

computers

Overview

A pioneer in scholarly, open access publishing, MDPI has supported academic communities since 1996. Based in Basel, Switzerland, MDPI has the mission to foster open scientific exchange in all forms, across all disciplines.

Our 516 diverse and open access journals, including 507 peer-reviewed journals and 9 conference journals, are supported by more than 295,000 academic experts who share our mission, values, and commitment to providing high-quality service for our authors. We serve scholars from around the world to ensure the latest research is freely available and all content is distributed under a [Creative Commons Attribution License \(CC BY\)](#).

MDPI's portfolio comprises at least 298 journals with impact factors, 64% of which are ranked in the top 2 quartiles of their respective fields. To view the current impact factors for MDPI journals (according to the [Journal Citation Reports](#)), please visit our yearly announcement page [here](#).

With additional offices in Beijing, Wuhan, Tianjin and Nanjing (China), Philadelphia (USA), Barcelona (Spain), Belgrade and Novi Sad (Serbia), Manchester (UK), Tokyo (Japan), Cluj and Bucharest (Romania), Toronto (Canada), Kraków (Poland), Singapore (Singapore), Bangkok (Thailand) and Seoul (Republic of Korea), MDPI has published the research of more than 330,000 individual authors and our journals receive more than 25 million monthly webpage views.

More Information about MDPI

Management Team

Stefan Tochev (Chief Executive Officer)



Stefan Tochev joined the MDPI in 2020. He holds a BA Honours in Sociology from the University of Guelph (Canada) and a Post-Diploma in Marketing Management from George Brown College (Canada). With over a decade of experience as a Project Manager and Research Consultant for global market research studies, primarily in the pharmaceutical and healthcare sectors, he brings a strategic, insight-driven approach to brand marketing and communications. Since stepping into a leadership role at MDPI, Stefan has led the expansion of the corporate marketing and communications department and played a key role in strengthening the company's global brand presence. He is committed to driving meaningful organizational change, creating a culture of opportunity and collaboration, and positive, high-impact work environment that enhances employee engagement and supports long-term growth. He continues to invest in his leadership development, including completing the *altMBA* program.

Alistair Freeland, Executive MBA (Chief Operating Officer)



Alistair Freeland initially joined MDPI in February 2006, supporting Dr. Shu-Kun Lin as an editor of the International Journal of Molecular Sciences. In 2008, he graduated from the University of St. Gallen with a degree in Business Administration. From 2008 to 2013 he worked at IBM, with responsibilities in the areas of IT delivery and IT service management. From 2013 to 2019, Alistair served as a member of MDPI's executive team in his capacity as Chief Operating Officer (COO). In 2020, he joined SIX Group, where he played a significant role in developing the digital asset platform SDX (SIX Digital Exchange) as a Senior Product Manager. He also founded the not-for-profit scholarly webcast platform Leadwire. Alistair rejoined MDPI in October 2023. He also holds a degree in Performing Arts from the University of East Anglia and an Executive MBA from the University of St. Gallen.

Dietrich Rordorf (Chief Technology Officer)



Dietrich Rordorf leads collaboration between MDPI's Product and IT teams to deliver innovative, high-quality technical solutions for scholarly publishing. He first joined MDPI in 2005, holding early roles as Assistant Editor and Managing Editor before moving into executive leadership, including positions as CEO and CTO. From 2016 to 2020, he focused on software development projects outside MDPI before rejoining the company in 2020. Since then, he has overseen major technology initiatives, including the adoption of a modern front-end stack. He holds a BA in Business & Economics and an MSc in Business Information Systems.

Constanze Schelhorn, PhD (*Head of Publishing*)



Dr. Constanze Schelhorn is Head of Publishing at MDPI, where she has strategic responsibility for Publishing functions across Indexing, Publication Ethics, and Books. In this role, she provides governance oversight and strategic direction to ensure the consistent application of publishing standards, research integrity frameworks, and external compliance requirements across MDPI's scholarly portfolio. Constanze joined MDPI in 2016 and has held a range of editorial and publishing leadership roles. Appointed Publisher in 2019, she focused on establishing collaborations with learned societies and has served as Project Manager for MDPI's Journal and Article Management System (JAMS). She also supported the Board of Scientific Officers as Scientific Officer for Physical Sciences until 2022. Since 2023, she has led MDPI's Indexing Department, holding primary responsibility for the indexing and database positioning of MDPI's expanding portfolio of journals, books, and preprints. Constanze holds a Master's degree in Physics from the University of Würzburg and a PhD from the Technical University of Munich, completed in collaboration with the Institute for Research in Biomedicine, Barcelona.

Helen Li, PhD (*Publishing Director*)



Dr. Helen Li holds a PhD in Marine Geology from Tongji University, China. She joined MDPI in September 2016 and has since advanced through various editorial positions, including

Assistant Editor, Managing Editor, and Publisher. With extensive experience in editorial processes and journal operations, she brings deep expertise in article processing and editorial management. As Publishing Director, Dr. Li oversees and coordinates the global Publisher team, leads journal development and strategic initiatives, and plays a key role in optimizing MDPI's publishing service ecosystem. Her leadership supports MDPI's mission to provide high-quality, efficient, and author-focused publishing services.

Tim Tait-Jamieson, PhD (*Head of Publication Ethics*)



Dr. Tim Tait-Jamieson holds a MSc and PhD in Geography from the University of Fribourg, Switzerland. Tim joined MDPI in 2021 and has worked in several roles within the Publication Ethics department throughout this time. He has built an extensive level of experience by developing and implementing various MDPI publication ethics policies and process, as well as successfully handling numerous ethic cases. As Head of Publication Ethics, Tim leads the development of MDPI's global ethics strategies, the implementation of ethics policies and processes, and is responsible for promoting a culture of integrity, safeguarding publication quality, and maintaining trust in the scientific record.

Aleksandra Cuculovic (*Head of Finance*)



Aleksandra joined MDPI as financial assistant in June 2014. She holds a Bachelor degree in Economics with major in Operations Management. From October 2018 to October 2019, she served as Financial Coordinator where she was responsible for internal financial processes and reporting. From November 2019, she worked as Financial Controller, responsible for cost controlling, annual reporting and budget planning. Currently, as Head of Finance, Aleksandra oversees all MDPI's financial operations and supervises the finance teams working in MDPI subsidiaries around the world.

Kurtis Jackson, MA (*Head of Author Services*)



Kurtis Jackson first joined MDPI in 2016. He holds a first-class Bachelor's degree in French and Spanish and a Master's degree in Translation Studies from Cardiff University. In 2019, he opened and established MDPI's office in Manchester, UK. After serving as Office Manager for two years, he became Head of English Editing, contributing to MDPI's efficient and high-quality service to authors. He is committed to developing MDPI's Author Services to support authors more fully in the writing and publication of their research.

Laura Wagner (*Head of Books Division*)



Laura holds a Bachelor degree in Art History and History from the University of Basel. After her studies, she started her career at an art gallery in Basel. Since joining MDPI in 2014, she held several roles within the firm. This included editorial work, development of reprint and book services and the temporary management of the journal *Arts*. Currently Laura holds the role Books Manager and is in charge of the development and strategic direction of MDPI Books.

