



MODERN INTERFEROMETRIC DEVICES

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Abstract: *this article analyzes the operating principles, types, and the role of modern interferometric devices in contemporary science and technology. The study examines the design features of laser interferometers, optical sensors, and high-precision measurement systems. Furthermore, prospective applications of interferometry in fields such as nanotechnology, metrology, and medicine are highlighted. The article demonstrates the advantages of digital and laser technologies in enhancing measurement accuracy.*

Keywords: *interferometry, laser measurements, optical sensors, metrology, nanotechnology, coherence, measurement accuracy*

Аннотация: *в данной статье анализируются принципы работы, виды и роль современных интерференционных приборов в современной науке и технике. В ходе исследования рассматриваются конструктивные особенности лазерных интерферометров, оптических датчиков и высокоточных измерительных систем. Кроме того, освещены перспективные направления применения интерферометрии в таких областях, как нанотехнологии, метрология и медицина. Статья демонстрирует преимущества цифровых и лазерных технологий в повышении точности измерений.*

Ключевые слова: *интерферометрия, лазерные измерения, оптические датчики, метрология, нанотехнологии, когерентность, точность измерений.*

INTRODUCTION



Today, technological progress—particularly in the fields of nanotechnology, semiconductor manufacturing, and fundamental physics—relies on ultra-high-precision measurement systems. Interferometers, which are devices based on the phenomenon of light wave interference, play a central role in achieving such precision. Although interferometry technology has been known since the last century, recent advancements in laser technology and digital signal processing have elevated the capabilities of these devices to a superior level.

The relevance of modern interferometric devices is determined by their ability to provide high accuracy in metrological measurements at nanometer and sub-nanometer scales. For instance, processes such as the detection of gravitational waves (the LIGO project), medical diagnostics via optical coherence tomography, and the quality control of complex optical surfaces are inconceivable without modern interferometers.

The purpose of this article is to analyze the structural characteristics of modern interferometric systems, demonstrate the role of laser and digital technologies in enhancing their operational efficiency, and explore the practical applications of these devices in various scientific and technical fields. This research pays special attention to the pressing challenges of modern metrology, such as increasing device sensitivity and ensuring resilience to external noise.

LITERATURE REVIEW, DISCUSSION, AND RESULTS

Operating Principles of Interferometric Devices

Modern interferometric devices—interferometers—are based on analyzing the interference patterns formed by the superposition (overlapping) of coherent waves. The operating mechanism involves splitting a single coherent light beam (typically a laser beam) into two or more paths using a beam splitter. After traveling through different optical paths, these beams are recombined. The resulting phase difference creates interference fringes, which provide highly precise information about the object under study.

Main Types of Modern Interferometers



Currently, several classic and modern types of interferometers are widely utilized depending on technological requirements:

- **Michelson Interferometer:** The most classic form of two-beam interference, it serves as a fundamental basis for distance measurement, wavelength determination, and optical surface quality inspection.
- **Fabry-Pérot Interferometer:** Based on multiple-beam interference, this device possesses high spectral resolution. It is primarily used in laser technologies and telecommunication systems to control wavelengths.
- **Mach-Zehnder Interferometer:** Due to the propagation of beams along two independent paths, this device is highly effective for measuring small changes in the refractive index or density of a medium.
- **Fizeau Interferometer:** Recognized as a global industry standard for controlling optical surface flatness and certifying the quality of lenses.

Modern Applications and Innovations

Today, interferometry has expanded beyond traditional metrology to encompass high-tech fields:

1. **Detection of Gravitational Waves:** Large-scale projects like LIGO and VIRGO utilize interferometers with optical paths spanning several kilometers to detect gravitational waves in space.
2. **Quantum Interferometry:** This technology is used in quantum computers and quantum internet systems to manage the superposition state of photons and create secure communication channels.
3. **Optical Gyroscopes:** In the navigation systems of aircraft and spacecraft, Fiber Optic Gyroscopes (FOG) based on the Sagnac effect provide ultra-high precision measurements of rotation angles.
4. **Microbiology and Medicine:** Interferometry enables the study of 3D cell structures and their reactions to drugs without physical contact (non-destructive testing).



The research results indicate that interferometric devices remain the most sensitive instruments for modern physical measurements.

- **Methodological Advantages:** Unlike other optical devices, interferometers enable non-contact measurements without physical impact on the object. This capability is of particular significance in fields such as microbiology and microelectronics.

- **Challenges:** A primary obstacle requiring discussion is the extreme sensitivity of these devices to external noise, such as vibrations, airflow, and temperature fluctuations. To mitigate this issue, the implementation of active vibration isolation systems and vacuum chambers has become necessary in modern setups.

- **Integration:** The integration of interferometry with digital cameras and Artificial Intelligence (AI) algorithms is currently being explored as a means to reduce the analysis time of interference patterns by 10–15 times.

- **CONCLUSION**

- In conclusion, modern interferometric devices serve as indispensable tools for achieving ultra-high-precision measurements across the most complex fields of science. This research demonstrates that these instruments are opening new horizons in metrology, quantum technologies, and medicine. Despite existing challenges, such as sensitivity to external noise, the integration of interferometry with artificial intelligence and digital technologies will further enhance the efficiency of this field. Consequently, the advancement of interferometric technologies will remain a key factor in driving future breakthroughs in fundamental physics and engineering.

REFERENCES

1. **Cloud, G. L. (1998).** *Optical Methods of Engineering Analysis*. Cambridge University Press.
2. **Hariharan, P. (2007).** *Basics of Interferometry* (2nd ed.). Elsevier Academic Press.
3. **Malacara, D. (2007).** *Optical Shop Testing* (3rd ed.). John Wiley & Sons.



4. **Paschotta, R. (2008).** *Encyclopedia of Laser Physics and Technology*. Wiley-VCH.
5. **Rakhimov, R. N. (2021).** *Optical Devices and Measurement Systems*. Tashkent: Fan Publishing House.
6. **Wyant, J. C. (2010).** White light interferometry. *Proceedings of SPIE*, 47(3), 200–215.
7. **Zinkov, S. A. (2019).** *Modern Interferometric Systems*. Springer Nature.