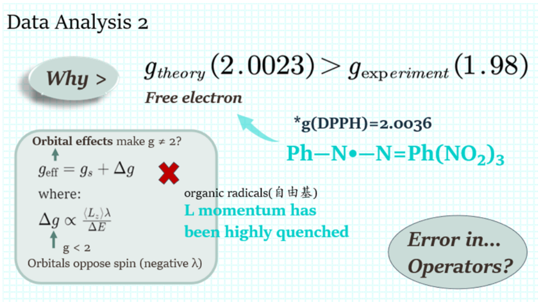
Raw



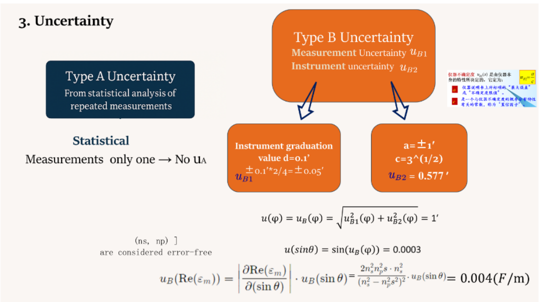


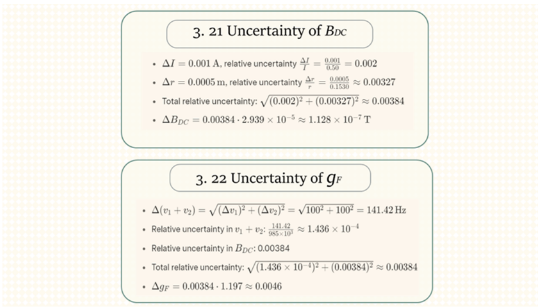
Data fitting and anaalysis





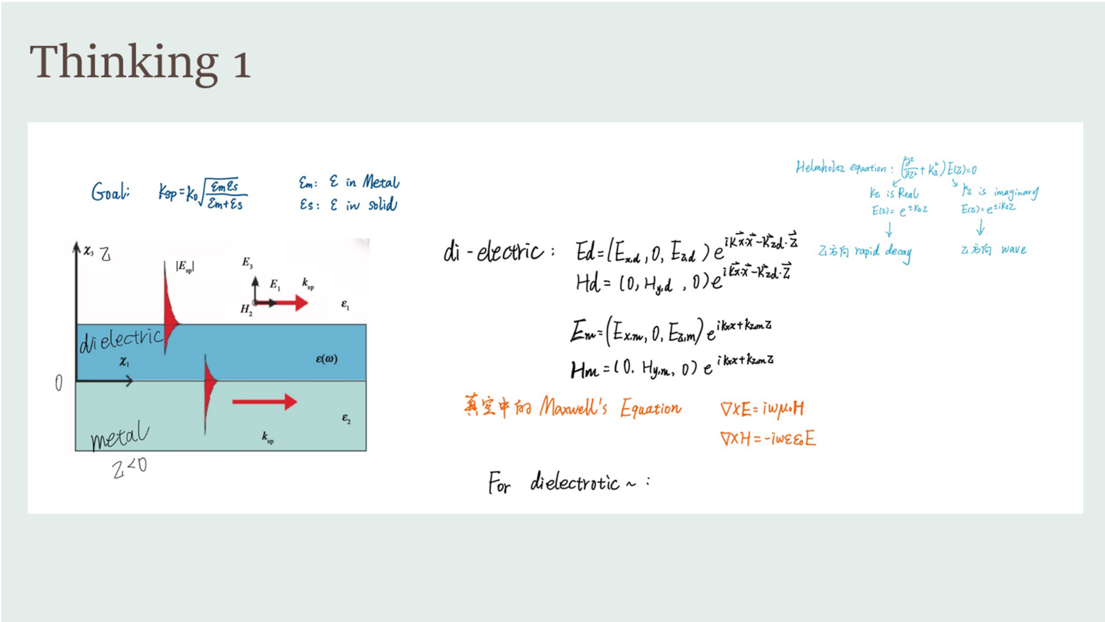
5. Uncertainty calculation





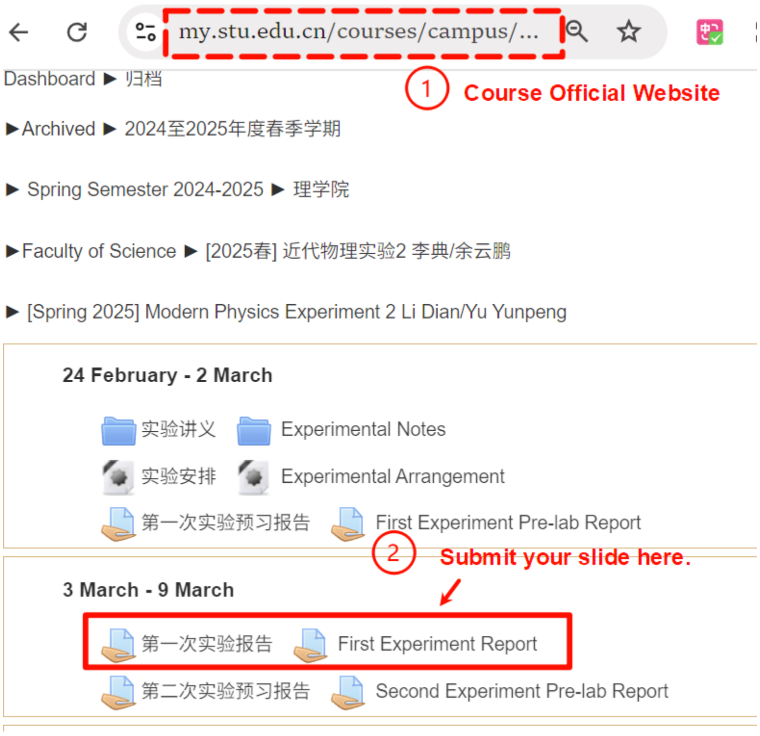
6. Reflection questions

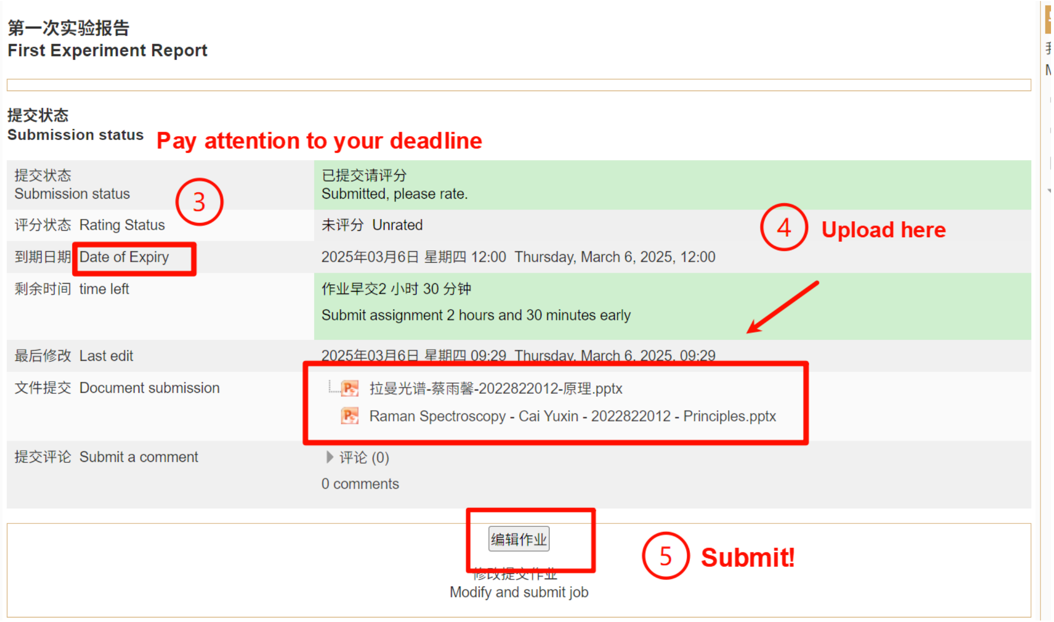
Here is Proof of formula: $k_{sp} = k_0\sqrt{\dfrac{\epsilon_m n_s^2}{\epsilon_m + n_s^2}}$ (This question from the Handbook of **Surface Plasmon Resonance for Liquid Refractive Index Measurement**)



Submission via Course Website

The presentation file **must be submitted via the Course's official website.** Please ensure submission is completed before the specified deadline (DDL).





