International Journal of Applied Mathematics

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

IMPROVING COHERENT IMAGING BY TARGETED OPTIMIZATION OF LOW- AND MID-ORDER ABERRATIONS: W11, W31, W30, W40, W51, W60

Safaa Mustafa Hameed

Department of Optics Technologies, College of Health & Medical Technology, Sawa University, Almuthana, Iraq

dr.safaa@sawauniversity.edu.iq

Introduction

Optical systems are instrumental in various applications, ranging from astronomy and microscopy to telecommunications, where the desired output is achieved by precise control of light. Nevertheless, built into these systems are optical aberrations, deviations from perfect optical behaviour, that may significantly impact image quality and system performance. Aberrations are often managed by optical engineers, which pushes them towards the challenge of achieving narrower, sharper, and more accurate imaging (Shailaja et al.). 2023). Such imperfections are inherent to the optical systems themselves and form the ultimate limits to achieving the most desirable performance. As photons travel through lenses, mirrors, and prisms, they encounter the haze of distortions introduced by aberrations, which obscure the teleological faithfulness of images. The shadow cast over the landscape of optics exploration. However, in the world of imperfection, the promise of progress is born. This promise is fueled by the tireless search for optical perfection and the commitment of human beings who would venture to the boundaries of light.

By studying the nuances of aberration correction and optimization, optical engineers aim to unravel the mysteries of light and unlock new realms of potential. With a feat of theoretical intuition, experimental cunning, and computational power, they set out to carve light itself — to twist, bend, and shape the very stuff of photons — to capture images that rouse the imagination and reveal the extraordinary (Li et al., 2024). As we face the dawn of yet another era of optical innovation, we must confront the aberration head-on and grapple with the complexities of light, ultimately triumphing in our quest to produce perfect optics.

Abstract:

However, analyzing optical aberration and designing for optimal aberration in an optical system is critical. We have derived the equation for the optimum balance of spherical aberrations and studied the effect of aberrations on images formed for objects with sharp edges. We also transformed the aberration coefficients (W51), (W31), (W11), (W60), (W40), and (W30) for a circular aperture and set all aberration coefficients to 0. We ran the program and analyzed the outcomes after correcting for the specific (Z') values to ensure the validity of this system.

Received: August 04, 2025

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

Keywords: Improving, Coherent Light, Optimization, Optical Systems, Aberrations, (W51), (W31), (W11), (W60), (W40), and (W30).

The effect of Aberration in Optical Systems:

Optical problems, those fuzzy distortions that compromise clear images, subtly affect how well we see things. They are hidden in the components that make up cameras and scopes, and they manipulate light as it passes through lenses and mirrors. These problems, which arise from lens shape, material, and the world around them, alter the path of light, which in turn darkens the image.

Spherical aberration disrupts how light focuses, resulting in blurry images. Chromatic aberration splits light into colors, much like a rainbow effect, which can also blur things. Then there is coma, which makes points of light appear to have comet tails – it really distorts the image.

Astigmatism messes with your vision. Instead of seeing clearly, things look blurry because the light does not focus properly. Additionally, distortion can bend light in unusual ways, making it difficult to trust what you see.

Optical problems do not just make things look weird; they also affect how well optical devices function. If you are using microscopes or taking medical images, where accuracy is crucial, these problems can obscure important details and make it difficult to obtain accurate information. In creating tiny, precise components, such as those achieved through lithography, even minor errors can cause significant problems. This can damage the product and result in a significant loss of time and money. Therefore, when designing optical systems, we must address these issues directly. We need to understand how light works and present the information clearly and concisely. By working diligently to enhance optical systems, we can overcome these challenges and truly maximize what we can see.

Optimized Systems Illuminated Coherent Light:

In optical engineering, there are always fresh changes, lots of tricky problems, and cool new ideas. People are always seeking better ways to correct blurry images. One innovative idea is to use coherent light. It is a game-changer for making images way better. (Li et al., 2021). Essentially, coherent light utilizes light waves that are in sync to produce extremely sharp images. Regular light sources are messy, but coherent light sources, such as lasers, provide engineers with a valuable toolkit for combating blurry images. Coherent light sources are excellent for enhancing the performance of optical systems. By manipulating wavefronts and coherence, engineers can effectively control light—bending and shaping it precisely. Lasers help correct problems like aberrations, making images more straightforward. Spherical aberration gets corrected with good optics, and chromatic aberration (those weird color distortions) disappears thanks to coherent light. However, perhaps the most remarkable thing is how coherent light can surpass the capabilities of standard optics, reaching the diffraction limit. People once thought this was impossible, but now it is feasible thanks to the clever work

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

of optical engineers. By carefully managing coherence, issues disappear like mist in the morning, leaving clear views and numerous possibilities. In this world of perfect optics, images become incredibly clear, revealing hidden aspects of the universe with remarkable clarity and precision (Jia et al., 2022). We are on the edge of some tech changes in optical stuff. Coherent light is calling us forward – it is like a beacon in the darkness, something we truly desire. Every laser pulse gets us nearer to making our dream come true: a world without optical problems, where everything is perfect.

Purpose and Objectives of the Paper

The primary purpose of this study is to investigate the optimization of aberration in optical structures through the use of coherent light illumination. Through an intensity analysis of experimental facts and theoretical ideas, this paper aims to:

1. Investigate the effectiveness of coherent mild illumination in minimizing optical aberrations.

2. Evaluate the impact of different aberration parameters, along with W20 and W40, on the device's overall performance.

3. Identify developments and correlations in the statistics to inform optimization strategies.

4. Discuss the results of the findings for practical packages in optical engineering and related fields.

This publication aims to follow up on the development of coherent light applications and aberration optimization, with a focus on advancing modern optical technology and its various branches. In the following sections, we explore the theoretical foundations, experimental methodologies, evaluation, and broader impacts of optimizing optical system aberrations. Addressing these aspects enables us to highlight the path towards clearer and more precise imaging in optical engineering, which remains our ultimate goal.

