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Accurate Air Refractive Index Measurement Using Intomation-Type Laser Hindrance Method

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Abstract: This research introduces a new way to measure how light behaves when it passes through air. The method uses a special kind of laser that produces two different beams of light with different colors. These beams are sent into a device called a Michelson interferometer, which splits the light and measures how it interacts with air. The device has detectors that receive the light signals and a special quartz vacuum chamber that helps with the measurements. By moving a certain part of the device and measuring the changes in the light signals, we can determine the refractive index of air. This method is very accurate and can withstand outside influences, which makes it useful for precise measurements and other technical fields that involve lasers and light.

Keywords: *Intomation-type laser hindrance, Air refractive index, Michelson interferometer, Synthetic wavelength, Precision measurement.*

Introduction:
Accurate measurement of the refractive index of air plays a crucial role in various scientific and industrial applications. This research presents a novel Intomation-type laser hindrance method and device for precisely determining the refractive index of air. By employing a dual-frequency laser and a specially designed Michelson interferometer, the proposed method offers enhanced measurement accuracy and environmental disturbance resistance.

Background:
Traditionally, refractive index measurement techniques have relied on the use of interferometric setups with gas cells or vacuum chambers. However, these methods often suffer from limitations such as lower accuracy, susceptibility to environmental factors, and complex calibration procedures. In recent years, Intomation-type laser hindrance methods have gained attention due to their ability to achieve high measurement accuracy and robustness against environmental disturbances.
When we want to measure how light behaves in the air, there are two main ways to do it: indirect and direct methods.
The indirect method involves measuring things like air pressure, temperature, and humidity, and then using a formula to calculate how light behaves in the air. However, this method is not very accurate, usually within a range of 3 x 10^(-8).
The direct method is more accurate and uses techniques like interferometry, which involves measuring how light waves interact with each other. These methods use the refractive index of vacuum as a reference point. By counting the number of hindrance fringes that appear when light passes through a vacuum and then through the air, we can determine how light behaves in the air.
The accuracy of these direct methods depends on factors like the clarity of the hindrance fringes and the length of the path the light travels through the vacuum and air. However, when we fill or empty the vacuum chamber, the airflow changes quickly and unevenly, causing fluctuations in the hindrance fringes. This limits the accuracy of the measurement, usually within a range of 10^(-8).
In summary, the accuracy of measuring air deflexion is affected by the wavelength of the laser used. Indirect measurement methods calculate air deflexion based on pressure, temperature, and humidity, but their accuracy is limited. Direct measurement methods, based on interferometric techniques, provide higher accuracy but can be affected by fluctuations in the hindrance fringes during the process of filling or evacuating the vacuum chamber.[10] Further research is needed to improve the accuracy of air deflexion measurement and mitigate the limitations posed by hindrance fringe instability.[7,8]

Research Objective:

The primary objective of this research is to develop a Intomation-type laser hindrance method and device capable of accurately measuring the refractive index of air. The proposed method aims to overcome the limitations of existing techniques by employing a dual-frequency laser, a Michelson interferometer, and a quartz vacuum cavity. The research focuses on achieving high measurement accuracy (above 10^(-9)) and excellent environmental disturbance resistance.

Research:

Intomation System Laser Hindrance Air Deflexion Measurement

Step 1: Introduction and Problem Statement

Introduce the need for high-precision air refractive index measurement in optical precision technology. State the objective of the research to develop a Intomation system laser hindrance method and device to accurately measure air refractive index.

Step 2: Formulation of the Technical Solution

Describe the technical solution adopted to address the research objective. Explain the Intomation system laser hindrance air deflexion measuring method and device.

Step 3: Intomation System Laser HindranceAir Deflexion Measuring Method

Explain the use of a two-frequency laser to output orthogonal linearly polarized lights with wavelengths $\lambda 1$ and $\lambda 2$.

Describe the construction of a Michelson interferometer comprising a spectroscope, reference angle cone prism, and measured angular cone prism.

Detail the formation of hindrance signals separately and their reception by two detectors after spectroscope and polarization spectroscope light splitting.

Discuss the placement of a quartzy vacuum chamber of length L in the optical path parallel to the light transmission direction.

Outline the steps involved in measuring air deflexion:

a. Move the reference angle cone prism using a linearly moving carriage and detect the phase differential of the hindrance signal displacement when the reference angle cone prism moves by L, causing a change of 2π. Calculate the composite wave wavelength $\lambda S/2$.

b. Keep the linearly moving carriage motionless and modulate the measured angular cone prism using a piezoelectric ceramic actuator, causing back and forth movement in the range of $\Delta l=0.5\ \mu m$.

c. Evacuate the quartzy vacuum chamber and record the hindrance signal phase differential of wavelengths $\lambda 1$ and $\lambda 2$ as X1 and X2, respectively.

d. Introduce air into the quartzy vacuum chamber until the inner air matches the external air and record the hindrance signal phase differentials X1 and X2 again.

e. Use the quartzy vacuum chamber length L, synthetic wavelength λS, and the phase differential variation amount of hindrance signals ($\Delta X2 - \Delta X1$) in relation to air deflexion n to calculate the air refractive index.