3 Experiment Topics

3.1 General Physics Experiment

3.1.1 Mechanics

University physics experiments 1

Young's Modulus Measurement

- Stretching method for measuring Young's modulus of a metal wire
- Light-lever method for detecting small length variations
- Data treatment using successive differences and graphical analysis

Simple Pendulum

- Measuring gravitational acceleration
- Automatic timing techniques
- Graphical data analysis
- Extrapolation to obtain the period at infinitesimal amplitude

Viscosity Coefficient

- Timing and velocity measurement using a laser photoelectric sensor
- Determination of the viscosity coefficient of castor oil via Stokes' law

- Condition check and correction for the falling-ball method

Moment of Inertia

- Determining moments of inertia using a torsion pendulum
- Measuring the torsional constant and comparing with theory
- Verification of the parallel-axis theorem

Collision

- Operation of air tracks and photoelectric timing devices
- Testing momentum conservation through collision cases
- Characteristics of elastic vs. completely inelastic collisions

General Physics Comprehensive Experiment

High-speed Photographic Dynamics Experiment

- 1.1 Simple Pendulum Motion

  - Observe the motion process and trajectory of a simple pendulum and calculate its period.
  - Measure gravitational acceleration.

- 1.2 Projectile Motion

  - Observe the process and trajectory of projectile motion.
  - Decompose projectile motion into horizontal and vertical components.
  - Measure the initial velocity of projectile motion.

- 1.3 SHM of a Spring Oscillator

  - Observe the motion of a spring oscillator and measure its oscillation period.
  - Measure the spring constant.

- 1.4 Conservation of Momentum

  - Observe the collision process and measure the velocities before and after collision.
  - Verify the conservation of momentum.

- 1.5 Free Fall Motion

  - Measure the relationship between velocity and time for a freely falling object.
  - Measure gravitational acceleration.

Experiment on String Vibration Using a Monochord

- Understand the propagation laws of string vibration and observe the waveform when standing waves form.
- Measure the propagation speed of transverse waves on the string and the relationship among linear density, tension, and wave speed.
- Listen to sounds corresponding to different frequencies.

Forced Oscillation Experiment

1. Use the Pohl pendulum to quantitatively observe phenomena such as free oscillation, damped oscillation, forced oscillation, magnetic damping, and beats.
2. Study amplitude-frequency and phase-frequency characteristics of Pohl oscillation and the resonance phenomenon.
3. Learn the basic principles of sensors by using data acquisition devices and rotary sensors to observe Pohl oscillations. Observe the spectrum of Pohl oscillations.
4. Observe the phase diagram of the Pohl pendulum and the conversion and conservation of mechanical energy during oscillation.

Sound Speed Measurement Experiment

1. Understand the working principles and functions of ultrasonic transducers.
2. Learn the principles and techniques of the resonance-interference method, phase-comparison method, and time-difference method for measuring sound speed.
3. Familiarize yourself with the adjustment and operation of measuring instruments and oscilloscopes.
4. Measure the speed of sound in air.
5. Measure the speed of sound in water.
6. Measure the speed of sound in solids.

Doppler Effect Experiment

1. Verify ultrasonic Doppler frequency shift and use it to calculate sound speed.
2. Understand the principles, methods, and techniques for measuring sound speed using the Doppler effect.
3. Compare the differences between direct and reflective Doppler methods and explain them in combination with practical applications.
4. Use the Doppler effect as a motion sensor to study various kinematic scenarios.
    - (1) Free fall motion, determining gravitational acceleration from the slope of the v–t linear relation.
    - (2) Simple harmonic motion, measuring period and other parameters and comparing with theoretical values.
    - (3) Uniformly accelerated linear motion, measuring the relationship among force, mass, and acceleration to verify Newton’s second law.
    - (4) Other non-uniform linear motions.

3.1.2 Thermal

University physics experiments 1

For the mechanical equivalent of heat experiment, the contents include:

1. Measuring the mechanical equivalent of heat using the electrical heating method;
2. Performing heat-loss correction using Newton's law of cooling and correcting the final temperature.

General Physics Comprehensive Experiment

For the quasi–steady-state method for measuring the thermal conductivity and specific heat of poor conductors, the contents include:

1. Understanding the principles of measuring thermal conductivity and specific heat using the quasi–steady-state method;
2. Learning the principles and usage of thermocouples for temperature measurement;
3. Measuring the thermal conductivity and specific heat of poor conductors using the quasi–steady-state method.

For the air heat engine experiment, the contents include:

1. Understanding the working principles and cyclic processes of heat engines;
2. Measuring the mechanical equivalent of heat at different hot–cold end temperatures and verifying Carnot's theorem;
3. Measuring the relationship between heat engine output power, load, and rotational speed, and calculating the actual efficiency of the heat engine.

3.1.3 Electromagnetism

University physics experiments 1

Oscilloscope Experiment

1. Gain an initial understanding of the structure of a cathode-ray tube.
2. Master the display principles and operating procedures of a dual-trace oscilloscope.
3. Learn how to use an oscilloscope to measure voltage, current, frequency, and phase difference.

DC Bridge Experiment

1. Understand the working principle of the Wheatstone bridge.
2. Learn how to use the Wheatstone bridge to measure medium-value resistance.

Modification and Calibration of Electrical Meters

1. Master the principles and methods for converting a micro-ammeter into a higher-range ammeter or voltmeter.
2. Learn how to calibrate ammeters and voltmeters.
3. Use the modified instruments to measure the resistance of an unknown resistor.

Measurement of EMF Using a Potentiometer

1. Understand the working principle and structural features of the potentiometer.
2. Master the operating procedures of the potentiometer.

Magnetization Curve and Hysteresis Loop Measurement Using an Oscilloscope

1. Understand the basic principles for displaying hysteresis loops with an oscilloscope.
2. Learn how to measure magnetization curves and hysteresis loops using the oscilloscope method.

Resonance in AC Circuits

1. Investigate resonance phenomena in AC circuits.
2. Understand the influence of the quality factor on selectivity and bandwidth.
3. Learn to operate common electronic measurement instruments

Electromagnetic Experiments of General Physics

Measurement of Magnetic Field of a Solenoid Using a Ballistic Galvanometer

1. Understand the working principle of a ballistic galvanometer.
2. Learn the method of measuring magnetic flux density using the galvanometer technique.

Measurement of EMF Using a Potentiometer

1. Understand the operating principle and structural features of the potentiometer.
2. Master its operating procedures.

Measurement of Magnetization Curves and Hysteresis Loops Using an Oscilloscope

1. Understand the principles of oscilloscope-based hysteresis display.
2. Learn to measure magnetization curves and hysteresis loops.

Transient Processes in RLC Series Circuits

1. Examine the transient processes in RC and RL circuits to deepen understanding of capacitance and inductance.
2. Examine the transient process in RLC circuits to gain insight into damped oscillations.