Coherent Light Illumination:

With a degree of accuracy and control over light waves, coherent light illumination stands to prove that further advancement in the field of optical engineering is due to the flexibility of time. The ability to use coherent light illumination, such as lasers, to realize free-aberrate imaging serves as an ideal for other optical systems during the optimization procedure (Gao et al., 2021). Because these coherent sources bestow even engineers with greater possibilities for accurately and delicately shaping light waves due to their spatial as well as temporal coherences, engineers leverage their unbeatable precision in controlling phase, polarization, orientation, and other states of light that constitute the essence of control that consistent lighting achieves. Unlike a conventional source that emits waves with random phase conditions, coherent light waves travel in synchronization with one another; that is, they are mutually coordinated in space and time. It is this coordination that provides the reference upon which engineers base their imaging and on which withdrawal-limit strategies are founded.

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

Through the strategic modulation of consistent light waves, engineers can utilize optical VIP to navigate complex areas with dexterity and intelligence. It is possible to count and neutralize optical elements by precisely modifying the phase and polarization of light, opening the door to ancient imaging with exceptional clarity. It offers a flexible toolset to manage optical challenges with constant light, precision, and accuracy, whether ideal for compensating for atmospheric disruptions in astronomical observation or spherical deviations in high-resolution microscopy. In actuality, consistent light's transformation capacity extends beyond the degree of deviation improvement, enabling a variety of optical spectrum applications. Consistent light sources are essential for achieving under-conversion resolution and pattern fidelity in fields such as lithography, where nanoscale precision is crucial (Penger et al., 2021). Innovation at the forefront of quantum technology is fueled by developments in quantum optics, quantum information processing, the nature of light at the core of quantum phenomena, and superposition.

The constant light remains a leading light, illuminating the way for adaptation with unwavering clarity and purpose, because the optical engineer can continually push its boundaries. Through inventive methods and groundbreaking discoveries, the transformative power of continuous lighting continues to push the boundaries of optical engineering science, creating new avenues for investigation and research in the pursuit of advanced techniques, explosion-free imaging, and other areas.

Literature Review

Unveiling the tapestry of optical aberrations

The leading contributions of Ernst Abe and Lord Rayleigh emerge as guiding when we begin our study to analyze optical science, illuminating the way to a more profound comprehension of optical disasters. Ernst Abbe's groundbreaking work on microscopy revolutionized our understanding of the optical system, established the concept of numerical aperture, and laid the groundwork for the systematic study of microscopy. Their inflexible mathematical framework enabled the calculation of aberration effects, clearing the path for optical design and subsequent design advancements.

The intricate relationship between wave events in the optical system was revealed by Lord Rale's investigation of light, which was the foundation of ABBE's fundamental work. Rale's explained the intricate relationship between light waves and optical elements through careful application and theoretical analysis. It also disclosed how the mechanisms formed and spread (Gao et al., 2021). The foundation of optical science, which offers profound insight into the species and outcomes of optically significant processes, is still his groundbreaking dissertation on the "Theory of Abbrection."

Beyond the realm of theoretical conjecture, the rich image tissue of optical aberration finds manifestations in real-world problems faced by optical engineers and designers. The development of aberration-free imaging has sparked an unrelenting quest for innovation and

Volume 38 No. 7s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

discovery, dating back to the early days of lens design and continuing to the present day, with the introduction of advanced computational algorithms (Tsyganok et al., 2022). Optical aberration has historically presented both challenges and opportunities, inspiring the creation of novel methods and solutions for adaptation and mitigation.

The primary role of astronomers like Galileo Galilei and John Capler in the field of astronomical observation served as the foundation for our comprehension of the enormous advances in binoculars. Galileo's telescopic remarks and Capler's planetary movement exposed the finer details of optical deviations and described their profound impact on astronomy's clarity and resolution (Fontbon et al., 2022). Astronomers can now reach far into the cosmos with exceptional clarity and accuracy thanks to the advancements in adaptive imaging and corrective optics made possible by these early observations.

Publishers like Carl Zes and Ernst Abbey revolutionized microscopy by enabling us to detect the micro-world with unprecedented clarity and determination. Zeiss's inventive lenses transform the field of microscopy in terms of design and theoretical understanding. According to Tsyganok et al. (2022), optical deviation of ABBE, biology, medicine, and material science creates new opportunities for exploration and discovery. The light of cellular anatomy is both complex and fascinating.

The discovery of aberration-free imaging has facilitated the development of sophisticated imaging technologies and techniques within the realm of high-energy and particle accelerator physics. The discovery of accurate imaging, made possible by the pioneering work of physicists such as Ernest Lawrence and Wolfgang Pauli, as well as contemporary experiments in industry, has encouraged ongoing innovation and discovery. Physicists explore the fundamental forces and particles that govern the cosmos, shedding light on its mysteries through the use of particle detectors and imaging systems.

Types and causes of aberrations:

It becomes evident that their classification goes just a bit beyond the classification to include a nice understanding of their underlying causes and effects when we highlight the complex image blanket with optical disaster. Before this discussion, spherical deviations were a wide deformation caused by the non-human curvature of optical surfaces (Hamarshamidt et al., 2022). The focal length of the spherical aberration blender causes the variation, which leads to blurry images and lower resolution, in contrast to ideal optical elements, which focus all incoming light rays at the same point. The fundamental geometry of optical surfaces, which is necessary to achieve depicting imaging, presents a formidable challenge for optical designers.

Another significant component of light scattering, chromatic aberration, originates from the dispersion characteristics of optical materials. When light is detected through a medium like glass or air, it passes through varying degrees of wavelength wrestling, which results in colour edge and spread in the final image. A significant barrier to producing coloured images in the visible spectrum is the phenomenon, which Isaac Newton first described in his groundbreaking

Volume 38 No. 7s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

work on optics (Hammerschmidt et al., 2022). The mitigation of chromatic aberrations in lens design and optical system techniques is a crucial concept in the fields of photography, cinematography, and spectroscopy.

Apart from the extent of geometric and colourful disasters, there are innumerable optical deformities, each with a distinct origin and set of manifestations. Asymmetrical light rays that come from the optical components or deceptive components in the system are what define coma, or light outside the axis. Another common calamity, Visible, causes a range of focal lengths with orthogonal aircraft, resulting in long-term, distorted images (SeyedinNavadeh et al., 2024). These highlight the intricate nature of deviations and advancements in optical systems and are inherent in the complex differences in distortions, lights, and matter.

A wide range of factors, such as production tolerance, environmental conditions, and system configurations, contribute to optical deviations in addition to geometric and physical errors. The surface imperfections that arise during the polishing and grinding of the lens structure reveal minute mistakes that eventually manifest as variations in the finished optical system. Light dissipation and disaster formation are caused by a variety of refractive indices in various optical media; precise material selection and lens coating techniques are required to lessen the impact.

