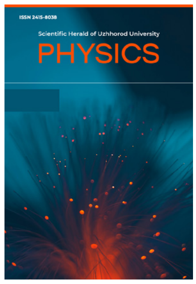
Scientific Herald of Uzhhorod University
Series "Physics"

Journal homepage: https://physics.uz.ua/en
Issue 53, 19-30
Received: 02/20/2023. Revised: 04/30/2023. Accepted: 05/15/2023



UDC 535.41
PACS 42.25.Hz
DOI: 10.54919/physics/53.2023.19

The scientific process of two interferometers (optical) development and the mitigation of external influence

Vitaliy Panov*

Senior Researcher
Dnipropetrovsk Department of the All-Union Research Institute of Mining and Rescue
49000, Heroiv Maidanu Sq., Dnipro, Ukraine
https://orcid.org/0000-0002-2672-7748

Abstract

Relevance. The research relevance is predefined by the fact that the presented object of analysis, namely the interferometer, plays an important role in modern science in obtaining accurate measurements and their results, which sets the requirements for improving interferometers and eliminating external influences.

Purpose. The research aims to analyze the progress of the development process of two interferometers, which are used in many scientific spheres, especially in optics, and play an important role in accurate measurement results of research, as well as finding new and effective technologies to eliminate external influences.

Methods. Among the methods used are an analytical method, logical analysis method, functional method, statistical method, synthesis method, and others.

Results. Throughout the study, two compensators and the differences between them were noted, and the features of these compensators' operation and their reliability were also analyzed. The negative factors that prevent more accurate measurements by interferometer were identified, and the most damaged elements in interferometers and their causes of damage were also identified. It is important to analyze the functioning of interferometers and compensators, and their operating conditions to assess the degree of efficiency, relevance, and progress in optics. The issues of evaluation of the development and problems of two schemes of interferometers with trapezoidal and square beamsplitters were also considered, and recommendations were proposed that would contribute to a more effective mechanism for regulating this issue.

Conclusions. It was determined that the process of developing new generation interferometers and eliminating external influences on them plays a crucial role in the development of optics, significantly affecting the progress in this area. The practical value lies in the application of the identified results, solving the problems of the process of developing interferometers and their progress in operation, taking into account various external influences, which will help to change the scheme of approach to the development of this mechanism and increase resistance to negative external influences

Keywords: compensators; measurements; negative factors; schemes; beam entry

Suggested Citation:
Panov V. The scientific process of two interferometers (optical) development and the mitigation of external influence. *Sci Herald Uzhhorod Univ Ser Phys.* 2023;(53):19-30. doi: 10.54919/physics/53.2023.19

*Corresponding author

Introduction

In modern science and technology, the requirements for accurate measurements by interference methods are rapidly growing and require the improvement and development of new innovative interferometers. To solve certain measurement problems it is possible to use only these methods and the interferometer. The problems of the interferometer development process and the elimination of external influences are associated with insufficient attention to engineering issues and their theory at the design and development stage, poor research of the causes that reduce the efficiency of this device, expensive materials of elements that are components of the interferometer. Following Yu.V. Kolomiytsov [1], the field of interference devices has significantly expanded due to the creation of new light sources (lasers) and the development of electronics. It is important to precisely control the thickness of nanoscale films of transparent materials during their application to the substrate during the development and manufacturing technology of various optoelectronics devices and optical nanosensors. For example, laboratory research in the chemical and pharmaceutical industries and ecology, in particular for air quality monitoring, uses highly sensitive devices based on the phenomenon of surface plasmon resonance and gas analysis.

As pointed out by Z. Chen *et al.* [2], interferometers are devices that are widely used for quantitative phase analysis to record small differences in optical arm lengths and control them with an accuracy of fractions of wavelengths of light radiation. The high sensitivity of the devices also has negative aspects. Thus, random changes in air pressure and temperature can cause changes in the indicators, and even very small fluctuations in temperature, air movement, and mechanical vibrations of the structure can lead to shifts that introduce noticeable random and systematic errors in the measurement results. Following B. Chen *et al.* [3], interferometers allow size measurements by comparing them with a natural constant, the wavelength of a frequency-stabilized laser, the laser radiation is a very close approximation to an ideal monochromatic wave. The accuracy of measuring the length of this fundamental physical quantity depends on the level of development of science and has a significant impact on progress in industrial technologies.

M. Hu *et al.* [4] note that the device for measuring interference lengths consists of two elements, an interferometer and an electronic system for calculating interference bands and processing measurement results. The analysis of laser interferometer interference circuits shows that in the practice of length measurements, a two-beam Michelson-type interferometer, the moving element of which is firmly connected with the object to be measured, is actively used. To eliminate the errors that are directed to the parameters of the interference field, the moving mirror is provided in the form of an angular reflector. Following H. Zhang *et al.* [5], some features and capabilities of interferometers used in optics are calculated by the Jones method, this method is mainly used to calculate many properties, but most often polarization. To calculate the polarization properties in the scheme, it is necessary to have the polarization azimuth that can be found from the matrix values. This method is used in many devices, but most of all in ballistic gravimeters.

The purpose of the research is to perform an objective analysis to identify problems in the process of developing interferometers and eliminate external influences at the present stage of optics development. This goal will provide an opportunity to develop effective interference methods to improve the accuracy of measurements and calculations in scientific research.