Peter Roth (*Senior Executive Advisor*)



With a career in publishing going back to 1986, Peter Roth has witnessed the development of the Open Access publishing concept since its inception. Peter, who joined MDPI in 2019, has a keen focus on ensuring that the Open Access model delivers a 'triple win': success for our customers, success for ourselves as a company, and success for the scientific community at large. He was for many years Director of the Editorial Division of Karger Publishers, a worldwide publisher of scientific and medical content based in Basel, Switzerland. Peter has extensive experience of editorial strategy, publication concept development and management, and new business development and customer relationship

management on all continents, especially in Asia. Within MDPI, he has overseen the establishment of a range of new journals and books, reorganised editorial governance, and set up our first office in Japan.

MDPI Board of Directors

Dr. Shu-Kun Lin (Founder and Chairman of the Board)



Shu-Kun Lin graduated with a BSc from Wuhan University in January 1982; he also studied physical chemistry at the Lanzhou Institute of Chemical Physics, Chinese Academy of Sciences (1982–1986, MSc in 1985) and at the University of Louisville, USA (1987–1989). He completed his doctorate on organic chemistry at the Swiss Federal Institute of Technology (ETH-Zürich) in 1992 and subsequently worked at Ciba-Geigy Ltd. (Basel, Switzerland) for three years. He was also a member of Prof. Dr. B. Giese's group (Organic Chemistry Institute, University of Basel) as a postdoctoral research associate for 6 months in 1996. In the same year, he initiated the sample collection and exchange project; to implement this, he founded the international organization MDPI in Switzerland, launching its inaugural journal, *Molecules*. He is the founder or co-founder of several other open-access journals, including but not limited to *Entropy* (1999), the *International Journal of Molecular Sciences* (2000), *Sensors* (2001), *Marine Drugs* (2003), and the *International Journal of Environmental Research and Public Health* (2004). He became the Editor-in-Chief of the Springer Verlag journal *Molecular Diversity* in 2002 and held this position until his resignation in June 2007. He is a Member of the Swiss Academy of Engineering Sciences (SATW) and principal author of over 40 publications.

Dr. Yu Lin (Member of the Board)



Dr. Yu Lin graduated with a BSc from Wuhan University of Technology in June 2010, majoring in materials chemistry before working as research assistant in the Experimental Teaching Center of WHUT (2010-2011) while working as a part-time editorial assistant for the MDPI international scientific journal *Materials*. Dr. Yu Lin obtained his MSc in advanced energy materials from Wuhan University of Technology (2014). During this period, he worked as part-time R&D technician for WUT New Energy Co., Ltd. In 2018, he graduated with a PhD in Materials physics and chemistry from Rheinisch-Westfälische Technische Hochschule Aachen (Germany), after studying for 4 years in the group of Prof. Dr. Werner Lehnert at the Laboratory of High Temperature Fuel Cell - IEK-3, Jülich Research Center (Germany). He is the principal author of 10 publications.

Dr. Andreas Schlatter (Member of the Board)



Andreas Schlatter was born in 1966 and got his PhD in mathematics from ETH Zürich in 1994. He was a member of the faculty of mathematics at Princeton University before joining the Asset Management wing of UBS, the largest Swiss bank, in 1997. He stayed at UBS until 2016 and was CEO of UBS Asset Management Switzerland from 2008-2014 and Global Head of Distribution of the Asset Management division of UBS from 2014-2016. Today Andreas Schlatter is Chairman of the Investment firm Emeran AG and a member of various boards, among them the Swiss financial regulatory authority Finma. He has also been publishing various scientific articles in mathematics and physics over the years.

Prof. Dr. Peter Seitz (Member of the Board)



Peter Seitz was born in Basel, Switzerland. He studied physics and obtained his Master's degree in solid-state/semiconductor physics from ETH Zurich. His Ph.D. thesis, which was also completed at ETH, was on 2D and 3D X-ray imaging and computed tomography. Peter subsequently worked for RCA in Princeton (NJ) and Zurich, for General Electric, for the Paul Scherrer Institute, and for CSEM, where he was Vice President Photonics and Vice President Nanomedicine. From 2000 to 2008, he was Extraordinary Professor of Optoelectronics at the University of Neuchatel, and from 2009 to 2021 he was Adjunct Professor of Optoelectronics at EPFL. Peter was Editor-in-Chief of the MDPI flagship journal *Sensors* from 2006 to 2010. From 2012 to 2016 he built up the Innovation and Entrepreneurship Lab of ETH (ieLab), where he was the first Managing Director. Since 2012 Peter has also been working for the Japanese company Hamamatsu Photonics with the role "Senior Technologist Europe". Peter was co-founder of a dozen deep-tech start-up companies in Switzerland and in the USA, assuming various positions such as CEO, CTO, CSO, Chairman, and board member. Peter is a Fellow of the European Optical Society as well as Vice President of the Swiss Academy of Engineering Sciences (SATW), Vice President of the European PPP Photonics21, a member of the Scientific Advisory Board of the Werner Siemens Foundation, and Senior Visiting Professor at Shanghai University. Peter Seitz has authored and co-authored approximately 200 publications in the fields of applied optics, semiconductor image sensing, machine vision, optical metrology, and in the MedTech domain. He is the inventor or co-inventor of

more than 70 patents, and, together with his teams, he has obtained 25 national and international awards.

Prof. Dr. Peter C. Hauser (Member of the Board)



Prof. Dr. Peter C. Hauser started his career in chemistry with an apprenticeship as a laboratory technician. He then completed his undergraduate studies in Chemistry and Chemical Engineering at the ZHAW (Zurich University of Applied Sciences) in 1982. Afterward, he obtained an MSc at the University of British Columbia (UBC), Canada, working on ICP-OES, in 1985. Subsequently, he carried out his PhD studies at La Trobe University (Melbourne, Australia) on Flow-Injection Analysis in 1988. This was followed by postdocs at the ETH Zurich, working on chemical sensors, as well as at the Paul Scherer Institute, Switzerland, working on fuel cells. After a lectureship at Auckland University, New Zealand, from 1991 to 1996, he was given a professorship in Analytical Chemistry at the University of Basel in 1996. His research interests include various aspects of the analytical sciences, including flow-injection analysis, electrochemical detection, capillary electrophoresis, optoelectronic detectors, and miniaturized plasma spectrometers and detectors. A strong focus of his is the use of electronics in analytical devices. Moreover, thanks to the work of his research laboratory, instruments have been developed and are commercially available from eDAQ in Sydney, Australia, and from CE-Line, Emmeloord, the Netherlands. Peter C. Hauser is the co-author of around 245 scientific publications and a member of the editorial advisory boards of *Analytica Chimica Acta*, *Electrophoresis*, *Sensors*, and *Molecules*, and he is also editor-in-chief of *Hardware*.

Prof. Dr. Florian M. Thieringer (Member of the Board)



Florian M. Thieringer is an oral and cranio-maxillofacial surgeon and a medical 3D expert, with a focus on tumor, trauma, reconstructive and orthognathic surgery, located at the University Hospital Basel and the University of Basel, Switzerland. Professor Thieringer serves as chair and full professor of oral and cranio-maxillofacial surgery at the University Hospital Basel. He also serves as head of the Medical Additive Manufacturing research group (Swiss MAM) at the University of Basel's Department of Biomedical Engineering (UNIBAS DBE). He is an internationally recognized expert in the field of computer-assisted

surgery (CAS) and medical additive manufacturing. He has extensively explored and promoted the integration of virtual surgical planning, 3D printing and other innovative technologies at the point-of-care (POC), including the additive manufacturing of patient-specific implants (PSI) in various (bio-)materials, such as bioprinting and regenerative surgery. Professor Thieringer serves as editor-in-chief of the journal *Craniofacial Trauma & Reconstruction* and is a member of several international expert panels and committees.