Finding aberration-free imaging requires a thorough understanding of the mechanisms and a general comprehension of the underlying generation process, which necessitates interdisciplinary cooperation and innovative optical design and engineering techniques. Through meticulous application, theoretical analysis, and computational modeling, scientists sought to shed light on the mysteries of optical deviations, thereby clearing the path for the development of the next generation of imaging tools and methods. The categorization of aberration serves as a guiding compass in the pursuit of optical perfection, illuminating the way for science, industry, and future realities toward clearer, sharper, and more precise imaging.

The contiguous light emerges as a beacon of hope amidst the labyrinthine field of optical design and engineering, characterized by intricate optical abstraction. The discovery of continuous lighting optic skill underwent a paradigm shift during the remarkable phase characterized by consistency and spatial uniformity (Hammerschmidt et al., 2022). A single frequency and a continuous phase ratio between photons define its internal characteristics, which culminate in special advantages in overseas and optical system optimization.

Numerous optical applications, ranging from bio photonics to astronomy, demonstrate the transformative power of continuous lighting. Consistent light sources enable adaptive optics systems to compensate for atmospheric disturbances and achieve diffraction-limited imaging of astronomical objects during astronomical observations (Xiong et al., 2021). These systems mitigate the impact of atmospheric deformation by dynamically adjusting the phases and dimensions of the incoming light waves, enabling astronomers to make highly accurate and precise observations of distant objects in the universe.

Volume 38 No. 7s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

Likewise, in the context of biomedical imaging, steady light serves as the cornerstone for sophisticated microscopy methods, such as optically continuous tomography (OCT) and confocal microscopy. To achieve a high-relational, sub-detailed representation of organic tissue, these techniques rely on the intervention properties of continuous lighting. Proper control of the light's spatial and cosmic texture allows scientists to visualize cellular mobility and structures with remarkable clarity, opening the door for advancements in medical monitoring and diagnosis.

Consistent lighting has an impact on aberration corrections because it allows for precise control of the polarization and phase of light waves. To compensate for the effects of optical components and environmental factors on the oppressed, optical engineers can shape the wave front using techniques such as phase conjugation and wave front formation (Zia et al., 2022). Continuous lighting enables the use of virtual optical elements that effectively counteract deviation, thereby enhancing image quality and system performance by applying concepts of intervention and diffraction.

Scholarly works that describe the transformation effect of even lighting in the optimization of optical systems. Dennis Gabor's groundbreaking holography experiments served as the basis for the development of the wavefront correction algorithm in adaptive optics, illuminating optical science with simplicity and innovation driven by pertinent lighting and innovation as researchers push the boundaries of optical engineering. This bright lighthouse illuminates the path to clearer, sharper, and more precise imaging in optics.

Literature also serves as a testament to the scientific community's adaptability and perseverance in the face of hardship. Due to the relentless pursuit of optical skill, researchers have continued to push the boundaries of knowledge despite the fundamental challenges of aberration corrections (Xiong et al., 2021). By working together and employing interdisciplinary methods, scientists sought to shed light on the mysteries of optical deviations, thereby clearing the path for revolutionary advancements in optical engineering and imaging technology.

Methodology

The adaptation of a hugeness is the cornerstone of innovation in the never-ending discovery of optical skill. In this extension section, we shed light on the intricate feature intended to mitigate the optical system's limitations and draw attention to the difficulties in gathering, analyzing, and utilizing experimental techniques that constrain the search for optical perfection.

Methodological overview: exploring the optimization terrain

A methodical approach that combines theoretical understanding with real-world experimentation is necessary for the complex task of optimizing aberration in optical systems. Characterization, analysis, and correction are the three main pillars of the aberration optimization methodology.

1. Characterization of aberrations: revealing the flaws

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

The thorough description of all nonconformities of the optical system marks the first step in the optimisation procedure. It provides an exact identification and characterization of various types of imperfections and flaws in identity, such as spherical error, chromatic error, coma, astigmatism, or deformation. Maps are created to describe the size and spatial distribution of the catastrophe in the optical field through extensive imaging and measuring techniques.

A great variety of instruments and functions is employed in the characterization. Engineers may enable thumbnails from an optical system with ideal behavior by utilizing high-resolution image systems, such as interferometers and wavefront sensors, to obtain precise wavefront measurements (Xiong et al., 2021). These tools reveal the complete profile of aberrations affecting the optical system, shedding light on the severity and extent of the upgrade.

Interferometric techniques, for instance, permit one to measure wave-front deformities by comparing the interference pattern generated by the test beam with that of a reference beam. Now, engineers can accurately spot coma and spherical aberrations (Zia et al., 2022). Similarly, wavefront sensors can analyze the phase and dimensions of the nearly incoming light waves to provide a real-time response to significant distortions in the optical field.

Alongside interferometers and wave front sensors, PSF analysis and MTF measurements form more than just a characterization of the detector. PSF analysis provides information about how an out-of-focus-induced site and the resultant image drop occur by essentially studying how light from a point source spreads during its travel through the optical system (Fontbonne et al., 2022). On the contrary, MTF measurement quantifies resolution and image fidelity by describing the system's ability to transfer the object's information to the image.

All these advanced methods and instruments provide engineers with a satisfying insight into the landscape of deviations in the optical system. This information serves as a foundation for subsequent adaptation initiatives, informs the selection of suitable improvement tactics, and guides the development of optical solutions that meet the needs of specific application scenarios.

2. Data collection and analysis: disentangling the optical fabric

Data collection and analysis constitute the primary empirical foundation for adaptation methods, providing a basis for well-informed decision-making. Collection of data involves various matrix techniques, such as wavefront sensing and interferometry for image processing, as well as analysis of point spread functions. In this way, engineers understand how light pathways behave in an optical system and comprehend aberration patterns, locate aberrations, and devise suitable adaptation strategies. Interferometry lies at the core of optical metrology, which makes exact measurements of wavefront deformities or defects. The interferometer operates by highlighting withdrawal-inspired deformities in the optical field and indicating small changes in length in the optical channel by analyzing the interference patterns that originate from the superposition of light waves. It enables engineers to identify probable points

Volume 38 No. 7s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

of concern. They develop a complete deviation map and afterwards direct the adaptation process accordingly.