Material and Methods

Research in the field of studying the problems of the scientific process of developing two interferometers and eliminating external influences on these objects was performed by applying methods that reveal the theoretical and practical significance of the object of study. The method of logical analysis helped to identify the problems of the development process of interferometers in optics considering external influences. The statistical method was applied to consider the main indicators, which in turn help to analyze the prospects of interferometers development, the implementation of this process and the improvement of the quality of materials of parts that make up the interferometers, the importance of innovative interferometers in various fields, especially in optics, thanks to which the process of efficiency of the development of this mechanism and its prospects were determined. Using the functional method, the role and essence of interferometers in optics and other areas, their advantages, and disadvantages, as well as the impact and contribution of the device in the development of modern scientific research for more accurate measurements were analyzed. One of the empirical methods, namely the method of modular inspection, was used, the negative factors that prevent more accurate measurements by interferometer were identified, the most damaged elements in interferometers and the process of efficiency of the development of this mechanism and its prospects were also identified, the issues of evaluating the development and problems of two schemes of interferometers with trapezoidal and square beamsplitters were also considered, drawings of interferometers according to the new scheme were proposed and provided.

The structural-functional method helped in the analysis of trends, factors, and models of interferometer elements, which determined that solving problems with the development process of interferometers, with the improvement of measurement results in scientific research using interference methods, with the reduction of external influences and the definition and optimization of interferometer performance at the design, modeling and development stages in the field of optics, will require an increase in funding, a new approach to the system of manufacturing and a new approach to the production of interferometers. The method of deduction helped in the disclosure of the concept of“interferometer” through the prism of highlighting the characteristic features for a full analysis of the work and problems of this mechanism. Applying the method of synthesis, the obtained results of theoretical and practical nature are summarized to provide recommendations that contribute to solving problems and improving the efficiency and prospects in the design and development of interferometers and their parts, especially in optics and other fields in which interferometers are used for measurement.

As such, the research will be divided into several stages. The first stage was to reveal the theoretical aspect of the work, namely, to define the concept of “interferometers”, and to analyze the characteristics and principles of this mechanism; especially in optics. In the second stage, the study of the mechanism and problems of the approach to the scientific process of developing interferometers and components, their advantages and disadvantages, the functioning of this mechanism in various fields, and the analysis of the activity of this object in optics and its importance in accurate measurements was carried out; an important step of this stage was to analyze the process of designing and developing interferometers in optics, the implementation of the development of new approaches and technologies to the design of innovative models of interferometers, the means of eliminating external influences or its partial decrease. The third stage, based on the identified results of theoretical and practical content, identified problems and recommendations for the development of this mechanism and its components, which will contribute to the solution of issues and development in many areas for more accurate measurements.

Results

To ensure accurate measurement results in modern scientific research, it is necessary to develop scientific processes of development of all devices, including interferometers, with the help of which measurements are carried out in all areas. The general scheme of the interferometer structure is shown in Figure 1.

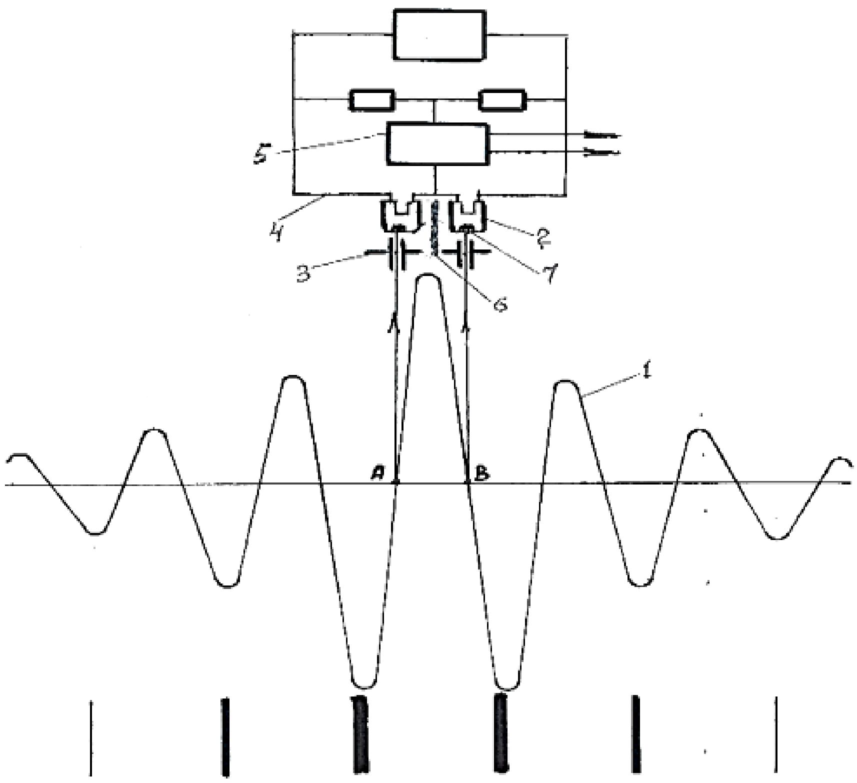


Figure 1. Interferometer with a light characteristic of the interference pattern

The interferometer consists of 1 – camera, 2 – isosceles pentaprism with an angle of 90° at the base and top, 3 – BR prism – 180°, 4 – triangular prism, 5 – parallelogram prism, 6 – light source, and 7 – lens. Mirrors are applied at the ends of a thin transparent plane-parallel plate, the middle part connected to the square faces, towards the camera, parallelogram, and through prisms. On the base of the beam splitter from the center, in opposite directions, with the front faces in the same plane, the bases are installed in the direction of the prisms: isosceles pentaprism, parallelogram – triangular prism. This connection of prisms is a light-emitting unit.