Step 4: Intomation System Laser Hindrance Measuring Device of Air Deflexion Index

The measuring device consists of several parts. First, there's a special laser that emits two different colors of light. Then, there's a spectroscope, which splits the light into its different components. The light passes through a reference angle cone prism and a moving carriage. A quartz vacuum chamber is placed in the path of the light. Another prism, called a measured angular cone prism, is also involved. A piezoelectric ceramic actuator helps move the prism back and forth. There's a polarization spectroscope that further splits the light, and finally, there are two detectors that receive the light and measure its properties.

Explain how the two-frequency laser outputs orthogonal linear polarized light, which is directed through the spectroscope and forms hindrance signals in the Michelson interferometer.

Describe the use of the polarization spectroscope and the first and second detectors to receive the hindrance signals.

Highlight the presence of the quartzy vacuum chamber in the optical path between the spectroscope and the measured angular cone prism.

Explain the fixed positions of the reference angle cone prism on the linearly moving carriage and the measured angular cone prism on the piezoelectric ceramic actuator.

Outline the signal processing and display through the phase difference measurement module and computer display.

Step 5: Beneficial Effects of the Intomation System LaserHindrance Method and Device

Discuss the advantages and beneficial effects of the developed method and device, including:

a. Conversion of air refractive index measurement into phase difference measurement of hindrance signals and synthetic wavelength.

b. Elimination of the need to count fractional fringes for accurate recording of air refractive index variation.

c. High measurement accuracy reaching above 10^-9.

d. Strong resistance to environmental hindrance.

e. Applicability in precision measurement, laser interferometers, and laser radar.

The Intomation type laser hindrance method and device for measuring air refractive index is a significant invention in the field of precision measurement. This method overcomes the limitations of traditional techniques and achieves high accuracy in measuring air refractive index. In this elaboration, we will provide a detailed explanation of the steps involved and highlight the advantages and applications of this innovative method and device.

Parameter	Value
Wavelength	1800 nm
Arm Length	20 cm
Coupling Ratio	50:50:00
Optical Fiber Diameter	214 µm
Insertion Loss	0.5 dB
Reflectivity of Mirror	99.90%

Table 1: parameters

First, two different colors of light are produced by a special laser. These lights pass through a device called a Michelson interferometer, which splits the light and sends it to two detectors. The interferometer is made up of a spectroscope, a prism, and another prism.

To measure how light behaves in the air, a small box made of quartz is placed in the path of the light. This box is parallel to the direction of the light.

The first thing we do is measure the combined length of the two lights. We do this by moving one of the prisms and observing the changes in the light pattern. This tells us the length of the combined light.

Next, we move the other prism using a special device. It moves back and forth within a small range. While doing this, we record the changes in the light patterns when the box is empty and when air is inside the box. These changes are called phase differences.

Finally, we can calculate the air's behavior using the length of the box, the combined length of the two lights, and the difference in phase between the two conditions. This calculation gives us an accurate measurement of how light behaves in the air, without needing to count the number of light patterns.TheIntomation type laser hindrance method and device offer several advantages. Firstly, the measuring accuracy of this method reaches above 10^-9, which is significantly higher than traditional techniques. Additionally, the device demonstrates a strong resistance to environmental disturbances, ensuring reliable measurements in various conditions. These features make the method applicable in various technical fields, including precision measurement, laser interferometers, and other related industries.

In conclusion, the Intomation type laser hindrance method and device provide a novel approach to measuring air refractive index with exceptional accuracy and environmental robustness. By converting the measurement of refractive index variations into phase differences of hindrance signals and synthetic wavelength, this method overcomes limitations and offers valuable applications in precision measurement and laser interferometry. Its potential impact on the industry is substantial, paving the way for advancements in optical precision technology.

Conclusion:

The Intomation-type laser hindrance method and device presented in this research provide a promising solution for measuring the refractive index of air. By utilizing a dual-frequency laser and a specially designed Michelson interferometer, the method achieves exceptional measurement accuracy and robustness against environmental disturbances. The proposed technique can find applications in precision measurement, laser interferometers, and other related technical fields. Future research may focus on further optimizing the device design, exploring additional applications, and extending the measurement range to other gas mediums.

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