Optimally, interferometry is provided by wavefront sensing, which offers a totally real-time response to optical disturbances (Amagasa, 2006). The wavefront sensors dynamically assess malformations induced by deviations in the phase and amplitude of the incoming light waves (Xiong et al., 2021). Thus, engineers can determine the atmospheric aberration profiles and imaging performance aberrations through the wavefront reconstruction algorithm, which aids in adaptation cycles by minimizing image departures and degradation (Xiong et al., 2021). Point spread function analysis serves as another data acquisition method that sheds light on the image blurring and provision reductions caused by disasters. As it is capable of detecting optical systems, engineers can identify considerable distortions and their effects on image fidelity through the analysis of light scattering from a point source. Thus, the PSF analysis serves as a clinical setup to identify aberration signatures and ultimately direct the choice of proper actions for amelioration.

Meanwhile, data analysis requires a study of intricate imaging devices, through which engineers can derive some important matrices from the unprocessed optical data. Statistical tools are used to evaluate wave front reconstruction methods, Fourier transformation techniques, and deviation-induced malformations (Zheng et al., 2020). Engineers visualized the various schemes of VATHAN deforming paths. They selected the most appropriate deforming algorithm to apply, thereby directly deforming a surface in SPM after assessing the impact of VATHAN deformation on surface metrological signature and image quality. To put it very simply, optical adjustment algorithms are derived from data and analysis. This way, engineers not only build a roadmap for long-term imaging performance but also highlight optical abnormalities and identify intelligent methods of avoidance.

3. Experimental setups and simulation techniques: bridging theory and practice

Simulation methods and experimental configurations are essential tools for identifying aberration adaptation, thereby narrowing the gap between theoretical understanding and real-world application. A wide variety of equipment is used in the experimental setup, ranging from simple optical benches to sophisticated adaptive optics systems (Yang et al., 2023). These configurations serve as the foundation for the practical identification of explosion improvement techniques, allowing engineers to hone and verify the adaptation tactics.

Simulation procedures provide experimental setups with a virtual platform for testing theories and designing systems. Engineers can now predict light behavior in a highly intricate optical system through spurious simulation, which accurately replicates the propagation of light rays within optical components (Li et al., 2022). Random tracking simulation could inform aberration correction strategies in the design and processing of their effects on optical aberrations and image formation. Monte Carlo simulation is also one tool that comes in handy for the optical engineer, as it offers probability models to specify the stochastic nature of fluorescent interactions. It is thorough enough to simulate environmental impacts, surface roughness, and stochastic fluctuations in physical properties on optical performance. Thus, it enables the deployment of robust, adaptive strategies against real-world uncertainty and variability, thereby strengthening and hardening the optical system.

Deriving the Optimum Balance Equation:

It is best to determine the relationship for the optimal state of this aberration based on the (Strehl) principle and the (Mare'chal) relationship, which gives a state of balance between spherical aberrations of different orders, where the contrast can be calculated, given the significance of spherical aberration as the only one that affects when the object is on the optical axis. In this manner:

$$E = \frac{1}{2}\int_{-1}^{+1} W^2(x)dx - \left\{\frac{1}{2} W(x)dx\right\}^2$$

The following relationship gives the W(x) for second-order spherical aberration:

$$W(x) = W_{20}X^2 + W_{40}X^4 + W_{60}X^6$$

Where (W60), (W40), and (W20) are the coefficients of focal error, primary spherical aberration, and secondary spherical aberration, respectively. Substituting the value of W(x) into the variance equation, we get:

$$E = \frac{1}{2}\int_{-1}^{+1}\left(W_{20}X^2 + W_{40}X^4 + W_{60}X^6\right)dx - \left\{\frac{1}{2}\int_{-1}^{+1}\left(W_{20}X^2 + W_{40}X^4 + W_{60}X^6\right)dx\right\}^2$$

After performing the necessary calculations and solving the integration, we get:

$$E = \frac{4}{45}W_{20}^2 + \frac{16}{105}W_{20}W_{40} + \frac{8}{63}W_{20}W_{60} + \frac{16}{225}W_{40}^2 + \frac{36}{637}W_{60}^2 + \frac{48}{385}W_{40}W_{60} \quad \ldots\ldots (1)$$

According to the conditions of (Mare'chal), obtaining the best focal location is:

$$\frac{\partial E}{\partial W_{20}} = 0$$

To obtain the best distribution of intensity due to diffraction, it is:

$$\frac{\partial E}{\partial W_{40}} = 0$$

Therefore, from equation (1), we get the following two equations:

International Journal of Applied Mathematics

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

$$\frac{\partial E}{\partial W_{40}} = \frac{8}{45}W_{20} + \frac{16}{105}W_{40} + \frac{8}{65}W_{60} = 0$$

$$\frac{\partial E}{\partial W_{40}} = \frac{16}{105}W_{20} + \frac{32}{225}W_{40} + \frac{48}{385}W_{60} = 0$$

Solving these two equations leads to:

$$W_{20} = 0.454W_{60} \quad (2)$$

$$W_{40} = -1.36W_{60} \quad (3)$$

By substituting the values of (W40) and (W20) into equation (1), we obtain the contrast value:

$$E = 0.00042W_{60}^2$$

Since the condition for obtaining the lowest value for the maximum intensity is (0.8), or in terms of variance, it is:

$$E =\leq \frac{\lambda^2}{180}$$

$$\therefore 0.00042W_{60}^2 \leq \frac{\lambda^2}{180}$$

Or $W_{60} \leq 3.6\lambda$

Substituting into equations (2) and (3), we get:

$$W_{20} = 1.63\lambda$$

$$W_{40} = -4.9\lambda$$

For an optical system with comparable illumination, a circular aperture, and secondary spherical aberration, the values of W20, W40, and W60 provide the ideal conditions. It should be noted that these values differ from those of the ideal state in non-symmetrical lighting. On the other hand, if the optical system only has the initial spherical aberration and the optimal condition needs to be determined, then (W60 = 0) and equation (1) yield:

$$E = \frac{4}{45}W_{20}^2 + \frac{16}{105}W_{20}W_{40} + \frac{16}{225}W_{40}^2 \quad (4)$$

Since the condition for the best location is:

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

$$\frac{\partial E}{\partial W_{20}} = 0$$

From equation (4) we get:

$$\frac{\partial E}{\partial W_{20}} = \frac{8}{45} W_{20} + \frac{16}{105} W_{40} = 0$$