Since 2016, Florian Thieringer has served as co-director of the multidisciplinary 3D Print Lab at the University Hospital of Basel. Since 2020 he has served as co-principal investigator of the innovative MIRACLE 2 project (Minimally Invasive Robot-Assisted Computer Guided Laserosteotomy). He is a co-applicant and, since 2021, a member of the steering committee of the University Hospital Basel flagship project "Innovation Focus Regenerative Surgery".

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by **Bahareh Masoudi, Nazila Razi and Javad Rezazadeh**

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REVIEWERS COMMENTS

9/18/25, 5:19 AM

MDPI | Reply review report

Review Report Form

Quality of English Language The English could be improved to more clearly express the research.
 The English is fine and does not require any improvement.

	Yes	Can be improved	Must be improved	Not applicable
Does the introduction provide sufficient background and include all relevant references?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Is the research design appropriate?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are the methods adequately described?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
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Are the conclusions supported by the results?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Are all figures and tables clear and well-presented?	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments and Suggestions for Authors

This study investigates the application of the JAYA optimization algorithm to improve indoor optical wireless communication (OWC) systems by optimizing the placement and intensity of diffuse spots. The primary goals were to maximize the signal-to-noise ratio (SNR) and minimize delay spread (DS). The authors report up to a 29% improvement in SNR and a 23.3% reduction in delay spread, along with enhanced system stability as indicated by reduced standard deviations in both metrics. The study also discusses the benefits of hybridizing optimization algorithms and increasing the number of variables for better adaptability. These results highlight the importance of strategic algorithmic optimization for enhancing indoor OWC system performance and point towards future research in real-time adaptive optimization.

The authors effectively demonstrate that the JAYA optimization algorithm can significantly improve both the SNR and delay spread, which are critical parameters for indoor OWC performance.

The study's findings on reduced variability in SNR and delay spread under realistic conditions, such as ambient light interference and multipath dispersion, indicate that the proposed approach is robust and practical for real-world applications.

The authors' suggestion to hybridize optimization algorithms and increase the number of optimization variables is promising, as it can enhance the system's ability to adapt dynamically to environmental changes.

9/18/25, 5:19 AM

MDPI | Reply review report

While the current work focuses on static optimization scenarios, it paves the way for future research into real-time adaptive algorithms, which could further improve the reliability and efficiency of indoor OWC systems in diverse environments.

The quality of figures throughout the paper is generally poor, making it difficult to interpret some results; particularly, Figures 1, 2, and the last figure would benefit from higher resolution and clearer presentation to better support the findings.

Response to Reviewers

We sincerely appreciate the reviewers' constructive comments, which have greatly strengthened our paper. The following steps were taken to address the suggested corrections:

We carefully studied the reviewers' comments to fully understand the required corrections.

The figure was enhanced using SolidWorks (solid modelling software) for accurate simulation representation.

All relevant parameters were correctly input into Figure 1, after which the diagram was automatically generated based on the data presented in the study.

The earlier mix-up in Figure 2—traced to a system software issue—was resolved by refining the figure, inserting the missing blocks, and binding them together to avoid recurrence of the mismatch challenge.




We employed MATLAB to carry out simulations for both SNR and Delay Spread (Average Delay). Following the proper mathematical modelling and computations, the results were generated and presented in Figure 5.

A comparative analysis of PSO and Jaya algorithms was conducted, and the outcome is presented as a percentage improvement.

The manuscript was also carefully proofread and improved for clarity, accuracy, and grammatical expression.

Article

Adaptive Optimization of Diffuse Spot Intensities and Locations for Enhanced Performance in Indoor Visible-Light Optical Wireless Communications

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Abstract

This study explores the application of JAYA optimization algorithms to significantly enhance the performance of indoor optical wireless communication (OWC) systems. By strategically optimizing photo-signal parameters, the system was able to improve signal distribution and reception within a confined space using circular and randomly positioned diffuse spots. The primary objective was to maximize signal-to-noise ratio (SNR) and minimize delay spread (DS), two critical factors that affect transmission quality in OWC systems. Given the challenges posed by background noise and multipath dispersion, an effective optimization strategy was essential to ensure robust signal integrity at the receiver end. Key achievements of JAYA optimization include significant performance gains, such as a 29% improvement in SNR, enhancing signal clarity and reception, and a 23.3% reduction in delay spread, ensuring stable and efficient transmission. System stability also improved, with the standard deviation of SNR improving by up to 5%, leading to a more consistent performance, while the standard deviation of delay spread improved by up to 9.9%, minimizing variations across receivers. Resilience against environmental challenges: Optimization proved effective even in the presence of ambient light noise and complex multipath dispersion effects, reinforcing its adaptability in real-world applications. The findings of this study confirm that JAYA optimization algorithms offer a powerful solution for overcoming noise and dispersion issues in indoor OWC systems, leading to more reliable and high-quality optical wireless communications. These results underscore the importance of algorithmic precision in enhancing system performance, paving the way for further advancements in indoor optical networking technologies.

Keywords: delay spread; communication; diffuse spot; signal-to-noise ratio; JAYA



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1. Introduction

In recent years, the demand for high-speed data transmission has surged exponentially, driven by the expansion of digital services, cloud computing, and the Internet of

Things (IoT). Traditional radio frequency (RF) communication systems, operating within the congested spectrum of 3 kHz to 300 GHz, face increasing limitations, struggling to accommodate the ever-growing data demands. Despite advancements in signal processing and modulation techniques, the saturation of RF bands presents a formidable challenge to future wireless systems [1].

In response to these constraints, optical wireless communication (OWC) systems have emerged as a promising alternative, offering access to a largely unexploited spectrum capable of delivering data rates from tens of gigabits per second (Gbps) to terabits per second (Tbps) [2]. OWC systems, particularly those designed for indoor environments, present unique advantages such as unlicensed spectrum usage, immunity to RF interference, and enhanced security. However, they are also prone to challenges, including intersymbol interference, background noise due to ambient lighting, and power constraints imposed by skin and eye safety regulations [3].

The ongoing transition to fifth-generation (5G) and the anticipated rollout of sixth-generation (6G) wireless networks demand solutions that address the limitations of RF communication. The saturation of RF channels reduces data transfer efficiency and increases latency, leading researchers to explore hybrid solutions integrating RF and Visible-Light Communication (VLC) systems [4]. Indoor OWC networks, while offering high data rates and frequency reuse capabilities, still face critical performance challenges related to signal degradation and multipath dispersion. One key aspect influencing system efficiency is the positioning and intensity distribution of diffuse spots, which play a significant role in optimizing signal-to-noise ratio (SNR) and delay spread (DS) [5]. This research aims to improve data transmission rates by optimizing the intensities and spatial distribution of diffuse spots using hybrid JAYA and particle swarm optimization (PSO) techniques. Through this approach, enhanced SNR values and minimized delay spread will be achieved, contributing to the advancement of OWC technologies as viable solutions for next-generation wireless communication networks [6].

The surge in demand for high-speed data transmission has propelled the exploration of alternative wireless communication technologies, particularly OWC. Traditional radio frequency (RF) wireless communication systems face bandwidth saturation issues, limiting their ability to meet future network requirements [2]. OWC offers an unlicensed spectrum with potential data rates extending to terabits per second, making it a viable candidate for next-generation communication systems [2].