Interferometers have various applications, including length measurement, control of the shape and micro geometry of surfaces, research of optical systems and aerodynamic flows, measurement of refractive indices of substances, spectral studies, and tension measurement. This highlights the range of interferometers being broad, so the process of developing this object is an important issue to be solved. Interferometers are designed according to a new blueprint. The blueprint consist of two compensators, one compensator, HIBRID, in the presence of an interference pattern with horizontal stripes, uses plates from different compensators: the Jeumann compensator works in the vertical plane, and the Panov compensator in the horizontal plane. The second compensator – Panov – shifts the beams in the horizontal plane from the center, in opposite directions. Both compensators create an interference pattern in the horizontal plane relative to the base with vertical stripes that reduce the external influence. The development of scientific methods for solving the problems of designing and modeling interferometers in scientific research is carried out by scientists and engineers from many countries of research and design organizations. For the development of various optoelectronics devices and optical nanosensors, it is important to have control of the film thickness, which is carried out by the photometric method based on the interference of waves in the film without absorption, the film thickness is proportional to the wavelength. An automatic interferometer for cutting off the explosive concentration of methane, tuned to ¼ of the achromatic band of the interference pattern [6], contains the following positive qualities monotonicity of illumination in the entire range, two working photodetectors, the absence of negative phenomena of “pass” and “shift” of the color of the bands, high sensitivity, linearity of the scale, manometric method of graduation by water column and small chamber length: the upper limit is 100 vol% length of 1 mm, 4 vol% – 12 mm for methane with double passage of the rays.

The disadvantages of this interferometer are low brightness and contrast of the interference pattern and sensitivity to external influences. The interferometer used a beam splitter in the form of a rectangular prism mounted at an angle of 45° to the rays of the light source with a translucent layer. In this beamsplitter, large light losses due to multiple reflections and the ends of the strips are highlighted by “glare”, which in turn reduces the contrast and increases the use of diaphragms.

The issue of improving the process of development and elimination of external influences of interferometers, to reduce their shortcomings in the work and their problems of application in scientific research are becoming increasingly relevant and of practical value. The analysis of this mechanism at the design and modeling stages depends especially on careful observation of the operating personnel to avoid errors and to consider external influences that may further cause defects. There are two types of beamsplitters: a trapezoidal one consisting of two prisms, a parallelogram, and a triangular passing one, connected through a translucent layer, and a square beamsplitter consisting of two equal triangular prisms connected through a translucent layer, this beamsplitter is used in Michelson interferometer [7]. The beamsplitters have a common point of separation and assembly of paired interfering beams, which can reduce the size into an interference pattern that is twice as bright and contrasty as the rectangular one.

In this complex process, the revision of the modeling and development problems of beamsplitters and interferometers in general and their solution is of particular importance, since the development of innovative devices and technologies for high-quality scientific research in various fields in the country is one of the urgent problems of our time. Passive stabilization of the Michelson interferometer, which is designed to work as part of a laser emitter of ultrashort pulses, can increase the stability of a laser resonator with a controlled Michelson interferometer by using original interferometer circuits containing refractive and mirror optical elements.

As a whole, the problem of optimization of effective and qualitative elimination of external influences is not completely solved in modern interferometer developments. Laser interferometry is a technology for ultra-precision processing, integrated circuit manufacturing, precision metrology, and many other scientific research. In laser interferometry, the phase demodulation technology largely determines the performance of displacement measurement, and this technology is also widely used in optical interferometers due to its high sensitivity, wide dynamic range, and tight protection against external factors that negatively affect it.

Two interferometer schemes were developed: with a trapezoidal beam splitter [8] and with a square beam splitter [9]. The trapezoidal interferometer is shown in Figure 2.

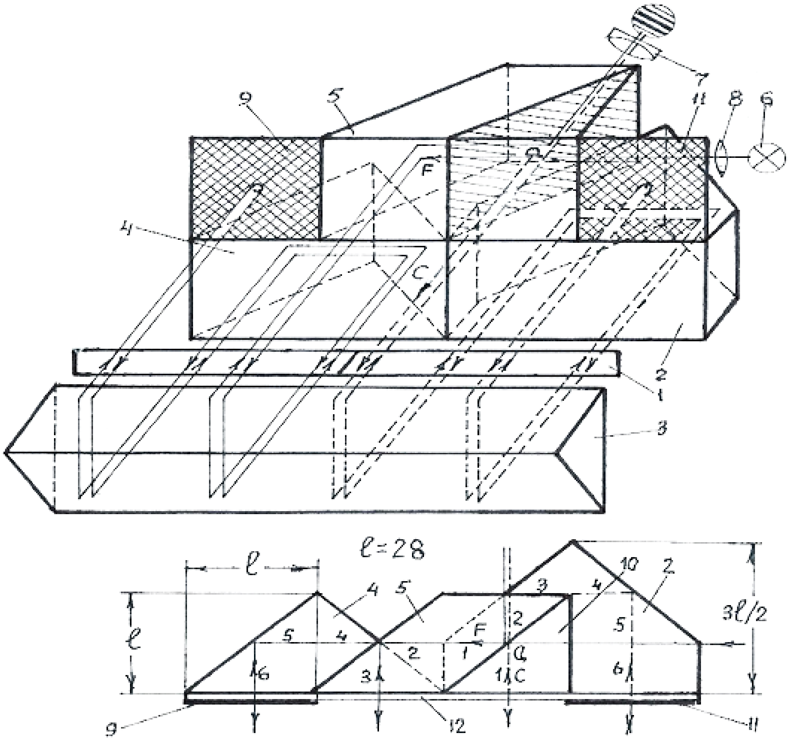


Figure 2. Trapezoidal interferometer with interference beam path

Number 1 – camera, 3 – BR prism – 180°, 4 – triangular prism, 6 – light source, 7 – lens, 8 – condenser, 9 – beam mirrors I, 10 – triangular passing prism, 11 – beam mirror II. Mirrors are applied at the ends of thin, transparent plane-parallel plates, the other ends of the plates are connected with square faces, towards the cameras, 14, 10 – equal triangular prisms. On the base of the beam splitter from the center, on opposite sides, there are two equal triangular prisms – 4, 13, with hypotenuse faces in the same plane and towards the chambers, with heights equal to the length of the sides of the square. Triangular prisms – 4, 13 are interconnected by mirror catenary faces, mirror towards the chambers.