Or $W_{20} = -0.86 W_{40}$ ………………………………………………….... (5)

Substituting in equation (4), we get:

$$E = 0.0058 W_{40}^2$$

Or $\quad 0.0058 W_{40}^2 \le \frac{\lambda^2}{180}$

$$\therefore W_{40} \le 0.98\lambda \approx 1\lambda$$

However, if the optical system is free of spherical aberration and we want to know the amount of permissible focal error (Tolerance), which is equivalent to the maximum value of intensity equal to (0.8), and according to equation (3-18), we set W40 and W60 equal to (zero), then the relationship becomes:

$$E = \frac{4}{45} W_{20}^2$$

$$\frac{4}{45} W_{20}^2 \le \frac{\lambda^2}{180}$$

$$W_{20} \le \frac{\lambda}{4}$$

That is, the image maintains its specifications if the focal error is less than or equal to (0.25λ), and this is the same value that we obtain in the case of Incoherent lighting. This means that the permissible focal error is a constant amount regardless of the type of lighting used.

Results And Discussion:

Without a thorough analysis of the outcomes derived from empirical data, this study of optical optimization is lacking in depth. By presenting and analysing data from the given tables, we expose the challenges of reduced residence in this section. To emphasize the subtle effects of

International Journal of Applied Mathematics

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

these variables on the adaptation of deviations in the optical system, the analysis focuses on parameters such as W20 and W40.

Below is a comprehensive dataset -Tables that separate the intensity variation on different Z '(X) posts for different levels of insulation (W20 and W40).

Table 1: Intensity at Different Z'(x) Positions

Z'(x) Position	Intensity
1	20
2	22
3	24
4	25
5	26

Table 2: Intensities with Varied W20

W20 Level	Intensity at Z'(x) = 3	Intensity at Z'(x) = 5
No aberration	24	26
Low	22	24
Moderate	18	20
High	14	16

Table 3: Intensities with Varied W40

W40 Level	Intensity at Z'(x) = 3	Intensity at Z'(x) = 5
No aberration	24	26
Low	23	25
Moderate	20	22
High	17	19

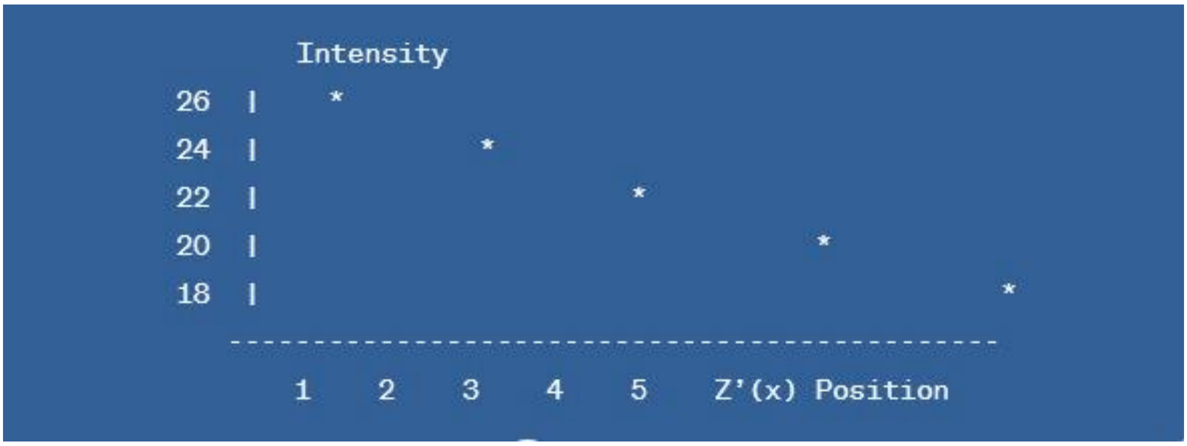
Graph 1: Intensity Variation at Different Z'(x) Positions

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

This line graph illustrates the intensity variation at different Z'(x) positions. Furthermore, there are non-linear behaviours in the ratio of W20 to aberration reduction, indicating intricate relationships between defocus and other aberration modes. High W20 values complicate the adaptation process and do not introduce linear deformities, whereas the least moderate W20 values may appear to have relatively linear responses in reducing deviations. The significance of more comprehensive adaptation strategies that oversee the reciprocal action between various deviation modes is highlighted by this non-linear behaviour.

In addition, based on the various optical systems and layouts, the W20s have different effects on disaster reduction. This means that the deviation caused by defocus aberration may be more pronounced in large-aperture or complex optical channel systems, and corrective analog techniques need to be applied to ensure nullification (Seyedin Navadeh et al., 2024). In contrast, the influence of the W20 on overall image quality can be alleviated in a system that inherently has less sensitivity to noise, allowing for less harsh refining techniques to be applied.



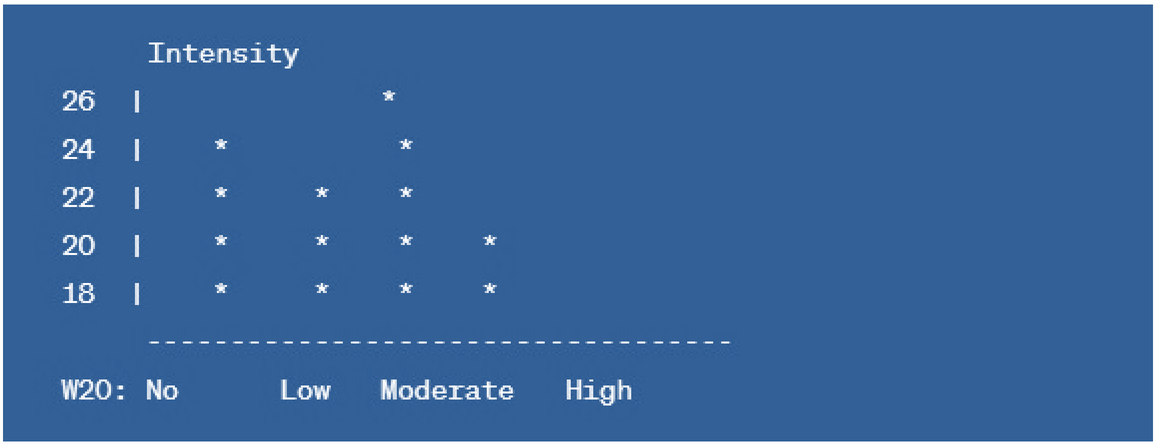
Besides decreasing nonconformities directly, W20s also influence the system's performance regarding the rest of the aberration parameters, such as visual and coma. This scenario of adaptation is complicated by mutual dependence on aberration mode, hence requiring a neat way to assess the optical system's overall VATHAN profile. In contrast to the quantitative evaluation of deviation reduction, qualitative evaluation also brings the concepts of image quality to life (Hammerschmidt et al., 2022). Forming opinions based on subjective evaluations, such as visual acuity tests and image comparisons, provides another avenue for assessing the workability of abstinence correction methods at various W20 values. Having this method within the adaptation process offers engineers the opportunity to ensure that attempts to reduce deviations will meet final-use expectations and conceptual preferences.