OWC systems present unique advantages, including high security, immunity to RF interference, and reduced latency [3]. They are ideal for indoor applications where frequency reuse can enhance capacity. However, several challenges persist, including signal corruption due to ambient light, intersymbol interference, and skin/eye safety concerns [5]. Researchers have proposed various approaches, including optimizing diffusion spots' locations and intensities, to mitigate these effects and enhance OWC efficiency [6].

The transition to 5G and 6G networks has necessitated the integration of hybrid optical-RF communication platforms. Studies indicate that merging visible-light communication (VLC) with RF in indoor environments can boost speed and suppress latency concerns [4]. The deployment of hybrid optical-RF solutions optimizes bandwidth usage and improves spectral efficiency [4]. Furthermore, non-line-of-sight (NLOS) configurations have been explored to enhance mobility and data transmission [7].

Researchers have identified the optimization of diffuse spots' locations and intensities as critical to enhancing SNR and reducing DS. The hybrid JAYA/PSO method has been investigated to improve transmission efficiency, showing significant advancements in achieving high bit rates with lower complexity and cost [8]. These optimization techniques help overcome multipath propagation losses and enhance system reliability [9].

The integration of organic semiconductors into VLC technologies offers promising results for achieving efficient white-light communication links [6]. As OWC systems continue evolving, innovative solutions such as adaptive modulation schemes and network densification strategies will be key to supporting the rapid growth of wireless data traffic [10].

2. Optimization in Optical Wireless Communication Systems

OWC systems have seen significant advancements through various optimization techniques aimed at enhancing performance. Previous approaches have tackled different aspects of system refinement, yet certain critical factors remain unaddressed. For instance, while genetic algorithms have been employed to regulate optical wireless channels, they often overlook DS in their fitness functions [3]. Similarly, divide-and-conquer strategies have successfully adapted transmitter characteristics [11], and simulated annealing has fine-tuned spot patterns in diffuse OWC links, improving DS and received power standard deviation, yet spot intensities were not considered. Even efforts focused on optimizing diffuse spot center dispersion have left intensity variations unexplored [3].

This study introduces the JAYA optimization technique as a holistic solution, simultaneously refining both the positioning and intensity distribution of diffuse spots. By prioritizing SNR enhancement and DS minimization, our approach ensures superior performance while accounting for multipath dispersion and background noise. Various optimization scenarios are examined to reveal their impact on system efficiency, with results benchmarked against a baseline model featuring a circular arrangement of equal-intensity spots centered on receivers. The proposed channel model and optimization algorithm pave the way for adaptable and high-performing OWC systems across diverse indoor environments.

3. Optical Wireless Communication System Model

This section presents a sophisticated model of an indoor OWC system, as depicted in Figure 1. The setup comprises key components, including transmitters (Tx), receivers (Rx), noise sources, and a dynamic feedback loop, each playing a crucial role in signal transmission and optimization.

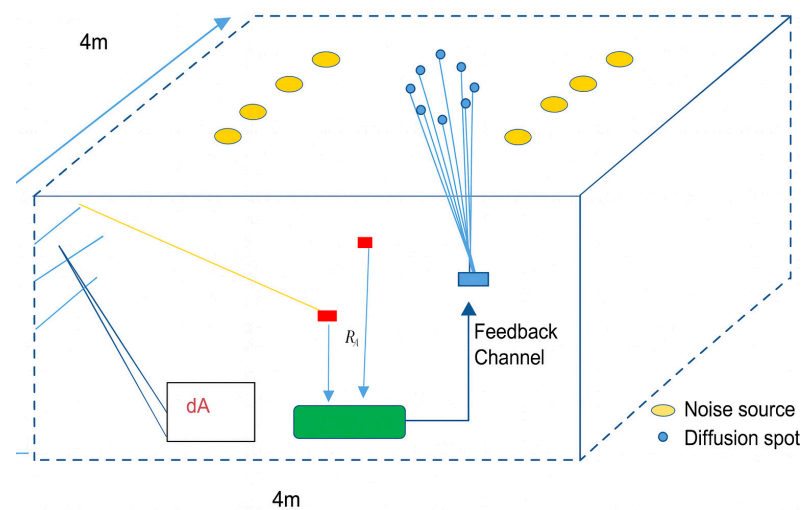


Figure 1. Showing the indoor OWC environment considered in this work.

At the core of the system, a single Tx, configured as either a two-dimensional vertical cavity surface-emitting laser diode (VCSEL) or a resonant cavity LED array [5], projects diffuse spots (DiSs) onto the ceiling. These spots effectively function as secondary indepen-

dent transmitters, ensuring robust signal distribution across the environment. The spatial arrangement of these diffuse patterns is highly adaptable, allowing for customization based on the room's dimensions and functional requirements.

A key feature of the system is its adaptive feedback mechanism, which continuously refines DiS locations and intensities to enhance communication efficiency. Given that DiSs exhibit Lambertian reflection characteristics [12], with a reflection coefficient denoted as ρ , only first- and second-order reflections are accounted for in the model. Higher-order reflections are excluded due to their negligible impact on system performance [8].

The system's behavior is mathematically characterized by the channel impulse response, formally expressed in Equation (1) [13]. This equation encapsulates the underlying dynamics of signal propagation, enabling precise analysis of OWC system performance within diverse indoor environments [14].

$$h(t : T_f : R_f) = \sum_{r=0}^k h^r(t : \tau : \mathcal{R}) \quad (1)$$

$$h^r(t : \tau : \mathcal{R}) = P_s \sum_{m=1}^{N_e} \frac{L+1}{2\pi} \frac{\cos^L(\varphi_{RT}) \cos(\theta_{RT})}{D_{RT}^2} \rho A_R \times \text{rect}\left(\frac{\theta_{RT}}{FOV_R}\right) \delta\left(t - \frac{D_{RT}}{c}\right) \quad (2)$$

Equation (1) encapsulates the fundamental parameters that define the behavior of an indoor OWC system. Here, L represents the Lambertian order, shaping the distribution of emitted optical power. The transmitted power, P_s , dictates the intensity of the signal, while T_x and R_x mark the initial transmission and final reception points, respectively.

To model the system's impulse response, the parameter t and the delta function characterize the arrival time at the receiver (R_x), relative to an ideal unit impulse radiated at $t = 0$ [7]. The reflection order, r further refines signal propagation, where $r = 0$ corresponds to a direct line-of-sight (LoS) transmission, while higher values denote reflections. The number of reflecting elements, N_e determines the complexity of multipath signal interactions.

A secondary transmission point (T) can be a diffuse spot or a Lambertian reflecting surface, ensuring efficient signal redirection. Similarly, the receiving point (R) may be either a photodetector (PD) or another reflecting surface, impacting signal absorption and redirection. The system's impulse response, $h(t; T; R)$, quantifies reflections up to the r th order.

Key physical attributes play crucial roles in signal propagation:

- D_{TR} represents the distance between transmission and reception points.
- A_R is the photosensitive or reflecting element area, affecting signal capture efficiency.
- FOV_R , the PD's field of view, is set at 170° to maximize reception. When the receiving point is a reflecting surface, FOV_R defaults to 1.
- $\text{rect}(x)$ serves as a bounding function, equaling 1 for $x \leq 1$ and 0 otherwise.

Additionally, θ_{RT} denotes the angle between D_{TR} and normality at the receiving point (n^R), while φ_{RT} defines the corresponding angle at the transmitting point (n^T). The speed of light, c , governs the fundamental transmission dynamics.