Hall Effect Experiment

1. Learn the fundamental principles of the Hall effect.
2. Learn how to measure the relevant parameters of Hall devices.

Magnetoresistance Effect and Magnetoresistive Sensor Characteristics

1. Understand the basic principles of magnetoresistance and its measurement methods.
2. Measure the relationship between resistance and magnetic flux density for an InSb sensor.
3. Learn methods for measuring magnetic fields using magnetoresistive sensors.
4. Observe the harmonic characteristics of magnetoresistive sensors under weak sinusoidal magnetic excitation.

Electron and Field Experiment

1. Understand the structure of the cathode-ray tube.
2. Understand the principles of electric deflection, electrostatic focusing, magnetic deflection, and magnetic focusing of an electron beam.
3. Master at least one method for determining the charge-to-mass ratio of electrons.
4. Understand the basic principles and internal structure of the oscilloscope.

Design Experiment — Determination of Meter Parameters Using a Potentiometer

1. Use the potentiometer method for precise measurement of small voltages and design a measurement circuit (using a UJ31 potentiometer) for determining the parameters of a micro-ammeter; provide the experimental principle, procedure, precautions, calculation formulas, and the designed data table.
2. Perform quantitative measurements and obtain a calibration curve to determine the meter class.
3. Discuss results and analyze measurement uncertainties.

Design Experiment — Measuring Capacitance and Inductance Using Multiple Methods

1. Using the available instruments, design measurement circuits for capacitance and inductance, propose at least three measurement methods for each, and provide the principles, procedures, and formulas.
2. Select two optimized methods for quantitative measurements and compare the results.
3. Compare the advantages and limitations of the different methods, and discuss potential issues when measuring over a wide dynamic range.

General Physics Comprehensive Experiment

Photovoltaic Characteristics of Solar Cells

1. Understand the basic structure and operating principles of solar cells.
2. Understand the fundamental photovoltaic characteristics and main parameters; master the basic principles and methods for measuring these parameters.
3. Measure the open-circuit voltage, short-circuit current, optimum load resistance, fill factor, and analyze the I–V characteristics, light-intensity dependence, and load characteristics of the solar cell.

3.1.4 Optics

University physics experiments 1

Focal Length Measurement of Thin Lenses

1. Master the measurement of the focal length of thin lenses.
2. Learn to adjust basic optical systems.

Adjustment and Operation of the Spectrometer

1. Understand the structure and operating principles of the spectrometer.

Study of Diffraction and Wavelength Measurement Using a Grating

1. Observe the diffraction of light through a grating and understand the characteristics of interference fringes.
2. Further develop proficiency in spectrometer adjustment and operation.
3. Use a transmission grating to measure the wavelengths of mercury spectral lines in the visible range.

Measurement of Lens Curvature Radius Using Newton's Rings

1. Learn to measure the radius of curvature of lenses using the Newton's rings method.
2. Strengthen conceptual understanding of equal-thickness interference.
3. Perform preliminary optical surface testing and assess surface quality.
4. Learn to apply the difference method for data analysis.

Laser Wavelength Measurement Using a Michelson Interferometer

1. Become familiar with the structure of the Michelson interferometer and master alignment techniques.
2. Learn an interference-based method for determining optical wavelength and deepen understanding of equal-inclination and equal-thickness interference.

Measurement of Refractive Index of a Prism

1. Learn to use a spectrometer to measure the refractive index of a triangular prism.

Electromagnetic Experiments of General Physics

Interference Using Fresnel Biprism

1. Learn to measure wavelength using the Fresnel biprism method.
2. Strengthen skills in optical path alignment and adjustment.

Diffraction by Single, Double, and Multiple Slits

1. Understand the principles of multi-slit diffraction and multi-beam interference.
2. Understand the influence of wavelength on diffraction patterns.

Polarization of Light and Refractive Index of Prisms

1. Observe polarization phenomena to enhance understanding of polarized light.
2. Master the principles and methods for generating and analyzing polarized light.

Measurement of the Sodium D-line Wavelength Difference Using a Michelson Interferometer

1. Measure the wavelength separation of the sodium D doublet.
2. Observe white-light interference fringes.
3. (Optional) Measure the coherence length of white light.

Ultrasonic Diffraction and Speed of Sound Measurement

1. Understand the generation principle of ultrasonic gratings.
2. Learn how sound waves modulate optical signals.
3. Measure the speed of sound in non-electrolyte liquids to deepen conceptual understanding.

Polarization Devices and Waveplates

1. Comprehensive Experiment on Polarization Devices: Understand the functions of various polarization components through integrated operation.
2. Half-Wave Plate Experiment: Learn the principles and applications of the half-wave plate.
3. Quarter-Wave Plate and Circular Polarization Experiment: Understand the principle of the quarter-wave plate and the change in polarization state after transmission.

Geometric Optics Comprehensive Experiment — Principal Points of a Lens System

1. Strengthen understanding of the principal points of a compound lens system.
2. Understand the structural features of a focometer.
3. Measure the principal points and focal lengths of a lens system using the nodal slide and the focometer method.

General Physics Comprehensive Experiment

Electro-Optic Modulation

1. Master the principles and methods of crystal-based electro-optic modulation.
2. Observe modulation phenomena and measure parameters of electro-optic crystals.
3. Implement a basic model of optical communication using electro-optic modulation.

Acousto-Optic Modulation

1. Master the principles and methods of crystal acousto-optic modulation.
2. Observe acousto-optic modulation phenomena and measure related parameters.
3. Implement a basic model of optical communication using acousto-optic modulation.

3.1.5 Advanced Experimental Techniques & Instrumentation

General Physics Comprehensive Experiment

Computer-Aided Measurement Experiment

1. Understand basic computer-aided measurement techniques.
2. Use a computer-based experimental setup to study transient processes during collisions of rigid bodies.

Virtual Simulation: Thermal Evaporation System for Nanomaterial Fabrication

1. Understand the principles of thermal evaporation deposition.
2. Learn infrared thermometry techniques.
3. Practice the fabrication of tungsten oxide nanostructures.
4. Explore the growth mechanisms of nanomaterials.

3.1.6 Solid-State / Condensed Matter Physics

General Physics Comprehensive Experiment

Virtual Simulation: Liquid Crystal Device Fabrication and Testing

1. This experiment uses virtual simulation techniques to reproduce the fabrication process of liquid-crystal cells. Students learn the key processing steps and technical workflow in liquid-crystal display manufacturing, including substrate cleaning, photolithography, etching, alignment-layer coating, and rubbing treatment. By adjusting simulation parameters, students investigate how different fabrication conditions influence display performance. The experiment aims to deepen understanding of essential liquid-crystal device fabrication technologies and to support further research and applications in liquid-crystal display engineering.

3.2 Advanced Physics Experiments

3.2.1 Atomic & Molecular Physics

Modern Physics experiments 1

Ramsauer–Townsend Effect

1. Understand the design principles of the electron-scattering tube and the measurement methods for atomic scattering cross-sections.
2. Measure the dependence of the scattering probability P_s of low-energy electrons on their velocity.
3. Determine the effective elastic scattering cross-section Q of gas atoms and identify the electron energy at which the cross-section reaches a minimum.
4. Verify the Ramsauer–Townsend effect and interpret the results using quantum-mechanical theory.

Sodium Atomic Spectrum Analysis

1. Understand the basic principles of atomic spectral analysis and its applications in studying atomic structure.
2. Observe and identify characteristic spectral lines of sodium atoms.
3. Determine orbital quantum defects and atomic energy levels from spectral data.
4. Calculate the effective nuclear charge experienced by valence electrons based on the wavelength separation of doublet components.

Zeeman Effect

1. Understand the basic principle of the Zeeman effect—the influence of an external magnetic field on atomic spectral lines.
2. Acquire the observational techniques needed to identify and measure magnetic-field–induced spectral-line splitting.
3. Analyze experimental data to study the effect of magnetic fields on atomic energy levels and electronic transitions.