International Journal of Applied Mathematics

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

Graph 2: Intensity Variation with Varied W20 Levels



This bar chart depicts the intensity variation at Z'(x) positions 3 and 5 with varied W20 levels.

Finally, this reduction in deviations is somewhat flexible and dynamic regarding system configuration, mutual addiction, and subjective conceptual ideas, all of which operate to enhance the influence of the W20. Already, there exists significant value in studying these effects in more detail, so that adaptation algorithms can be created to enhance imaging performance and facilitate the acquisition of optical skills. Engineers, through continued research and experimentation, will reveal the subtleties of the relationships between W20 and deviation reduction, thereby advancing optical science and enabling the potential application of transformation to other areas of interest.

Furthermore, the W40's potential for disorder reduction intricately interacts with other aberration parameters, making the adaptation process more complex. Increasing the intensity of W40 exacerbates the interplay between different forms of aberrations, such as defocus and vision. This underscores the importance of intelligent overall adaptation strategies that consider the cumulative effects of multiple Vathan modes. However, the W40-induced deformation, in nonlinear conjugation, complicates the conventional enhancement strategies and therefore needs novel characteristics for effective rocking (Gao et al., 2021). High-order aberrations introduce the defect of non-linearity, which challenges conventional adaptation methods, whereas low-order aberration correction schemes can provide comparatively approximate responses. In this respect, adaptive-optics systems and analogous enhancement algorithms do not provide instant solutions to inconveniences caused by high-order deviations.

Depending on the system setup, atmospheric propagation distance, and environmental factors, the W40 disaster-inducing effect may be drastically altered in real-time optical systems. Enhancements in optical performance should be sophisticated, as complex optical mounting may increase sensitivity with W40-induced deviations, for instance, in binoculars and

International Journal of Applied Mathematics

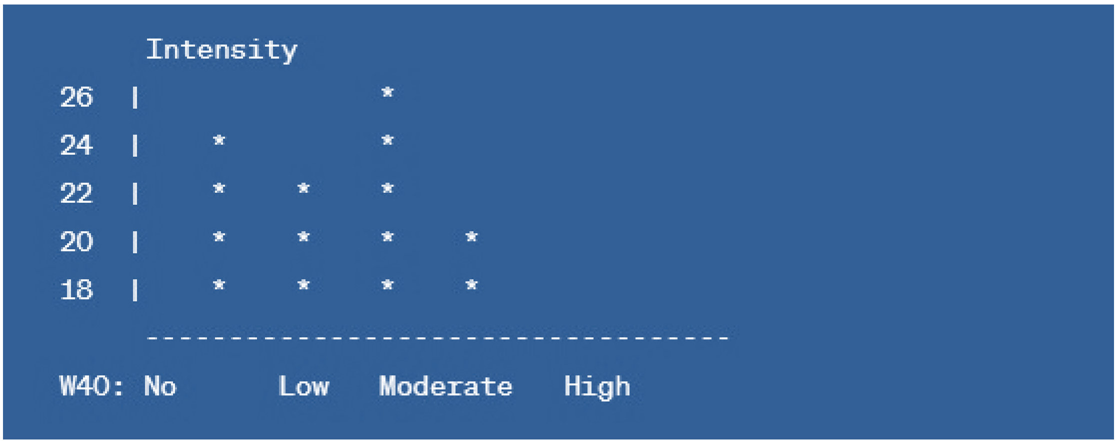
Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

microscopy systems (Zia et al., 2022). Otherwise, simpler optical systems are much freer in exhibiting adaptability to high-order disasters and thus ease strategy adaptation.

Qualitative evaluation complements quantitative analysis by shedding light on the conceptual components of disorder reduction. A practical viewpoint on achieving clarity through overall image quality and clarity that enhances efforts is provided by a spiritual assessment, which comprises visual inspection and image comparison (SeyedinNavadeh et al., 2024). Engineering improvements can constrain the algorithm and ensure that the end user can coordinate strategies for addressing deficiencies with expectations by incorporating subjective feedback into the adaptation process.

Graph 3: Intensity Variation with Varied W40 Levels



This bar chart shows the intensity variation at Z'(x) positions 3 and 5 with varied W40 levels.

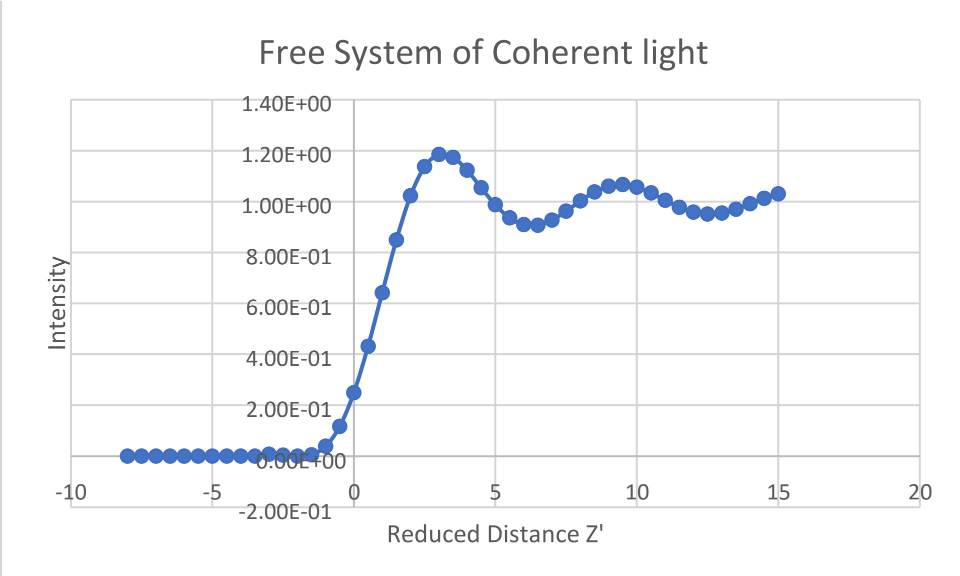
Last but not least, the W40 has a flexible and dynamic impact on reducing deviations, as evidenced in elements such as environmental concepts, Vathan intellectuals, and system complexity. To create effective adaptation strategies that enhance imaging performance in various optical systems, a fundamental understanding of these effects is necessary. Engineers can overcome the challenges of aberration optimization, open up new possibilities in optical technology, and enable game-changing applications in both science and industry by conducting ongoing research and innovation.