For an intensity modulation/direct detection (IM/DD) OWC system, the received photocurrent follows Equation (3), capturing the interplay of transmitted signal intensity, reflection orders, and environmental influences, essentially defining the system's responsiveness to diverse indoor conditions.

$$(t) = RPD x(t) * h(t : T_f; R_f) + n(t) \quad (3)$$

Equation (3) encapsulates key factors governing optical wireless communication system performance. The responsivity of the photodetector (RPD) determines how efficiently the incoming optical signal is converted into an electrical current. The transmitted signal,

$x(t)$ carries the modulated data, while $n(t)$ introduces additive white Gaussian noise, an inherent challenge in wireless systems that affects signal clarity and detection accuracy.

One of the most critical considerations in wireless communication is DS, which quantifies temporal dispersion in signal reception. It represents the duration over which the energy from an impulse response arrives at the receiver, influencing system reliability and data integrity. Excessive DS can lead to inter-symbol interference, degrading communication quality, especially in high-speed optical networks.

Equation (4) precisely defines S , capturing how multipath propagation impacts signal arrival timing [9]. By understanding and mitigating delay spread, optical wireless systems can optimize their performance, ensuring robust, high-fidelity data transmission in diverse indoor environments:

$$DS = \sqrt{\frac{\int (t - \mu)^2 (h(t; T_f; R_f))^2 dt}{\int (h(t; T_f; R_f))^2 dt}} \quad (4)$$

And μ is the mean delay, which is given by

$$\mu = \frac{\int t (h(t; T_f; R_f))^2 dt}{\int (h(t; T_f; R_f))^2 dt} \quad (5)$$

Note: $h(t; T_f; R_f)$ is the channel impulse response LOS while at a diffuse spot or a Lambertian surface, r th reflection order impulse response of: $h_r(t; T_f; R_f)$. The SNR is given in Equation (6) as shown below [15]:

$$SNR = \frac{(RP_r)^2}{\sigma_{total}^2} \quad (6)$$

where P_r is the average optical receiver power and σ_{total}^2 is the total variance of the noise, which is expressed as follows:

$$\sigma_{total}^2 = \sigma_{PA}^2 + \sigma_{BN}^2 \quad (7)$$

where σ_{PA}^2 is the noise variance of the pre-amplified signal and σ_{BN}^2 is the ambient light noise variance.

OWC leverages three primary modulation schemes: baseband, multicarrier, and multicolor [14]. Each approach serves distinct purposes in optimizing signal transmission and reception. Baseband modulation encompasses techniques such as pulse amplitude modulation (PAM), pulse position modulation (PPM), pulse interval modulation (PIM), and carrier-less amplitude phase (CAP) modulation, all of which are tailored to efficiently encode data while managing signal integrity.

Meanwhile, multicolor modulation, which is often implemented using wavelength division multiplexing (WDM) with blue, green, and red (BGR) LEDs, allows high data rates and multi-user access by transmitting information across separate wavelengths [6]. Although four-color laser diodes (LDs) have demonstrated superior performance compared to conventional three-color LEDs, challenges persist, particularly with white light LEDs, where the phosphor's slow response constrains modulation bandwidth. Overcoming these limitations requires sophisticated signal processing techniques and advanced modulation formats.

Complementing these developments, the JAYA algorithm [5] emerges as a groundbreaking optimization technique, which is applicable to both constrained and unconstrained

problems. Rooted in the principle of achieving the best possible solution while steering clear of the worst, JAYA continuously refines outcomes by dynamically shifting toward optimal configurations. Its name, derived from the Sanskrit word for “victory,” aptly reflects its approach to systematic improvement.

A defining strength of JAYA is its parameter-free nature, requiring only population size and iteration count, unlike other algorithms that demand multiple tuning parameters such as inertia weight, learning factors, and acceleration coefficients (e.g., particle swarm optimization). This streamlined methodology significantly simplifies implementation, accelerates computation, and enhances efficiency.

Mathematically, let $f(x)$ represent an objective function with D -dimensional variables ($j = 1, 2, \dots, D$). The estimated value of the j th variable for the i th candidate solution is $x_{i,j}$, forming the vector $x_i = (x_{i,1}, x_{i,2}, \dots, x_{i,D})$ to define the candidate’s position in the search space. The best solution, $x_{best} = (x_{best,1}, x_{best,2}, \dots, x_{best,D})$, exhibits the highest $f(x)$ value, while the worst solution, $x_{worst} = (x_{worst,1}, x_{worst,2}, \dots, x_{worst,D})$, represents the least favorable outcome. Equation (8) governs the iterative update of $x_{i,j}$, ensuring the system converges toward the optimal solution.

$$x_{i,j}^f = x_{i,j} + rand_1 \cdot (x_{best,j} - |x_{i,j}|) - rand_2 \cdot (x_{worst,j} - |x_{i,j}|) \quad (8)$$

Equation (8) plays a pivotal role in the JAYA optimization algorithm, guiding each candidate solution toward optimal performance. Here, $x_{best,j}$ and $x_{worst,j}$ denote the values of the j th variable for the best and worst solutions, respectively. The updated variable, $x_{i,j}$, represents the newly refined value based on the optimization process, while $|x_{i,j}|$ expresses its absolute magnitude.

A critical component of JAYA is the influence of $rand_1$ and $rand_2$, two randomly generated values uniformly distributed within the range $[0, 1]$. In Equation (8), the term $rand_1 (x_{best,j} - |x_{i,j}|)$ directs the solution towards improvement, continuously refining its position within the search space. This mechanism ensures that each iteration prioritizes better solutions, systematically avoiding suboptimal outcomes.

Unlike traditional optimization techniques which require extensive parameter tuning, JAYA adopts a self-sufficient approach, adjusting solutions dynamically. Once a solution is identified, the algorithm moves closer to the best and steers further from the worst, reinforcing the victory-driven nature of JAYA. Through this iterative refinement, the algorithm consistently strives for efficiency and precision, making it a highly effective optimization strategy.

The JAYA algorithm is implemented according to the following steps:

1. Initialize the population size (IPZ), design variables, and fitness function evaluation count (FEE).
2. Assess the fitness function value for each candidate solution.
3. Set $FEE = NP$ (initial evaluation count).
4. While $FEE < Max_FEE$, repeat the following steps:
 - Select the best candidate (x_{best}) and the worst candidate (x_{worst}) from the population.
 - For $i = 1$ to NP , evaluate the fitness function value for the updated candidate.
 - Increment $FEE = FEE + 1$.
 - Accept the new solution only if it outperforms the previous one.
5. End iteration once optimal criteria are met.

By continuously refining each candidate’s position, JAYA eliminates reliance on complex parameter tuning, making it an efficient and scalable optimization framework. Whether it is applied to engineering, data science, or machine learning, its ability to max-

imize potential while avoiding poor solutions makes it a standout algorithm for robust decision-making. Figure 2 shows the JAYA algorithm flowchart.