Franck–Hertz Experiment

1. Understand the fundamental principles of the Franck–Hertz experiment, including atomic excitation and quantized energy levels.
2. Operate the Franck–Hertz apparatus and record the periodic current–voltage characteristics.
3. Analyze experimental data to verify the quantization of internal atomic energy levels.

Nuclear Magnetic Resonance (NMR)

1. Understand the principles of nuclear magnetic resonance and the formation of resonance absorption signals.
2. Learn methods of magnetic-field calibration and g-factor determination using NMR techniques.

Advanced Physics Experiments

Electron Paramagnetic Resonance (EPR)

1. Become familiar with the microwave system used for observing electron–spin–resonance spectra and learn to operate fundamental microwave components and reflective resonant cavities.
2. Observe the EPR spectrum of DPPH free radicals, understand the characteristics of electron spin resonance, and learn to measure the resonance field, the g-factor, linewidth, and relaxation time to deepen understanding of EPR phenomena.

Optical Pumping Magnetic Resonance

1. Understand the principles of optical pumping and identify optical magnetic resonance phenomena.
2. Measure the g_F factor of rubidium (Rb) atoms and determine the magnitude of the geomagnetic field.

3.2.2 Nuclear & Particle Physics

Modern Physics experiments 1

Nuclear and Particle Physics Experiment

Experiment 1: NaI (Tl) Scintillation Spectrometer and Gamma-Spectrum Measurement

1. Learn the working principles and operation methods of scintillation γ-spectrometers.
2. Determine the energy resolution and energy linearity of the spectrometer.
   Perform energy calibration of the instrument.
3. Measure and analyze the γ-spectrum of 137^{137}137Cs.

Experiment 2: Radioisotope Half-Life Measurement

1. Master techniques for determining the half-life of medium-lifetime radioisotopes (ranging from days to seconds).
2. Understand the basic methods for producing artificial radioactive isotopes.
3. Learn to use the multi-scaling functions of a multichannel analyzer.

3.2.3 Solid-State / Condensed Matter Physics

Advanced Physics Experiments

High-Temperature Superconductors: Basic Property Measurements

1. Understand the principles of zero resistance and the Meissner effect in high-temperature superconductors.
2. Use the dynamic method to measure the $R-T$ characteristic curve and determine the critical temperature Tc and transition width ΔTc.
3. Observe magnetic levitation and verify perfect diamagnetism.
4. Become familiar with low-temperature experimental procedures (liquid-nitrogen handling) and four-probe resistance measurements.

Hall Effect Experiment

1. Understand the principles of the Hall effect and the methods for measuring the Hall coefficient and electrical conductivity.
2. Study the influence of temperature on semiconductor carrier concentration, mobility, and conduction type.
3. Using variable-temperature Hall measurements, determine the bandgap Eg and impurity ionization energy Ei of semiconductor samples.
4. Gain experience with low-temperature operation and data-acquisition techniques.

Raman Spectroscopy

1. Understand the principles of Raman scattering and the relation between Raman spectral features and molecular structure.
2. Observe Stokes and anti-Stokes lines and learn to calculate Raman shifts.
3. Operate a Raman spectrometer, correctly acquire spectra, and analyze sample vibrational features.

Ellipsometry Measurements

1. Understand the principles of reflection-type ellipsometry and the physical meaning of ellipsometric parameters (ψ and Δ).
2. Use ellipsometry to determine the complex refractive index of metals and the thickness of thin films.
3. Learn proper alignment of the optical path and acquisition of extinction-condition angles.
4. Analyze experimental data to calculate material dispersion properties and verify theoretical models.

Tunneling Magnetoresistance (TMR) and Giant Magnetoresistance (GMR)

1. Understand how tunneling magnetoresistance depends on magnetic field strength, junction current, and excitation voltage.
2. Study the structure and output characteristics of linear TMR sensors.
3. Become familiar with the output behavior of GMR devices.
4. Compare the output curves of GMR and TMR devices and analyze structural reasons for their differences.
5. Learn applications of linear TMR effects in contactless current sensing and understand the underlying physical principles of contactless current sensors.

Surface Plasmon Resonance (SPR) for Liquid Refractive Index Measurement

1. Understand the phenomenon of surface plasmon resonance and study how resonance angle varies with refractive index.

2. Learn the principles and procedures for measuring the refractive index of liquids from SPR resonance angles.

3.2.4 Optics & Photonics

Advanced Physics Experiments

He–Ne Laser Mode Analysis Experiment (He–Ne laser mode analysis)

1. Understand the formation and characteristics of laser modes (laser modes) and deepen the physical concepts behind them.
2. Learn the basic methods for mode analysis (mode analysis).
3. Become familiar with the working principles and performance of the confocal spherical scanning interferometer (confocal scanning interferometer) used in this experiment, and master its correct operation.
4. Understand the polarization properties of lasers (laser polarization) and learn the methods for polarization measurement.

Blackbody Radiation Experiment (blackbody radiation)

1. Master the spectral distribution of blackbody radiation—Planck's radiation law (Planck radiation law).
2. Master the integrated emission of blackbody radiation—Stefan–Boltzmann law (Stefan–Boltzmann law).
3. Master Wien's displacement law (Wien displacement law).

Light-Beat Method for Measuring the Speed of Light (optical beat method)

1. Master the principle and experimental method of measuring the speed of light using optical beats (optical beat frequency), and gain an initial understanding of the acousto-optic effect (acousto-optic effect).
2. Determine the speed of light by measuring the wavelength and frequency of the optical beat signal.

3.2.5 Electron & X-ray Diffraction / Materials Structure

Advanced Physics Experiments

Electron Diffraction Experiment (electron diffraction)

1. Master the basic principles of using Bragg diffraction (Bragg diffraction) for crystal structure analysis.

2. Verify the de Broglie relation (de Broglie relation) and understand the methods for measuring lattice constants and indexing diffraction rings in electron diffraction experiments.

3.2.6 Microwave & Electromagnetic Experiments

Modern Physics experiments 1

Microwave and Waveguide Characteristics Measurement (microwave & waveguide measurement)

1. Learn the fundamentals of microwaves and waveguides (microwave, waveguide).
2. Understand the structure, working principles, and operating characteristics of the Gunn diode oscillator (Gunn oscillator), and the three operating modes of a waveguide (waveguide modes).
3. Master the measurement methods of the three basic microwave parameters.

3.2.7 Advanced Experimental Techniques & Instrumentation

Modern Physics experiments 1

Single-Photon Counting Technology (single-photon counting)

Understand the basic principles and system architecture of single-photon counting technology.

Weak-Signal Detection Experiments

- 1.1 Detection of Weak Signals in a Strong-Noise Background
  - Understand the working principles and basic operation of a digital lock-in amplifier.
  - Master the correlation-based method for extracting weak signals buried in strong noise.
- 1.2 Multi-Harmonic Measurement of Weak Signals
  - Understand the capability of a lock-in amplifier to simultaneously measure fundamental and harmonic components.
  - Visually observe the high-frequency components of a square wave to verify its Fourier expansion.
  - Learn a lock-in-based method for measuring weak periodic signals.
- 1.3 Small-Impedance Measurement

- Master the principle of measuring small impedance using lock-in detection in combination with the four-wire method.
- Understand communication between LabVIEW (LabVIEW) and the lock-in amplifier.

- 1.4 Capacitance–Voltage Measurement of a Varactor Diode

- Understand the applications of lock-in amplifiers.
- Measure the PN-junction capacitance of a varactor diode as a function of the reverse-bias voltage.

- 1.5 Thermal Noise Measurement of Resistors

- Understand the mechanisms and measurement principles of electronic noise.
- Learn to analyze the statistical distribution of noise signals.
- Understand LabVIEW-based communication with the lock-in amplifier.