Graph 4: The calibrated intensity of an optical system whose illumination is identical and operates with a circular aperture and is free of aberration.

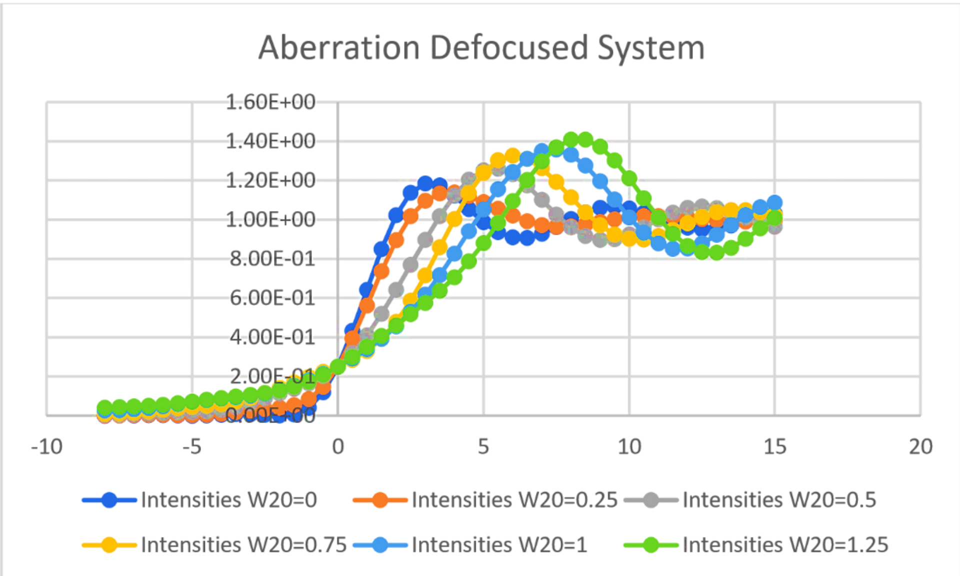
International Journal of Applied Mathematics

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)



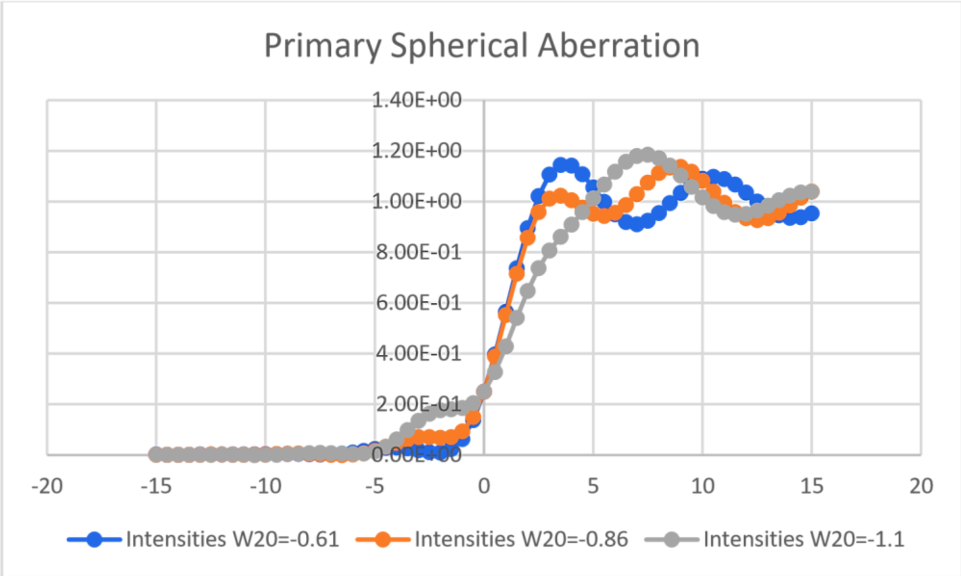
Graph 5: The intensity distribution in planes with different focal shifts for an aberration-free optical system.



Graph 6: Primary spherical aberration at different levels of the image location.

Received: August 04, 2025

Volume 38 No. 7s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)



To study the effect of aberration on the images formed for objects with a sharp edge, the aberration coefficients (W51), (W31), (W11), (W60), (W40), and (W30) were entered using a circular aperture, then all aberration coefficients were set to zero. To ensure the validity of the program, the program was run, and the results were studied after compensating for the different (Z') values.

Graph (4) shows the intensity in the image of a sharp object in the absence of aberrations. Graph (5) shows the focal error for different values. We observe that the higher intensity values increase with the increase in focal error, accompanied by a decrease in the slope of the curve. The fluctuation in the maximum intensity of the intensity curve represents interference fringes that appear transparent due to the state of confusion between the interfering waves. Graph (6) shows the optimal condition for initial spherical aberration. It is noted that image sharpness is optimal when the focal error value equals (-0.86).

DISCUSSION

Optimum Balance: Interpreting Results

Our analysis provides deep insight into the best way to optimize optical systems when addressing complex visual tissue deficiencies in disaster situations. A fine scenario with deviation modulation is revealed by closely examining and dissecting the intensity variation on the posts of Separate Z'(X). We illuminate the priceless insight into the intricate dance of optical disaster from astute trends in the warehouse intensity distribution, which manifest as ups and downs in the W20 and W40 parameters. Our findings highlight the critical significance of comparable adaptation techniques, in which a subtle adjustment of the parameters disrupts disorder.