Since the projections of the block have four squares on all sides, the unit of measurement is a square, it can be assumed that the length of the side of the square is l. So, a square beam splitter with sides l, hypotenuse face: length – 2l, height – l, prism heights – 4, 13 – l, between the rays – l, 9, 11 mirrors l by l. Substituting the length of the sides of the square l=25 mm (Fig. 3), it can be found the dimensions of the light unit and the entire interferometer.

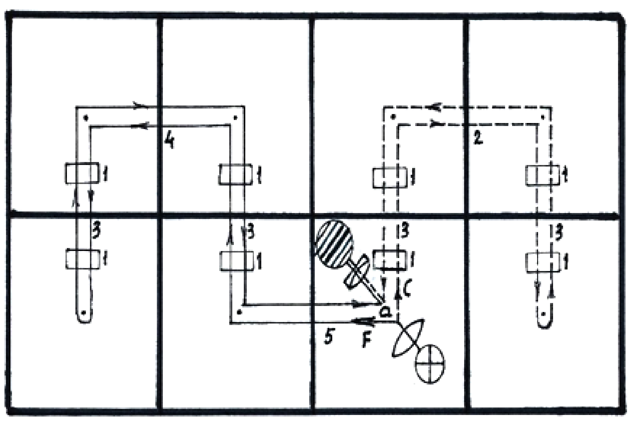


Figure 3. Projection of the light unit of the Panov interferometer with the course of the central rays

The production of interferometers and the application of interferometric methods has a long practice of being used both in international and Ukrainian experiments than the production and application of devices and methods with similar properties of work. For example, seismic interferometry can significantly reduce the influence of the source due to interference between seismic signals. This method can be used to process high-speed seismic signals and image the subsurface structure. Interferometers are susceptible to damage due to external influences, most often due to the base, which is made of invar, a metal alloy that is insensitive to external influences. When measurements are carried out by an interferometer, the wave displacement of the measured value converges to the value of the external influence with which it coincides in direction.

Currently, in many areas of scientific research, interferometry methods are the most widely used and developed [10]. In modern scientific research, interferometers are used, the radiation of which occurs with the help of two sources with a large difference in wavelengths, they are distributed in one way, and these waves can be represented by two types.

For the error signal to occur in the channel with short-wave radiation, the feedback method is used, the phase advance in the plasma is very small, and the systems in the interferometer, where the phase advance in the plasma deviates from the phase advance, caused by a change in the size of the interferometer measuring base due to the mathematical processing of signals registered in the measuring channels. Interference lines formed from pairs of equal optical length interference beams passing through the same interferometer device are identical, their zero lines are at the same point of the interference pattern and represent the same strip width. As a result, it is possible to obtain an increase in the brightness of the picture without reducing the diversity. A general interference pattern is obtained.

The prerequisite for the reliable functioning of the interferometer is to ensure stable operation and quality design of both some elements and the device as a whole. In the Michelson-type interferometer, the optical decoupling of the laser resonator and the interferometer is performed by standard polarizing elements or by separating the place of separation and recombination of the interfering beams.

For the comparative evaluation of two interferometers according to this scheme, an interferometer with a square beamsplitting prism was developed (Fig. 4). The length of the sides of the square is l=25 mm.

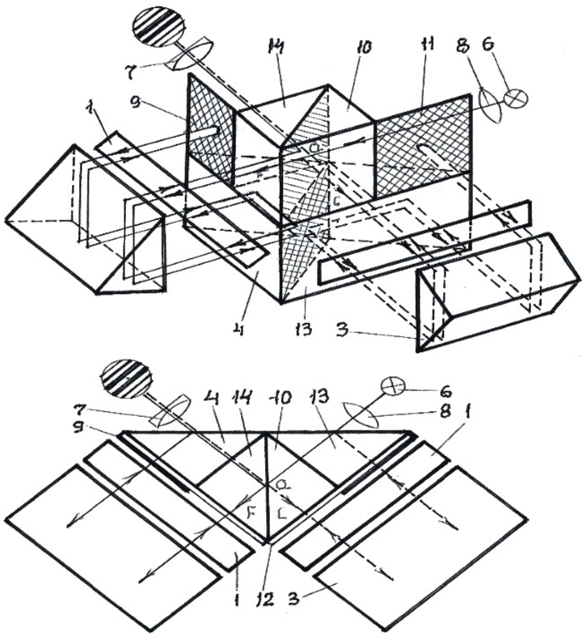


Figure 4. Square interferometer with the interference beam path

Solving the issues of developing an innovative and multifunctional interferometer requires the introduction of effective tools for modeling and designing quality elements of this mechanism. The methods that are still used to calculate the properties of interferometers are outdated and irrelevant, as innovative devices require more accurate calculations, without improving methods or introducing new ones, the operation of these interferometers will not be effective and accurate.

The interference pattern with horizontal or vertical stripes is arranged and rotated 90° in the vertical focal plane. The picture with horizontal stripes is located vertically along the length of the plane. Therefore, during measurements, the direction of displacement of the measured value of the horizontal stripes 15 is directed (the stripes are displaced along the picture) perpendicular to the base, parallel to external influences 16. perpendicular to the base. When measured, both values are added.