Vacuum Generation, Vacuum Measurement, and Thermal Evaporation Coating (vacuum system; thermal evaporation)

1. Master the basic principles and methods for achieving and measuring low and high vacuum environments (low vacuum / high vacuum techniques).
2. Learn the principles and procedures of thermal evaporation coating (thermal evaporation deposition).

4 Assessment Scheme

4.1 General Physics Experiment

4.1.1 University physics experiments 1

Assessment Component	Description of Assessment Content and Methods	Weight
Experiment Preparation	Before each experiment, students must log into the online laboratory teaching platform and complete the corresponding pre-lab quiz. Questions are randomly drawn from a question bank, and the system automatically grades the results. Each student may attempt the quiz up to three times, and the highest score will be taken as the final pre-lab grade for that experiment.	10%
Experimental Performance	0–59: Shows low engagement throughout the experiment; insufficient understanding of the fundamental principles; weak experimental skills; unable to analyze or reflect on common experimental issues.	40%

	60–69: Demonstrates limited engagement; shows an initial understanding of basic principles; average technical skills; inaccurate analysis of common experimental issues. 70–79: Shows good engagement; generally accurate understanding of principles; satisfactory technical skills; reasonably accurate analysis of common issues. 80–89: Actively participates; demonstrates accurate understanding of principles; solid technical skills; able to analyze and reflect on common issues with accuracy. 90–100: Consistently engaged; demonstrates deep understanding of principles; strong experimental skills; proficient operation; provides original and insightful analysis of common experimental problems.	
Lab Reports	0–59: Poorly prepared report; missing or incorrect theoretical principles; incorrect procedures; no data analysis or discussion; submitted beyond the required deadline. 60–69: Moderately organized report; demonstrates preliminary understanding of principles and procedures; inaccurate data analysis and discussion. 70–79: Well-organized report; demonstrates good understanding of principles and procedures; generally accurate data analysis and discussion. 80–89: Clear and well-structured report; demonstrates accurate understanding of principles and procedures; correct and reliable data analysis and discussion. 90–100: Highly structured and logically coherent report; demonstrates deep understanding of principles and procedures; accurate data analysis with insightful interpretation.	50%

4.1.2 Electromagnetic Experiments of General Physics

Assessment Component	Description of Assessment Content and Methods	Weight
Experiment Preparation	Before each experiment, students must carefully read the experiment manual, consult relevant literature for preparation, and write a preparation report. During class, instructors conduct random questioning based on their preparation.	10%
Experimental Operation	0–59: Low participation; poor understanding of basic principles; weak hands-on ability; unable to analyze common experimental issues. 60–69: Limited participation; basic initial understanding; average operational ability; inaccurate analysis. 70–79: Good participation; mostly accurate understanding; solid hands-on ability; reasonably accurate analysis. 80–89: Active participation; accurate understanding; strong hands-on ability; precise analysis.	40%

	90–100: Highly active throughout; deep understanding; excellent skills; insightful analysis of common issues.	
Experiment Reports	0–59: Careless or perfunctory; missing or incorrect principles; incorrect procedures; no data analysis or discussion; submitted late beyond allowed period. 60–69: Reasonably structured; demonstrates initial understanding; inaccurate data analysis/discussion. 70–79: Clear structure; good understanding; mostly accurate data analysis/discussion. 80–89: Well-organized; accurate understanding; correct and complete analysis/discussion. 90–100: Fully standardized; deep understanding; accurate and insightful analysis/discussion.	50%

4.1.3 General Physics Comprehensive Experiment

Assessment Component	Description	Weight
Experimental Operation	Complete experimental operations according to the requirements	60%
Laboratory Report & Presentation	Completion of written reports and oral presentations as required	30%
Preparation	Completion and accuracy of pre-lab preparation	10%

4.2 Advanced Physics Experiments

4.2.1 Modern Physics experiments 1

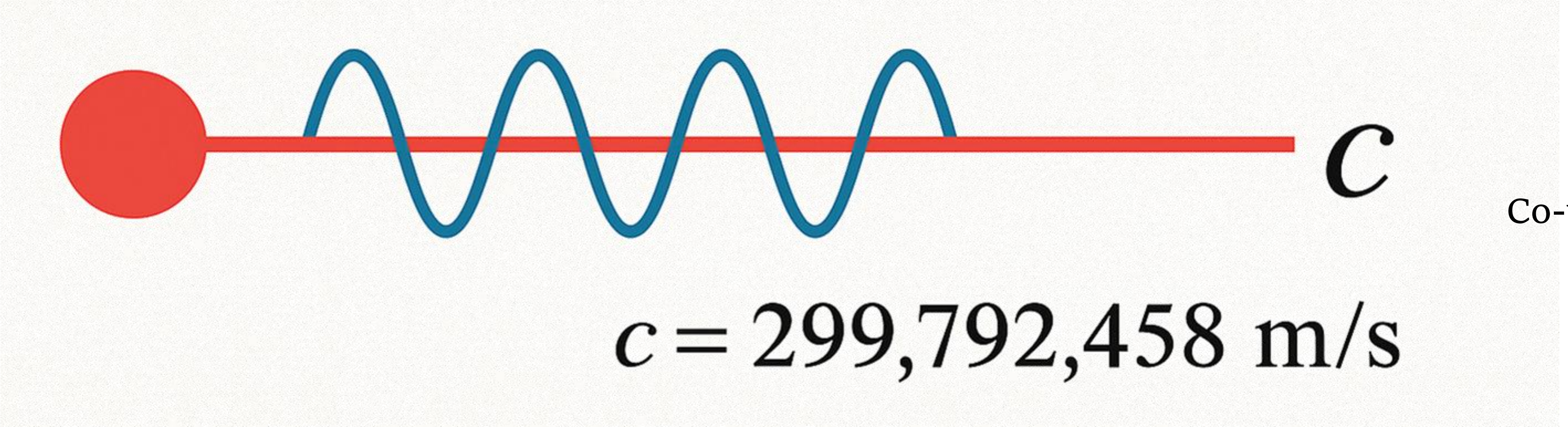
Assessment Component	Description	Weight
Laboratory Performance and Discipline	Complete experimental operations according to the requirements	40%
Reports and Communication	Submit experimental reports or deliver PPT presentations as required	50%
Pre-lab Preparation	Complete pre-lab preparation as required	10%

4.2.2 Advanced Physics Experiments

Assessment Component	Description	Weight
Laboratory Performance and Discipline	Complete experimental operations according to the requirements	40%
Reports and Communication	Submit experimental reports or deliver PPT presentations as required	50%
Pre-lab Preparation	Complete pre-lab preparation as required	10%

5 One representative document of an advanced experimental lab experiment

Light speed measurement experiments

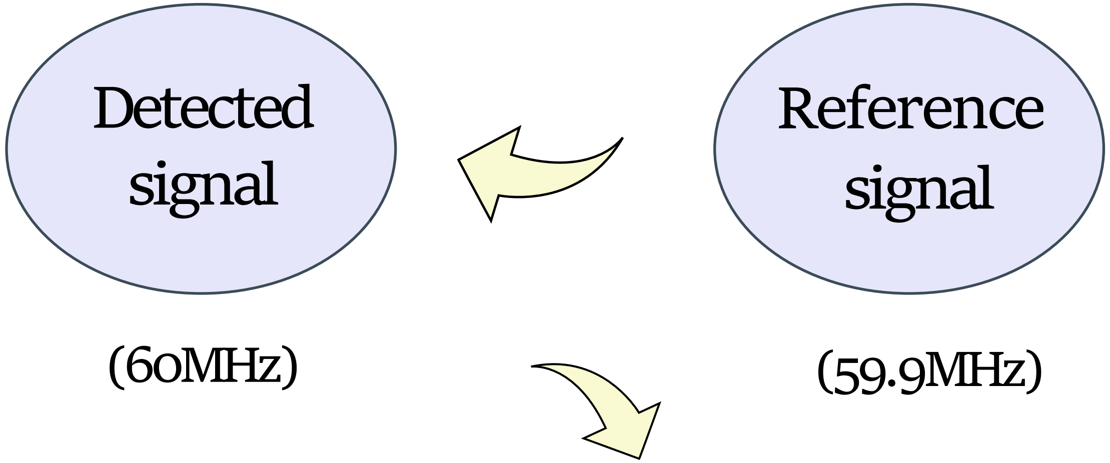


Presenter:蔡雨馨

Co-worker:陈殷、 洪灿纯

Supervisor:余云鹏

How to detect high-frequency light wave signals?