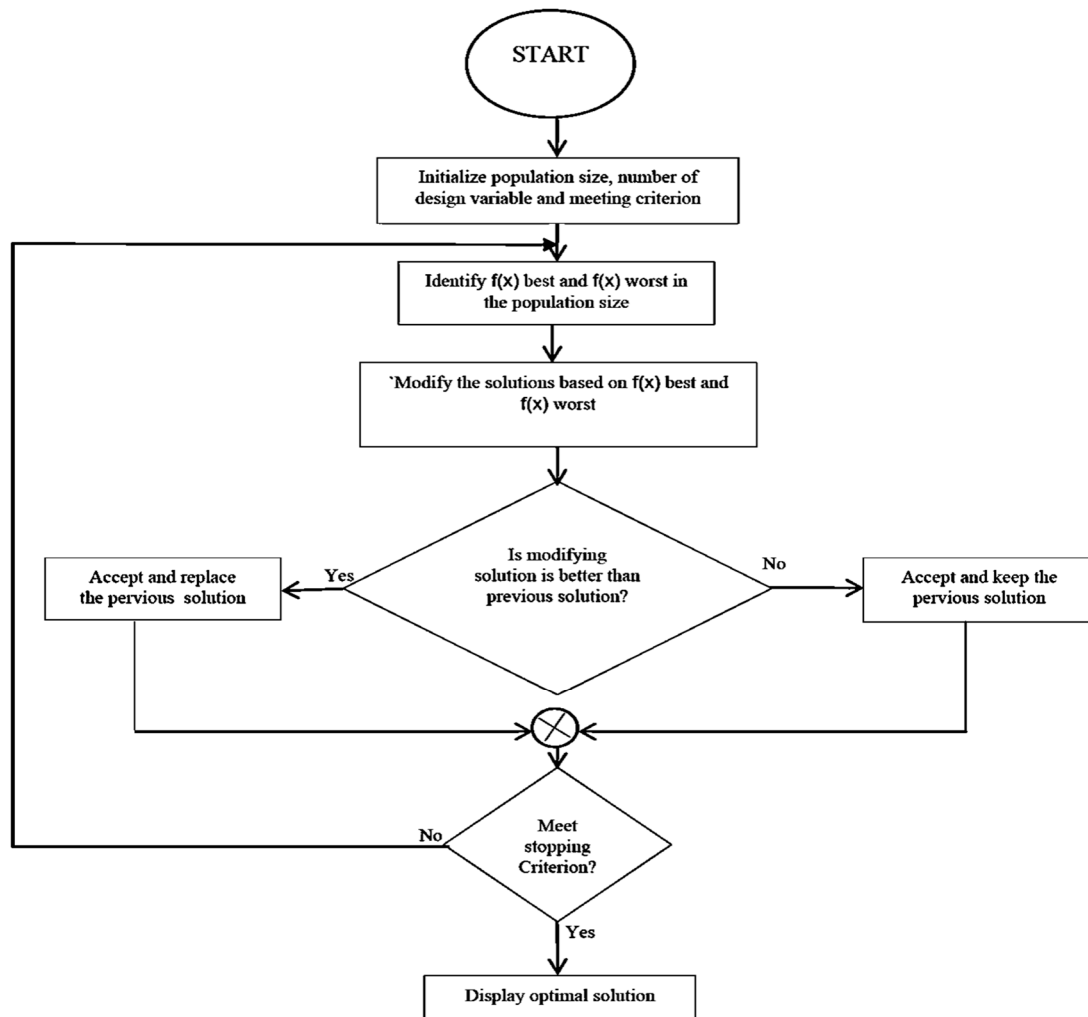


Figure 2. Jaya algorithm flow chart.

4. Results and Discussion

To evaluate system performance, a controlled indoor simulation environment was designed, replicating real-world conditions within a $4\text{ m} \times 4\text{ m} \times 3\text{ m}$ room. Receivers were strategically positioned 1 m above the floor, ensuring varied signal propagation pathways.

4.1. Noise and Transmission Sources

Eight Luminous-LED PLYC4545 (PAR38) light-emitting diode lamps (Conglom, Inc. 2600 Avenue Marie-Curie, Montreal, QC, H4S 2C3, Canada) were incorporated as noise sources. With a Lambertian order of 33.1 and an emitted power of 65 W, these sources exhibited highly directive characteristics, significantly influencing system performance. Their high Lambertian order made them more focused than the diffuse spots, reinforcing their role as interference factors.

Simultaneously, eight diffuse spots, functioning as secondary independent transmitters, were implemented to facilitate signal distribution. These spots played a crucial role in adaptive transmission, ensuring robust signal coverage across the indoor space.

4.2. Optimization Scenarios

To investigate the impact of transmission patterns, two distinct optimization scenarios were considered:

- Scenario P: The eight diffuse spots were uniformly arranged along the perimeter of a 0.5 m radius circle, creating a structured and predictable transmission pattern.
- Scenario Q: The eight diffuse spots were randomly distributed within the room, generating a more dynamic and unpredictable transmission environment.

Despite differing placements, the diffuse spot intensities remained non-uniform, with random distributions ensuring varied transmission characteristics. However, the total emitted power remained consistent at 2 W, standardizing energy output for comparative analysis.

Table 1 provides a comprehensive overview of the key simulation parameters utilized for both PSO and JAYA algorithms, highlighting essential system attributes that guided performance evaluation.

Table 1. Simulation parameters.

S/No	Parameter	Values
	PSO Algorithm	
1	Nos of Iteration	100
	Nos of Particles	50
	Nos of Evaluations	5000
2	Jaya Algorithm	
	Population size, N	100
	Dimension, D	4
	Room dimension	4 × 4 × 3
	Reflectivity of the wall	0.8
	Reflectivity of the ceiling	0.8
	Reflectivity of the wall	0.3
	Receivers location	(1.6, 2.1, 1), (4.8, 4.5, 1), (3.3, 0.7, 1), (0.4, 2.2, 1)
	Noise source location	(1.1, 3), (1, 2, 3), (1, 3, 3), (1, 4, 3), (4, 1, 3), (4, 2, 3), (4, 3, 3), (4, 4, 3)
	Photodectetor (PIN) responsivity	0.5 A/W
	Bit rate	100 Mbps
	Receive bandwidth	70 Mhz

To evaluate system performance, a controlled indoor simulation environment was designed, replicating real-world conditions within a 4 m × 4 m × 3 m room. Receivers were strategically positioned 1 m above the floor, ensuring varied signal propagation pathways.

$$F = \sum_{k=1}^{NR} (\omega_1 \times SNR_r - \omega_2 \times DS_k) \quad (9)$$

The fitness function used for optimization (Equation (9)) considered both delay spread (DS_k) and signal-to-noise ratio (SNR_r) at each of the NR receivers (Rxs). It is defined as follows:

$$Fitness = \omega_1 \times \sum DS_k + \omega_2 \times \sum \frac{1}{SNR_k} \quad for \ k = 1 \ to \ NR \quad (10)$$

where $\omega_1 = 1$ and $\omega_2 = 1 \times 10^9$ represent the weights assigned to each component of the fitness function. These weights balance the influence of delay spread and SNR_k on the overall optimization objective. The large value of ω_2 suggests a strong emphasis on maximizing SNR_r .

4.3. Impact of Delay Spread and Optimized DiS Configurations

Delay spread (DS_k) is a critical factor in optical wireless communication systems, as it directly influences the achievable bit rate and bandwidth (BW) at the receivers. Excessive DS_k can lead to intersymbol interference, reducing signal clarity and limiting transmission efficiency. To counteract these effects, DS_k is strategically incorporated into the fitness function, ensuring the optimization process prioritizes minimal signal dispersion while maximizing overall system performance.

4.4. Optimized DiS Placement and Intensity Distributions

Figure 3a,b illustrate two distinct scenarios for DiS placement and intensity allocation, highlighting their impact on receiver signal quality:

- Figure 3a—circular arrangement: Rxs 1 and 4 experience the highest susceptibility to noise due to their proximity to multiple noise sources. Conversely, Rxs 2 and 3 are less affected, since each one is near only one noise source, leading to improved signal reception and reduced interference.
- Figure 3b—scattered distribution: The intensity allocation reveals a significant power concentration in DiS 8, which exceeds the output of other DiSs. This is because DiS 8 is tasked with simultaneously serving two receivers (Rxs 1 and 3), with Rx 3 positioned farther away. To ensure reliable signal transmission at greater distances, DiS 8 must emit higher power, compensating for signal attenuation over the propagation path.