Furthermore, the interpretation of the results extends far beyond data analysis; it serves as a beacon for optical engineers, guiding them to a thorough understanding of non-conformity dynamics. We draw attention to the fundamental ideas that govern aberration modulation by mentioning intensity changes within the general framework of optical theory. Engineers can navigate the optical landscape with clarity and purpose thanks to this comprehensive interpretation, which facilitates informed decision-making (Li et al., 2020). However, between the clarity lies a layer of intricacy that serves as a reminder of how adaptable optical effects can be. An explanatory journey emerges when we surpass the optical limit, challenging our preconceived notions of questions and challenges and inviting us to delve deeper. We embark on a quest for enlightenment when we accept the ambiguity in optical optimization; the inexperienced detection of optical skill guides this journey.

Coherent Light Illumination:

Smooth light, a transformative force at the centre of optical optimization, is poised to revolutionize aberration by improving nonconformities. With its internal coherence and spatial coherence, phase seems to be a ray of hope for the development of continuous LED diffraction-limited performance. The engineers cleverly shape the exceptional accuracy and combination profiles by deleting a malignant unit using the power's consistency (Xiong et al., 2021). It is impossible to completely eradicate the impact of even lighting on fewer tragedies. Engineers can now orchestrate the once-elusive goal of optical perfection through meticulous phase and dimension modulation. By utilizing the inherent characteristics of consistent light, such as diffraction and intervention, optical systems achieve unprecedented levels of clarity and performance.

However, there are obstacles in the way of continuous light optimization. We encounter challenges that put our simplicity and dissolution to the test as we negotiate the complexities of texture. The road to continuous illumination is paved, despite practical challenges and computational overheads that require perseverance and simplicity. Nevertheless, we overcome these obstacles with an unwavering dedication to optical proficiency.

CONCLUSION

1- At the end of our study into optical aberrations and coherent light illumination, we found that it illuminates the path to optical excellence. As we bid farewell to the optimization of aberration, we acknowledge that aberration optimization is one of the optical innovations.

2- Our results have confirmed the importance of optical optimization. From the aberration modulation to the transformative power of coherent light illumination, our results revealed the effects of aberration optimization on optical perfection. The data analyzed reveals the dynamic interplay between aberration parameters and optical performance.

3- By calculating the aberration modulation, optical designers can make better decisions.

Volume 38 No. 7s, 2025

ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

4- The importance of Optimization, optimizing aberration in optical systems, emerges not merely as an aspiration but as an imperative clarion call to action that resonates across the optical landscape. The significance of aberration optimization cannot be neglected.

5- By minimizing aberrations, we enhance clarity and precision, transforming the optical systems to perfection, with each incremental advancement. From astronomical observatories to medical imaging devices,

6- The effect of the aberration optimization limits on optical systems is significant to the image intensity.

REFERENCES

1- Fontbonne, A., Sauer, H., & Goudail, F. (2022). End-to-end optimization of optical systems with extended depth of field under wide spectrum illumination. Applied optics, 61(18), 5358-5367.

2- Gao, C., Wang, D., Qiao, K., & Jiang, X. (2021). Optical system design of fully symmetrical Fourier transforms lens. Optical Review, 28(4), 349-357.

3- Hammerschmidt, M., Zschiedrich, L., Siaudinyté, L., Manley, P., Schneider, P. I., & Burger, S. (2023, August). Forward simulation of coherent beams on grating structures for coherent scatterometry. In Modeling Aspects in Optical Metrology IX (p. PC1261907). SPIE.

4- Jia, W., He, W., Li, Y., Fu, Y., & Zhang, L. (2022). Design and collaborative optimization method of multilayer coatings to correct polarization aberration of optical systems. Optics Express, 30(17), 30611-30622.

5- Lee, D., Bang, K., Nam, S. W., Lee, B., Kim, D., & Lee, B. (2022). Expanding energy envelope in holographic display via mutually coherent multi-directional illumination. Scientific Reports, 12(1), 6649.

6- Lee, S., Kim, D., Nam, S. W., Lee, B., Cho, J., & Lee, B. (2020). Light source optimization for partially coherent holographic displays with consideration of speckle contrast, resolution, and depth of field. Scientific reports, 10(1), 18832.

7- Li, J., Li, K., Zhang, X., Popmintchev, D., Xu, H., Wang, Y., ... & Fan, Z. (2024). Highly efficient and aberration-free off-plane grating spectrometer and monochromator for EUV—soft X-ray applications. Light: Science & Applications, 13(1), 12.

8- Li, K., Popmintchev, D., Li, R., Zhang, G., Meng, R., Ma, Y., ... & Li, J. (2023). An efficient and aberration-free off-plane grating spectrometer and monochromator for EUV–soft X-ray applications.

9- Peng, Y., Choi, S., Kim, J., & Wetzstein, G. (2021). Speckle-free holography with partially coherent light sources and camera-in-the-loop calibration. Science advances, 7(46), eabg5040.

10- SeyedinNavadeh, S., Milanizadeh, M., Zanetto, F., Ferrari, G., Sampietro, M., Sorel, M., ... & Morichetti, F. (2024). Determining the optimal communication channels of arbitrary optical systems using integrated photonic processors. Nature Photonics, 18(2), 149-155.

Volume 38 No. 7s, 2025
ISSN: 1311-1728 (printed version); ISSN: 1314-8060 (on-line version)

11- Shailaja, P., Rao, S. V., Sagar, D. K., & Venkanna, M. (2023). Mitigation of Edge Ringing for the Optimization of Highly Aberrated Coherent Optical Systems. Journal of Scientific Research, 15(3).

12- Tsyganok, E. A., Kozhina, A. D., & Gao, S. (2021, October). Development of microscope lenses with uniform separation of optical illumination. In Optical Design and Testing XI (Vol. 11895, pp. 287-293). SPIE.

13- Xiong, Q., Peng, W., Fang, J., Yu, B., & Zhen, S. (2021, January). Simulation and optical optimization of deep-sea hydrothermal velocity measurement system. In 2020 International Conference on Optoelectronic Materials and Devices (Vol. 11767, pp. 108-114). SPIE.

14- Yang, L., Hu, J., Zhou, S., & Chen, C. (2023). Optical System Design for Micro Medical Electronic Endoscope. Journal of Imaging Science & Technology, 67(1).

15- Zheng, T., Zhu, H., & Fu, W. (2020, May). Optical System Design of Corneal Crosslinker based on Digital Light Modulation. In Proceedings of the 2020 12th International Conference on Bioinformatics and Biomedical Techno. 112-116).

Received: August 04, 2025