$$U \cdot U' = [a \cdot \cos(2\pi \cdot f \cdot t - \Delta\varphi)] \cdot [a' \cdot \cos(2\pi \cdot f' \cdot t)]$$

$$= \frac{1}{2} aa'[\cos(2\pi \cdot f \cdot t - \Delta\varphi + 2\pi \cdot f' \cdot t) + \cos(2\pi \cdot f \cdot t - \Delta\varphi - 2\pi \cdot f' \cdot t)]$$

$$= \frac{1}{2} aa' \cos[2\pi \cdot (f - f') \cdot t - \Delta\varphi] + \frac{1}{2} aa' \cos[2\pi \cdot (f + f') \cdot t - \Delta\varphi]$$

$$f + f' = 60.000 + 59.900 = 119.000\,\mathrm{MHz}$$

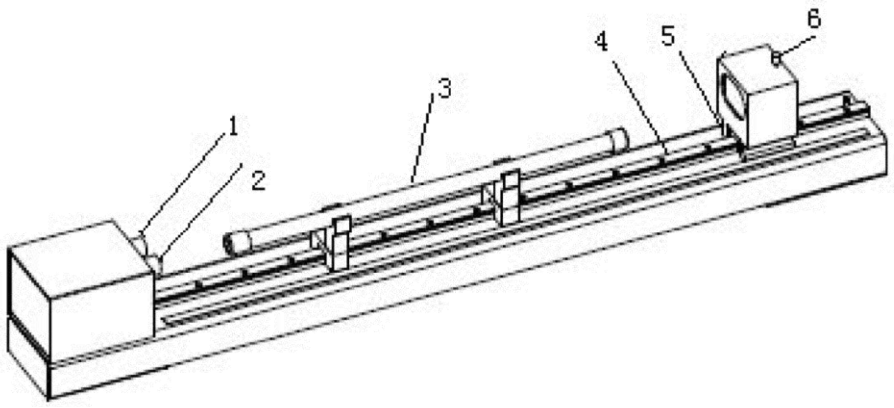
$$f_1 = f - f' = 60.000 - 59.900 = 100\,\mathrm{KHz}$$

1.Phase

$$C_a = \frac{\Delta s}{\Delta t_1} T_1 f$$

Change the optical path→change the phase

$$\Delta\varphi = 2\pi \cdot f_1 \cdot \Delta t_1 = 2\pi \cdot \frac{\Delta t_1}{T_1}$$



Experiment data

编号	测量信号频率(kHz) (f)	T_1 μs	光程差(m) Δs	时间差（μs） Δt_1	光速 $C_a = \frac{\Delta s}{\Delta t_1} T_1 f$	Er
1	59.9994	10	$2 \times 0.4231 \times 10^{-3}$	1.75	291229582	2.8%
2	↓	10	$2 \times 0.5080 \times 10^{-3}$	2.11	29009242	3.3%
3	↓	10	$2 \times 0.2295 \times 10^{-3}$	1	276447884	7.8%

靠近光源

(original)

In air

number	Detected signal f (kHz)	T_1 (μs)	Δs (m)	Δt_1 (μs)	C_a (m/s)	Er
1	59.9994	10	$2 \times 0.4231 \times 10^{-3}$	1.75	291229582	2.8%
2	59.9994	10	$2 \times 0.5080 \times 10^{-3}$	2.11	29009242	3.3%
3	59.9994	10	$2 \times 0.2295 \times 10^{-3}$	1	276447884	7.8%

Experiment data

In Glass

number	Lm (m)	X1(m)	X2(m)	Cm (m/s)	n
1	0.5000	0.5277	0.6311	2120772906.06	1.4316
2	0.5000	0.7100	0.8221	2069818133.35	1.4444
3	0.5000	0.6365	0.7171	2267033106.47	1.3224

Note:
Calculation method of average refractive index (excluding group 3):
n = (n1 + n2) / 2 = 1.42
Note: The data of group 3 deviates greatly

石英玻璃

编号	测试样品长度 L_m（m）	滑块及反射棱镜的位置 X_1(m)	滑块及反射棱镜的位置 X_2(m)	介质中的光速 $C_m=\frac{C_a}{n_m}=\frac{C_a\times L_m}{L_m+2X_2-2X_1}$ m/s	n (折射率) $=\frac{2\Delta X+Lm}{Lm}$
1	0.5000	0.5277	0.6311	2120772906.06	1.4136
2	0.5000	0.7100	0.8221	2069818133.35	1.4444
3	0.5000	0.6365	0.7171	226703310.647	1.3224

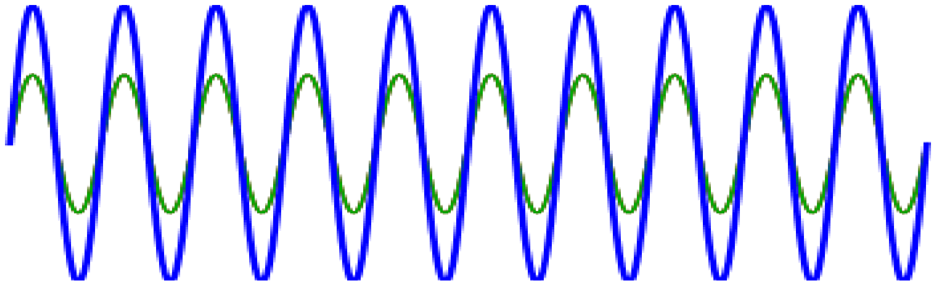
不容易读出变化

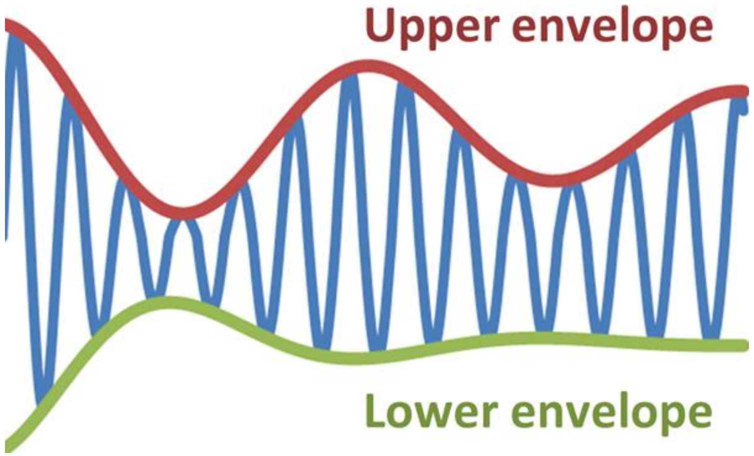
$n_{玻璃}=\frac{n_1+n_2+n_3}{3}=1.3935$

✓ $n_{玻璃}=\frac{n_1+n_2}{2}=1.429$
(不考虑误差较大的组3)

(original)