With the rotation of the interference beams of the horizontal strips by 90° through the compensator plates, the HIBRID rotates, and the interference pattern by 90°, which is horizontal along the length in the focal plane, and the strips are vertical relative to the substrate. The displacement of the strips from the measured value is constant along the base, it is added to the magnitude of the external influence directed along the base. This influence is small. The external influence of perpendicular pressure on the base does not return with the rotation of the rays by 90°. During measurement, the external influence slightly moves the vertical bars on the scale. The displacement of the bars does not affect the measured value. The width of the achromatic line of horizontal and vertical stripes is equal. To have vertical stripes in the presence of an interference pattern with horizontal stripes (Fig. 5), the HIBRID compensator is used, plates (thickness 0.2÷1.0 mm) of different compensators: Jeumann compensator – works in the vertical plane and Panov compensator – works in the horizontal plane. The rays (t. F, C) are shifted utilizing the compensator plates. For example, the beam t. F goes down – F1 (Joumain), and the beam of t. C is shifted to the right – C1 (Panov) until the width of the achromatic bands is equal. The interference pattern (t. F1 C1) with vertical stripes is obtained. The direction of displacement of the measured value 15 was rotated by 90°, and the direction of perpendicular influence on the base (external influences) – 16 – did not change [11; 12].

The interferometer (Fig. 5) with the help of the prism BR – 180° angle ß was tuned to horizontal bands with a given width of the achromatic band. The HIBRID compensator was used to obtain vertical bands.

The HIBRID compensator acquired vertical stripes. “0” was set at horizontal and vertical bands. At constant mechanical impact on the interferometer body with vertical stripes, there was no “0” offset. Without removing the mechanical impact, the compensator is removed. With horizontal stripes “0” shifted by 0.25 scale. From the measuring gas chamber, the displacement of the vertical and horizontal bands was equal. The difference between the variants of vertical strips from each other is that the wave displacement of the measured value is directed along the scale to the right or left along the base, and the displacement from external influences is directed perpendicular to the scale and the base. The displacement of horizontal stripes from both influences is directed along the scale, perpendicular to the base [13].

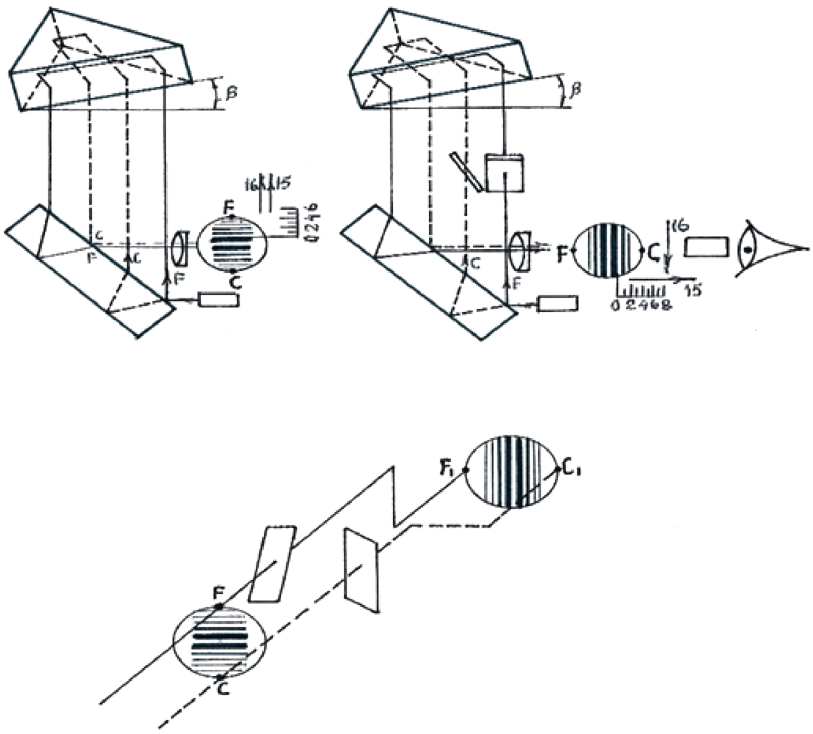


Figure 5. Obtaining vertical stripes with horizontal stripes

Item 17 in the figure – transparent plates with a thickness of 0.2÷1.0 mm, 18 – the base, Ɣ – the angle of the width of the vertical stripes, ß – the angle of difference of the interference beams. Each plate is rotated in opposite directions in the horizontal plane relative to the center by an angle Ɣ. The angle Ɣ is set so that the width of the achromatic band is equal to the calculated one. For the latest modifications of interferometers of the AI type, the angle is equal to – 12° at a plate thickness of 1 mm [14]. In the second method of obtaining vertical stripes without an interference pattern, the Panov compensator (Fig. 6) [8; 9] is used.

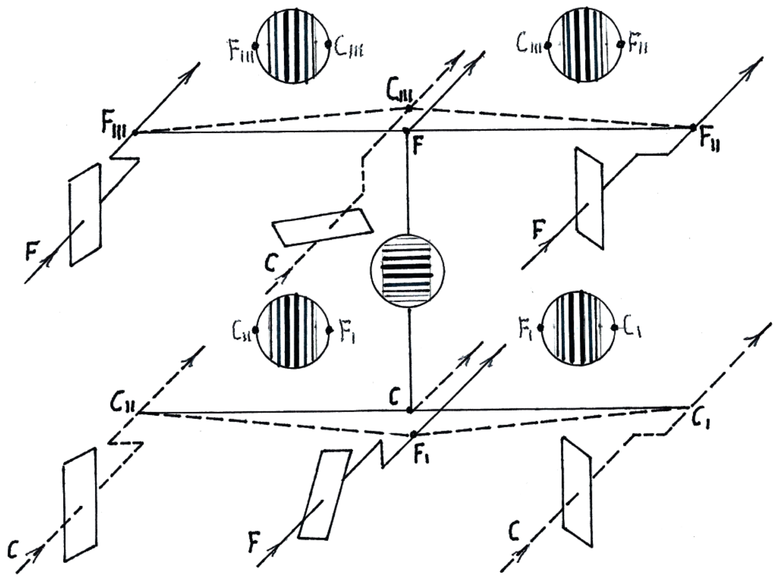


Figure 6. Panov compensator

Source: [8; 9]

Turning the plates symmetrically relative to the center on opposite sides, the width of the achromatic band is set. Between the rays of the horizontal plane, an interference pattern with vertical stripes with the above properties is formed. The compensator plates are in a vertical position, touching each other with the ends (center) and planes perpendicular to the interference rays and the center between the rays.