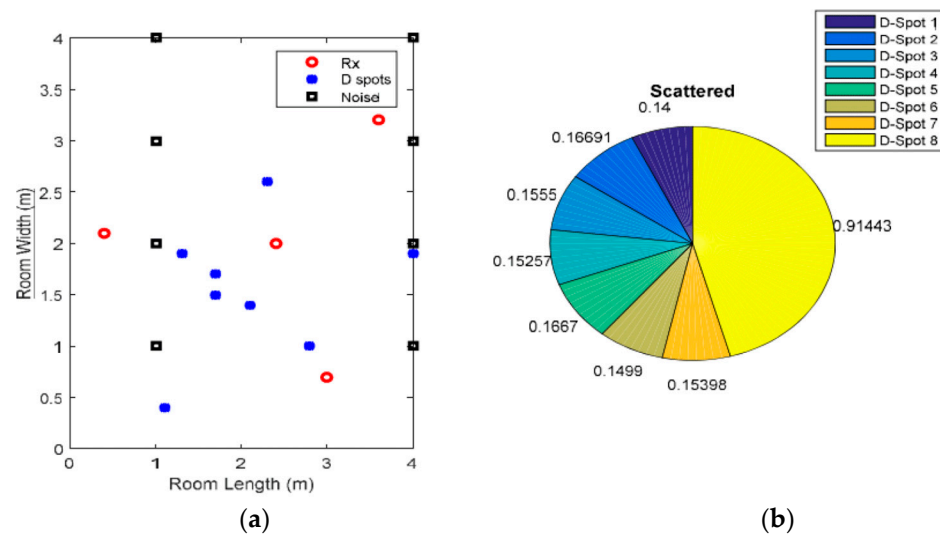


Figure 3. (a) Scattered distribution of DiSs spot and (b) intensities of the diffused spots post-optimization (scattered distribution).

These findings underscore the importance of strategic DiS placement and intensity adjustments, reinforcing their role in optimizing SNR, delay spread minimization, and overall transmission efficiency. By adapting emission characteristics based on receiver location and environmental factors, optical wireless systems can achieve superior performance, ensuring stable and high-quality data delivery across diverse indoor settings.

The diffuse spots were placed at sufficient distances from the corners of the room in the range >0.4 and <3 in order to actualize the optimized locations of the diffuse spots.

4.5. Optimized Diffuse Spot Placement and Performance Analysis

Figure 4 presents results from the second scenario, demonstrating how optimized diffuse spot (DiS) placement enhances system performance. The strategic positioning of DiSs closer to their respective receivers (Rxs) ensures improved signal transmission:

- S2 and S3 align near Rx3, optimizing coverage.
- S1, S6, and S7 cluster around Rx2, reinforcing signal stability.
- S4 and S8 support Rx4, mitigating interference.
- S5 targets Rx1, optimizing transmission efficiency.

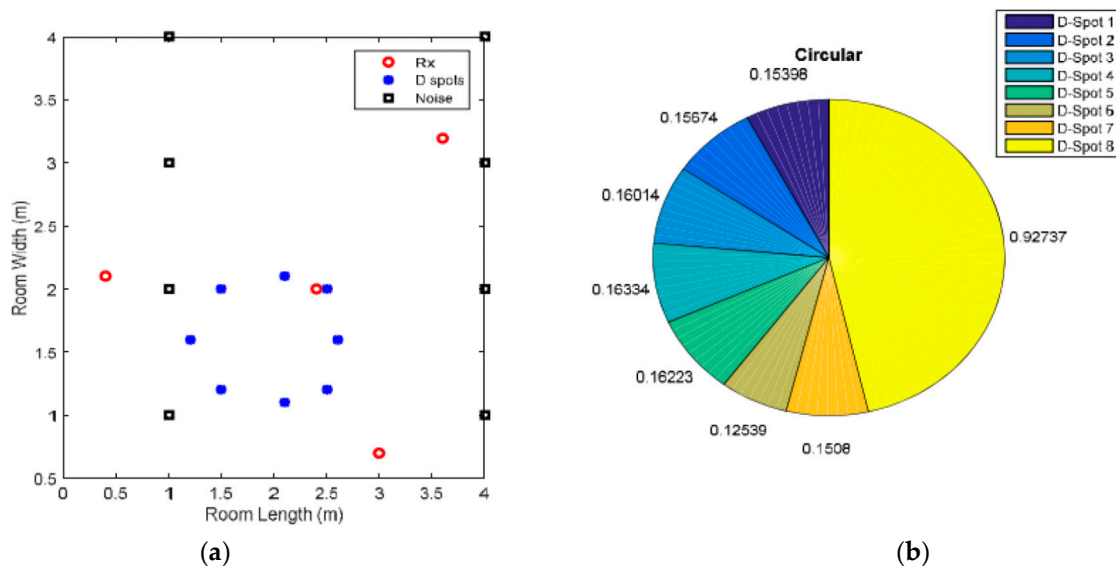


Figure 4. Optimized parameter for the diffuse spot of the first scenario (i.e., circular) from the top. (a) Circular distribution of DiSs spot; (b) intensities of the diffused spots optimized circular.

Notably, Rx1 and Rx4 are positioned near noise sources, making them more vulnerable to interference.

4.6. Intensity Distribution and Signal Optimization

Figure 4b reveals that S8 exhibits a higher power level than other DiSs. This is because S8 serves Rx4 while simultaneously being close to Rx1, both of which are nearby noise sources. The increased intensity of S8 compensates for signal degradation, leading to higher SNR values at Rx1 and Rx4. This distribution ensures a more uniform SNR balance across all receivers, stabilizing communication performance.

4.7. Comparative Performance Analysis

Table 2 and Figure 5 provide a detailed comparison of key system metrics, evaluating average SNR, DS, standard deviation of SNR, and standard deviation of delay spread across different optimization scenarios:

- Scenario 1—Initial unoptimized configuration.
- Scenario 2—Optimized DiS placement for refined signal transmission.
- Scenario X—Centrally positioned DiSs with uniform power distribution.
- Scenario Y—JAYA-optimized DiS distribution for maximum efficiency.

Key observations from JAYA vs. PSO optimization:

- Optimized center placement (JAYA vs. PSO):
 - JAYA's center-based optimization yielded a 23.26% improvement in average SNR and a 28.87% improvement in SNR standard deviation over PSO.

- Average DS improved by 19.7%, indicating better temporal signal distribution compared to Scenario 1's unoptimized layout.
- JAYA also demonstrated faster convergence and better delay spread control, though Scenario 1 exhibited slightly better standard deviations for SNR and DS.
- Optimized locations and intensities (Scenario 2):
 - Refining both the placement and intensity of randomly distributed DiSs in Scenario 2 led to a 1.76% increase in average SNR and a 12% reduction in average DS relative to Scenario 1.
 - JAYA's optimization outperformed PSO in DS standard deviation, though reference [8] reported slightly superior DS standard deviation results.

Table 2. Comparison of the optimization scenarios using PSO.