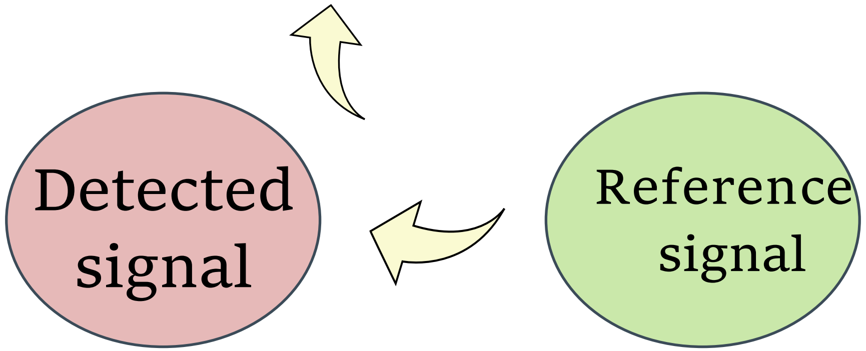
2.Beats





$$E = E_1 + E_2 = 2E_0 \cos\left[\frac{\omega_1 - \omega_2}{2}\left(t - \frac{x}{c}\right) + \frac{\varphi_1 - \varphi_2}{2}\right] \times \cos\left[\frac{\omega_1 + \omega_2}{2}\left(t - \frac{x}{c}\right) + \frac{\varphi_1 + \varphi_2}{2}\right]$$

$$Amplitude\colon\ 2E_0 \cos\left[\frac{\Delta\omega}{2}\left(t - \frac{x}{c}\right) + \frac{\varphi_1 - \varphi_2}{2}\right]$$



$$f = \frac{\omega}{2\pi}, \quad \omega = \frac{\Delta\omega}{2}$$

$$\Delta f = \frac{\Delta\omega}{4\pi}$$

$$\Delta\varphi = 2\pi \ \Rightarrow\ \Delta \mathrm{L} = \Lambda$$

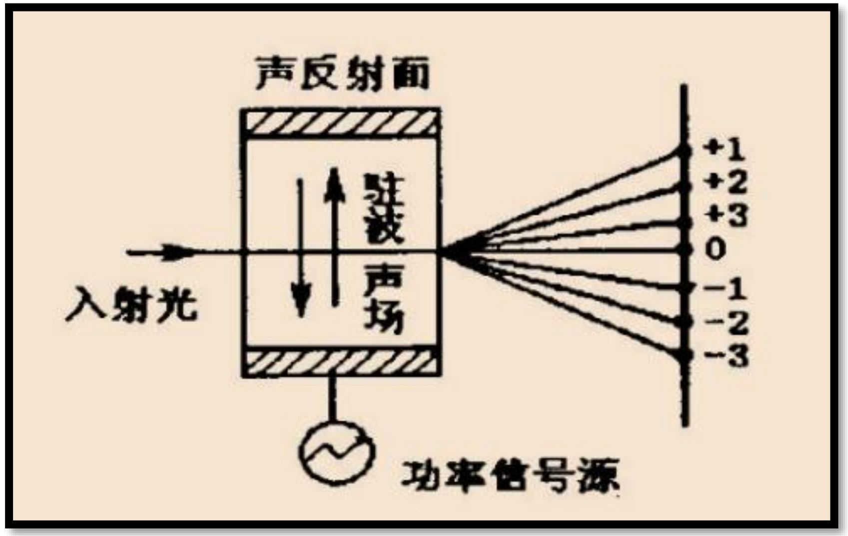
$$c = \Delta f \cdot \Lambda$$

2.1 Get Δf

ultrasonic wave(超声波)

Acousto-optic effect

Incident light (to be measured)



$$f_{L,m} = f_0 + (L + 2m)F$$

L: diffraction order

F: frequency of ultrasonic power signal source

m: standing wave mode

L=1

m=0 (basic standing wave mode (i.e. minimum thickness))

m=1 (One more round trip than m=0)

$$f_{1,1} - f_{1,0} = f_0 + (1+2)F - [f_0 + (1+0)F]$$

$$\Delta f = f_{1,1} - f_{1,0} = 2F$$

2.2 Get ΔL

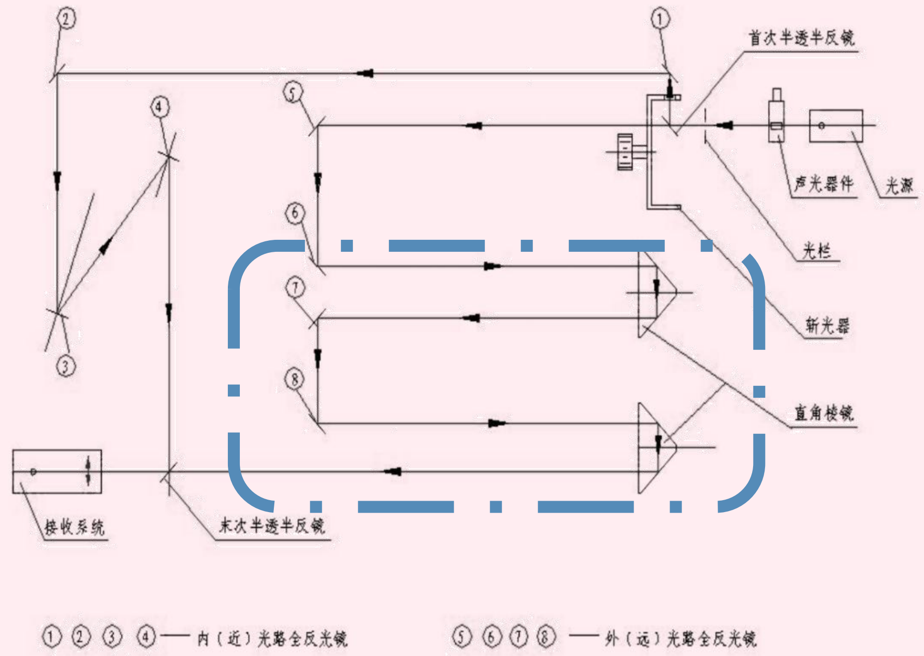
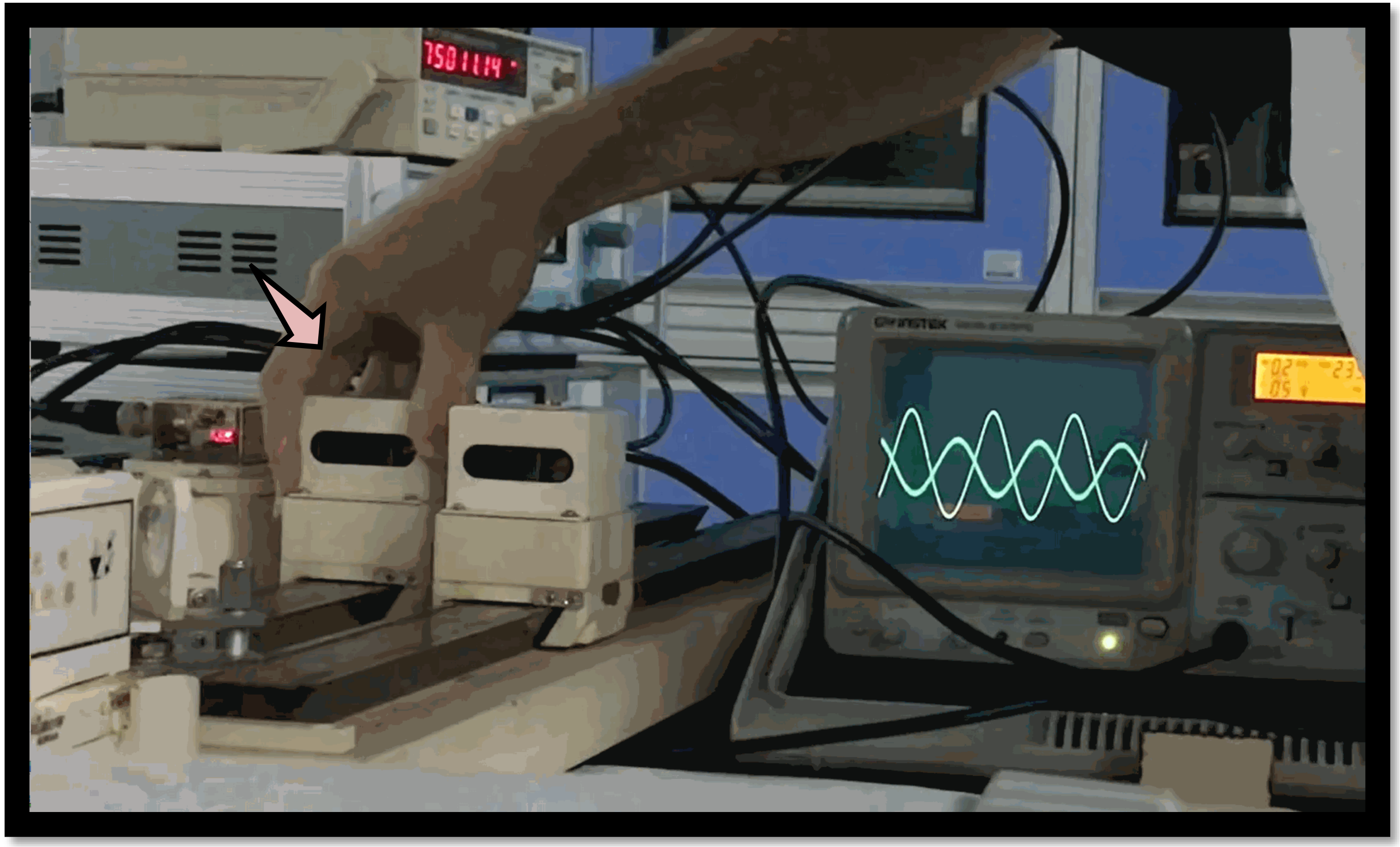
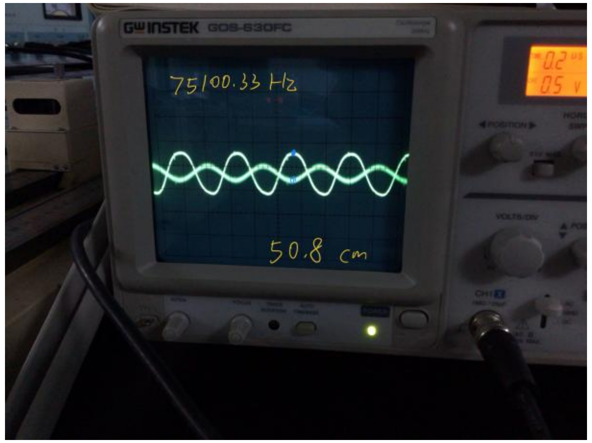