The development and modeling of affordable and multifunctional interferometers in real-time will allow us to bring the process of solving these problems to a new level in terms of the speed of the solution and the quality of the results obtained.

Discussion

The quality of measurements with the help of an interferometer depends on the correct production and its efficiency is one of the most urgent issues of modern science in many countries, and some problems require an immediate solution. The development of many modern spheres of science and technology requires improvement of ways to eliminate external influences of some devices and their elements and error-free diagnostics of these mechanisms. In the presence of interference patterns, vertical or horizontal stripes can be obtained. The difference between the variants of vertical bands from each other is that the wave displacement of the measured value is directed along the scale to the right or left along the base, and the displacement from external influences is directed perpendicular to the scale and the base. The displacement of horizontal stripes from both influences is directed along the scale, perpendicular to the base.

Studies carried out in recent years of the operation of interferometers and the most damaged elements of these devices allowed a better assessment of the impact of the environment on this mechanism and identify their main causes and damage to the elements that make up the object. Based on the results of recent studies by B. McKinley *et al.* [15], frequency reproducibility is an important characteristic, but for linear measurements, it is necessary to have an absolute value of the wavelength of emission, or as it is also called the absolute frequency of optical emission. The radio frequency bridges are used to measure the absolute optical frequencies, they are used to measure the frequency of lasers in the optical range. But the use of this experimental equipment is very expensive. This demonstrates that the design, modeling, and development of innovative interferometers and methods can provide more opportunities in various fields of research, it is necessary to increase financial support for the use of high-quality experimental facilities.

In different points of the interference field in which the interference pattern is observed, the phase difference sometimes has different values. To obtain interference, it is necessary that the phase difference of the oscillations, which are formed, remains the same during the time of observation or research.

It is worth noting that following modern international scientists and experts in the development of design and modeling of interferometers, Ukraine has made a major step forward over the past few years, and the demand for this device has also increased. Referring to the definition of Y. Pu & S.A. Cummer [16], heterodyne interferometry (HDI) based on three-wavelength photomixing, the HDI method can help to critically increase the sensitivity to small amplitudes of laser Doppler vibrometers and increase their noise immunity, in interference refractometers, as the investigated parameter is the phase of optical radiation, so the developments of HDI can be applied in refractometric measurements. The whole mechanism of the heterodyne interferometry method was analyzed, and as a result, it was decided that the disadvantage of this method is a large percentage of nonlinearity, which limits the measurement range, but it can be compensated, it is also necessary to monitor the stability of the chosen amplitude ratio, and to reduce the negative external influence, to have wave propagation in close conditions.

It is necessary to focus on the state of the devices used for this method and to determine the reason for the percentage of nonlinearity, it will help to highlight the problem and find an effective solution. The scientific process of developing interferometers in real time generates more and more new technical solutions for the implementation of the tasks, until recently, a large number of measurement results of scientific research in many areas were not available, since the existing devices were quite bulky and expensive.

It is important to note that the development of the next generation of interferometers will not be able to eliminate negative external influences or predict new ones. Researchers R.X Adhikari *et al.* [17] determined that some studies have provided the current characteristics, development rate, and development form of interferometers through observation and analyzed the process of self-sustained development of this device, but the research on the evolution of the initial stage to self-sustained development is still very limited. Furthermore, although the interferometer can accurately observe the initial stage of lightning at close range, the current location method has some errors in determining the location of the close-range discharge breakdown, which needs further improvement. The method of calibrating the positioning error of the interferometer for a specific close-range radiation source can be applied to avoid inaccuracies and some errors in measurements. It is very important to consider the importance of the proper study of these errors and their causes for further prospective development of interferometers. There is an assumption that the distance from the emission source to the interferometer is much larger than the reference length. If the emission source is near the interferometer, the assumption of a plane wave will bring some errors.

During the calculations in the development of interferometers and their elements in production facilities, considering external influences, models of this mechanism should adequately describe the process and be simple and realizable. K. Patel *et al.* [18] determined that the intensity distribution in the spot of the output emission was close to Gaussian, the output power level in the classical Michelson interferometer when tuned to the maximum intensity of the zero field was usually 0.2-0.3 W, which was about half the power level using the original Michelson interferometer, the long-term stability of the original Michelson interferometer was high and did not require its placement in an additional housing. This interferometer was analyzed and studied more precisely, and a comparison of the original and classical Michelson interferometer was made, it was found that such results of the classical interferometer could be due to an increase in the active losses of the resonator due to an increase in the number of reflections from the constituent optical coatings, or because during this study some decrease in efficiency was noted compared to the original interferometer.