图 4　光学系统示意图



Experimental apparatus

Experiment data



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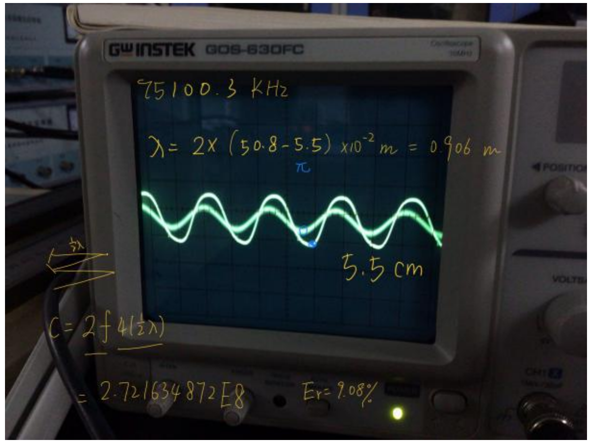

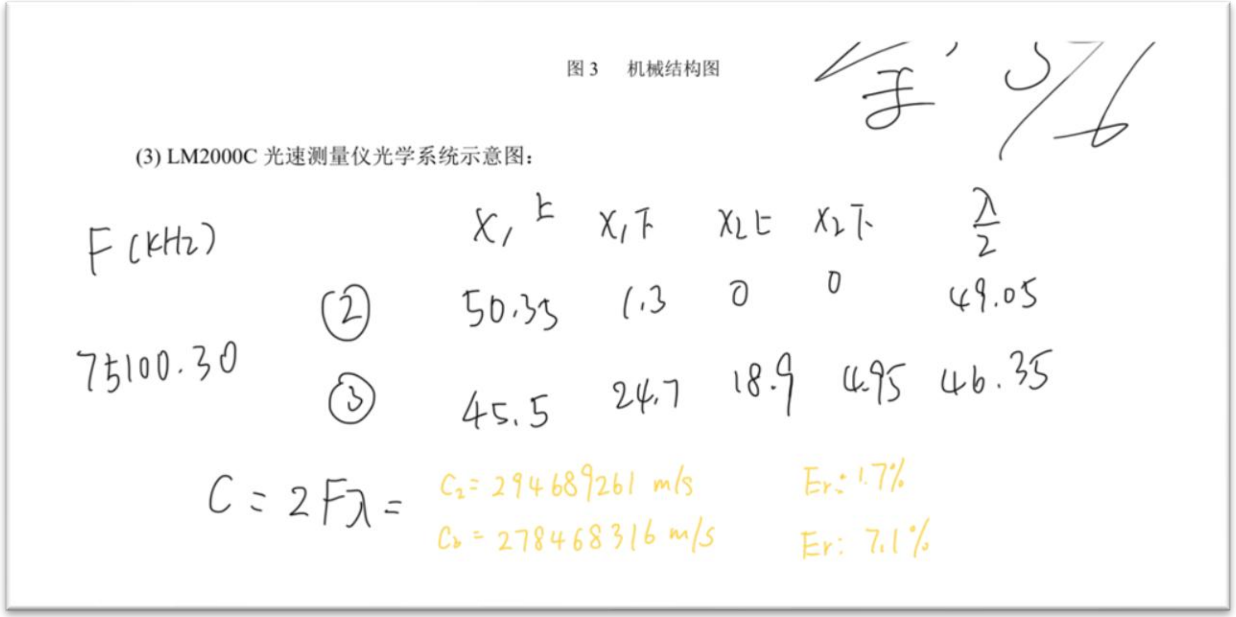

图 3 机械结构图

(3) LM2000C 光速测量仪光学系统示意图：

F (kHz)		X_1上	X_1下	X_2上	X_2下	$\frac{\lambda}{2}$
75100.30	②	50.33	1.3	0	0	49.05
	③	45.5	24.7	18.9	4.95	46.35

$C = 2F\lambda =$ C_2 = 294689261 m/s Er: 1.7%

C_3 = 278468316 m/s Er: 7.1%

C1=2.721634 872 E8 m/s
Er1=9.08%

C2=2.94 689261 E8 m/s
Er2=1.7%

C3=2.78468316 E8 m/s
Er3=7.1%

Error analysis

I. Systematic Errors

- Low instrument sensitivity

Even a 0.001 m error can significantly affect the final refractive index.

- Optical path is not aligned

If the light doesn't pass perpendicularly, the actual optical path differs from the assumed Lm

- Neglected boundary effects

At the edges, scattering or unstable fringes can disturb interference pattern reading.

II. Random Errors

- Reading error
- Table vibration or air disturbance
- Variable sliding friction

Uneven resistance during movement may cause the slider to overshoot or rebound slightly, affecting position readings