A big role in the feasibility and usefulness of this device for customers is its small size, the development of a device with greater capabilities and new properties, low cost, and the elimination of some external influences, at the moment there are very few interferometers developed that meet such criteria due to insufficient attention to these mechanisms, so it is necessary to intensify the development of interferometers and bring it to a new level. W. Kim *et al.* [19] showed by his works that the increased stability of the refractive interferometer has the following advantages over the traditional one simplicity and reliability of adjustment, no need for angular adjustment of the elements, the possibility of precise alignment without a piezo transducer, which is an element sensitive to random acoustic noise, reduced sensitivity to microscopic translational movements of the elements and vibrations of the surrounding air, since the beam trajectories in both arms are the same, testing the interferometer in the passive mode allows us to expect reproducible and stable results in the controlled mode as a component mirror of a solid-state laser resonator emitting ultrashort pulses. It was determined that this interferometer allows the solution of many issues that could not be solved with the help of old-generation interferometers, and will also be able to popularize this mechanism in many areas for high-quality measurements due to its stability and multi-functionality.

Professional development of the personnel who design and create models of interferometers is a priority in the training of specialists, which contributes to the professional development of employees in this direction and activates their regulatory framework for the qualitative and promising development of these mechanisms. As noted by R. Apsari *et al.* [20], a multi-beam three-mirror interferometer allows the analysis of gas environments by analyzing the adsorbed from the gas to the hypotenuse surface of a monomolecular layer of matter. Each beam of light flux is reflected from the surface with a full internal reflection repeatedly. After analyzing this mechanism and its properties, it can be said that the multi-beam three-mirror interferometer can be used in optics in the creation of interference devices for various purposes for spectroscopy, as well as in the processing of optical information as sensors of various sensors and analyzers [21; 22].

It is necessary to increase funding for scientific processes of interferometer development and improve the quality of materials from which they are produced, to start introducing new technologies to improve the design and modeling of this mechanism.

Conclusions

Summarizing the results of this research, the following conclusions can be made. The main problems of the scientific process of developing two interferometers in every area, especially in optics, are insufficient funding, problems of proper modeling, design, and development of interferometers and their elements, failure to address the influence of many external factors in the design, these problems are and will be relevant and require further research. In this research, the goal was fulfilled, namely, the presentation of two interferometers designed following a new scheme and two ways to eliminate external influences in interferometers with two compensators, the analysis of the development process of two interferometers used in optics, as well as effective tools for eliminating external influences. It was possible to fulfill all the tasks of the research, namely, to highlight the problems of the operation of two interferometers and to analyze them more accurately, and methods for solving these issues were found and proposed for more efficient operation of this mechanism. The principle considered in the research is the development of models of two interferometers considering the influence of the external environment and possible assumptions, allows to obtain a comprehensive and more accurate assessment of the prospects of interferometers developed according to the new scheme, which is operated under different external influences.

The results of measurements made using the interferometer should be determined considering the specific operating conditions of this object. The presented schemes of interferometers in different variations can be used to optimize the development, a more accurate understanding of this mechanism will help in further simplifying the design and modeling. The analyzed modern approaches to the problems of Ukrainian development of interferometers will try to respond to the modern needs of users of these devices. Further research will be aimed at identifying problems and prospects for the development of new technologies for innovative compensators and beamsplitters, as well as expanding the range of applications of interferometers and increasing the capabilities of this mechanism.

Conflict of Interest

The author declares no conflict of interest.

Acknowledgements

None.

References

[1] Kolomiytsov YV. Interferometers: Fundamentals of engineering theory. Application. Engineering. leningrad: Mashinostroyeniye; 1976. 296 p.

[2] Chen Z, Zhang Y, Fan Y, Wang J, Lyu W, Zheng D, *et al*. Close observation of the evolution process during initial stage of triggered lightning based on continuous interferometer. *Remote Sens*. 2022;14(4):863. doi: 10.3390/RS14040863.

[3] Chen B, Jiang J, Lou Y, Yan L. Active linearized PGC demodulation with fusion of PGC-Arctan and PGC-DCM schemes for nonlinear error elimination in SPM interferometer. *Opt Express*. 2022;30(13):22999-23010. doi: 10.1364/OE.463593.

[4] Hu M, Yao C, Ventura A, Hayashi JG, Poletti F, Ren W. A comparative study of mid-infrared photothermal spectroscopy with different fiber interferometers. In: Optics and photonics for sensing the environment. Washington: Optica Publishing Group; 2022:3717-3721. doi: 10.1364/es.2022.etu4h.2.

[5] Zhang H, Wang B, Ning J, Li Y. Interferometry imaging using high-speed-train induced seismic waves. *Chin J Geophys*. 2019;62(6):2321-2327. doi: 10.6038/cjg2019M0676.

[6] Lendiel V, Stepakhno I, Yarovoi L. Application of three-wave heterodine interferometry for nanorized layers thickness measurement in the process of their deposition. *Bull Kyiv Polytech Inst Ser Instrum Mak*. 2022;63(1):39-45. doi: 10.20535/1970.63(1).2022.260636.

[7] Gryaznov NA, Goryachkin DA, Kuprenyuk VI, Sosnov EN, Alekseev VL. Passive stabilisation Michelson interferometer. *Sci Instrum*. 2020;30(4):67-74.

[8] Panov VV, inventor; Ukrainian Institute of Intellectual Property, assignee. Panov interferomete. Ukraine patent 149469. 2021 Feb 08. Available from: https://sis.nipo.gov.ua/uk/search/detail/1651693/.

[9] Panov VV, inventor; Ukrainian Institute of Intellectual Property, assignee. Interferometer. Ukraine patent 149105. 2021 Feb 12. Available from: https://sis.nipo.gov.ua/uk/search/detail/1632108/.

[10] Kabashin AV, Nikitin PI. Interferometer using surface plasmon resonance for sensor applications. *Quantum Electron*. 1997;24(7):671-672. doi: 10.1070/QE1997v027n07ABEH001013.

[11] Koronkevich VP, Lenkova GA. Laser interferometer for measuring length [Internet]. 1971 [cited 2022 Nov 30]. Available from: https://scholar.google.com.ua/scholar_host?q=info:8sp9_uci1Z8J:scholar.google.com/output=viewportpg=4hl=ukas_sdt=0,5.

[12] Ostapchuk AA. Research and calculation polarization properties of the interferometer using the method Jones. *J Zhytomyr State Technol Univ Eng*. 2015;2(73):154-158. doi: 10.26642/tn-2015-2(73)-154-158.

[13] Vrancken P, Herbst J. Aeronautics application of direct-detection Doppler wind lidar: an adapted design based on a fringe-imaging Michelson interferometer as spectral analyzer. *Remote Sens*. 2022;14(14):3356. doi: 10.3390/rs14143356.

[14] Thaisongkroh P, Pullteap S, Seat HC. Low-pressure measurement using an extrinsic fiber-based Fabry-Perot interferometer for industrial applications. *Eng J*. 2021;25(2):317-325. doi: 10.4186/ej.2021.25.2.317.

[15] McKinley B, Trott CM, Sokolowski M, Wayth RB, Sutinjo A, Patra N, *et al*. The All-Sky SignAl Short-Spacing INterferometer (ASSASSIN)-I. Global-sky measurements with the Engineering Development Array-2. *Mon Not R Astron Soc*. 2020;499(1):52-67. doi: 10.1093/mnras/staa2804.

[16] Pu Y, Cummer SA. Needles and lightning leader dynamics imaged with 100-200 MHz broadband VHF interferometry. *Geophys Res Lett*. 2019;46(22):13556-63. doi: 10.1029/2019GL085635.

[17] Adhikari RX, Arai K, Brooks AF, Wipf C, Aguiar O, Altin P, *et al*. A cryogenic silicon interferometer for gravitational-wave detection. *Class Quantum Gravity*. 2020;37(16):165003. doi: 10.1088/1361-6382/ab9143.

[18] Patel K, Nagora U, Joshi HC, Pathak S, Jadeja KA, Patel K, *et al*. LabVIEW-FPGA-based real-time data acquisition system for ADITYA-U heterodyne interferometry. *IEEE Trans Plasma Sci*. 2021;49(6):1891-1897. doi: 10.1109/TPS.2021.3082159.

[19] Kim W, Jung J, Kim J, Shin I, Kim N, Lee M. A new approach in optical metrology with multi-angle information through self-interferometric ellipsometry. In: Applied optical metrology IV. Washington: SPIE; 2021. p. 26-33. doi: 10.1117/12.2593375.

[20] Apsari R, Syadyyah H, Ningsih K, Yhuwana YGY. The development of the real-time Michelson interferometer for the measurement of thermal expansion coefficients of dental composites nanofiller. *J Phys: Conf Ser*. 2022;2274(1):012009. doi: 10.1088/1742-6596/2274/1/012009.

[21] Lopez B, Lagarde S, Petrov RG, Jaffe W, Antonelli P, Allouche F, *et al*. MATISSE, the VLTI mid-infrared imaging spectro-interferometer. Astron Astrophys. 2022;659:192. doi: 10.1051/0004-6361/202141785.

[22] Flores-Bravo JA, Illarramendi MA, Zubia J, Villatoro J. Optical fiber interferometer for temperature-independent refractive index measuring over a broad range. *Opt Laser Technol*. 2021;139:106977. doi: 10.1016/j.optlastec.2021.106977.

Науковий процес розробки двох інтерферометрів (оптичних) та пом’якшення зовнішнього впливу

Віталій Васильович Панов
Старший науковий співробітник
Дніпропетровське відділення Всесоюзного науково-дослідного гірничо-рятувального інституту
49000, пл. Героїв Майдану, м. Дніпро, Україна
https://orcid.org/0000-0002-2672-7748

Анотація

Актуальність. Актуальність дослідження зумовлена тим, що представлений об’єкт аналізу, а саме інтерферометр, відіграє важливу роль у сучасній науці в отриманні точних вимірювань та їх результатів, що ставить вимоги до вдосконалення інтерферометрів та усунення зовнішніх впливів.

Мета. Метою дослідження є аналіз процесу розвитку двох інтерферометрів, які використовуються в багатьох наукових сферах, особливо в оптиці, і відіграють важливу роль в отриманні точних результатів вимірювань при проведенні досліджень, а також пошук нових ефективних технологій для усунення зовнішніх впливів.

Методологія. Серед використаних методів – аналітичний метод, метод логічного аналізу, функціональний метод, статистичний метод, метод синтезу та інші.

Результати. В ході дослідження було розглянуто два компенсатори та відмінності між ними, а також проаналізовано особливості роботи цих компенсаторів та їх надійність. Виявлено негативні фактори, які перешкоджають більш точним вимірюванням за допомогою інтерферометра, а також визначено найбільш пошкоджені елементи в інтерферометрах та причини їх пошкодження. Аналіз функціонування інтерферометрів і компенсаторів та умов їх експлуатації є важливим для оцінки ступеня ефективності, актуальності та прогресу в оптиці. Також розглянуто питання оцінки розвитку та проблем двох схем інтерферометрів з трапецієподібним та квадратним променерозсіювачами та запропоновано рекомендації, які сприятимуть більш ефективному механізму регулювання цього питання.

Висновки. Визначено, що процес розробки інтерферометрів нового покоління та усунення зовнішніх впливів на них відіграє вирішальну роль у розвитку оптики, суттєво впливаючи на прогрес у цій галузі. Практична цінність полягає у застосуванні виявлених результатів, вирішенні проблем процесу розробки інтерферометрів та їх прогресу в експлуатації з урахуванням різноманітних зовнішніх впливів, що сприятиме зміні схеми підходу до розробки цього механізму та підвищенню стійкості до негативних зовнішніх впливів

Ключові слова: компенсатори; вимірювання; негативні фактори; схеми; введення променя