Optimized Scenarios	Average Delay Spread (s)	STD of DS	Average SNR (dB)	STD of SNR
Scenario X [11]	1.0270×10^{-9}	0.8462×10^{-9}	17.9881	3.5656
Scenario Y [11]	0.9528×10^{-9}	0.5833×10^{-9}	19.4327	1.1508
Scenario 1	0.90296×10^{-9}	0.5095×10^{-9}	19.8667	1.0781
Scenario 2	0.85615×10^{-9}	0.4880×10^{-9}	22.7776	0.9974

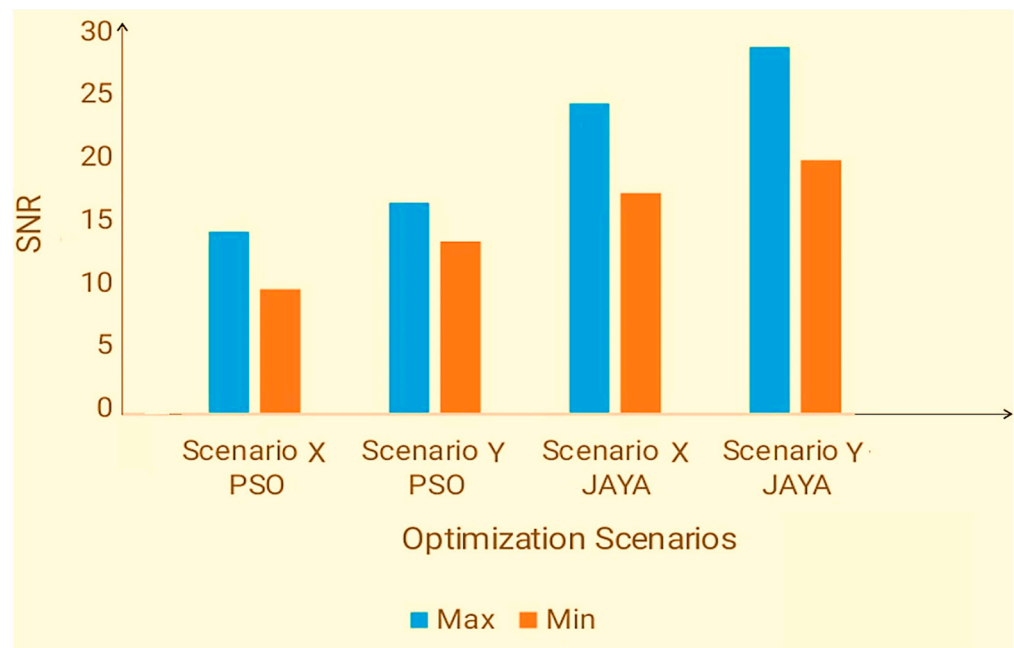


Figure 5. Minimum and maximum SNR obtained.

4.8. Impact of Variable Count on Optimization

Scenario 2 introduced 24 adjustable variables, exceeding Scenarios Y (2) and 1 (10), providing greater adaptability in DiS adjustments based on environmental factors. This higher degree of flexibility explains the observed improvements in SNR, DS, and SNR standard deviation.

Figure 4 visually highlights how optimized parameter tuning enhances DiS placement, enabling the system to intelligently adjust transmission characteristics for maximum efficiency and stable performance. Expanding optimization parameters allows greater precision, ensuring optimal wireless communication quality across dynamic indoor environments.

4.9. Analysis of SNR and Delay Spread Across Optimization Scenarios

A comparative evaluation of SNR and DS across multiple scenarios provides key insights into system performance improvements and trade-offs as presented in Table 3.

Table 3. Comparison of the optimization scenarios.

Optimized Scenarios	Average Delay Spread (s)	STD of DS	Average SNR (dB)	STD of SNR
Scenario 1	0.8284×10^{-9}	0.395×10^{-9}	24.6022	0.9422
Scenario 2	0.7306×10^{-9}	0.3595×10^{-9}	25.042	0.8990

4.9.1. Scenario 1 vs. Scenario 2: Performance Trade-Offs

Scenario 1 represents the initial setup, exhibiting solid SNR and delay spread values. However, Scenario 2, which incorporates optimized DiS locations and intensities, demonstrates measurable improvements:

- A 1.76% increase in average SNR;
- A 12% reduction in average DS.

Despite these gains, Scenario 2 introduces a higher standard deviation in SNR, reflecting a broader variation across receivers. Applying the Jaya algorithm, the delay spread standard deviation in Scenario 2 outperforms PSO, though it remains slightly worse than the reference [8].

4.9.2. Variable Count and System Adaptability

Scenario 2 benefits from an expanded optimization variable set (24) compared to Scenario Y (2) and Scenario 1 (10), giving it greater adaptability in refining the DiS configuration. This increased flexibility enables precise DiS positioning around the receivers (Figure 4), leading to significant improvements in the SNR and DS.

4.9.3. Evaluating SNR Stability (Figure 5-SNR Bar Chart)

Figure 5 visually contrasts the maximum and minimum SNR values across the four scenarios:

- Scenario Y (Jaya optimization) improves the minimum and average SNR, reducing the difference between max/min SNR, leading to a more stable SNR standard deviation (Table 2).
- Scenario 1 exhibits a higher max, min, and average SNR than Scenario A, but its standard deviation is higher due to the greater disparity between max/min SNR values.
- Scenario 2 shows broad improvements in average, min, and max SNR, yet displays a 2.8 dB gap between max/min SNR values. This difference suggests that while average SNR improves, the variation across receivers increases, impacting stability.

4.9.4. Eye Safety Considerations in Real-World Applications

In practical implementations, eye safety regulations must be prioritized when determining maximum transmit power. Factors such as DiS placement, number of transmitters, and Lambertian reflection properties all play crucial roles in ensuring compliance. While this study focuses on impulse response-based proof-of-concept optimization, real-world deployments must strictly adhere to safety standards, reinforcing operational integrity.

The analysis highlights the benefits and trade-offs of optimization algorithms, emphasizing the role of variable count, adaptability, and DiS placement in improving SNR and delay spread. By refining DiS positioning and intensity, optical wireless systems

can enhance communication stability while addressing safety constraints for real-world applications.

4.10. Focus on Signal-to-Noise Ratio Optimization

With the DS values successfully meeting the constraints for a maximum bit rate of 100 Mbps, the optimization emphasis now shifts toward SNR, as depicted in Figure 5.

By achieving acceptable DS levels, the system effectively minimizes intersymbol interference, ensuring stable high-speed data transmission. However, SNR remains a crucial determinant of communication reliability, as it directly impacts signal clarity, reception quality, and error rates across the transmission channel.

Figure 5 highlights how refined DiS placement and intensity adjustments influence SNR distribution, optimizing overall performance and signal stability. Higher SNR values across receivers translate to improved transmission fidelity, reinforcing the system's capacity to operate under dynamic indoor conditions.

This strategic focus on SNR enhancement ensures a robust optical wireless communication framework, capable of supporting efficient data transmission, minimizing noise interference, and providing superior overall connectivity.

5. Conclusions

This study explored the optimization of DiS placement and intensity in indoor visible light OWC systems, with the primary objective of SNR and minimizing DS. By analyzing various optimization scenarios, this research assessed how the number of optimization variables impacts SNR and DS performance across different user environments.

Key Findings and Impacts:

- Significant performance gains: the Jaya algorithm demonstrated its effectiveness by achieving up to a 29% improvement in SNR and a 23.3% reduction in delay spread, reinforcing its superiority in signal refinement.
- Enhanced stability: the optimization process contributed to better standard deviations in SNR (up to 5%) and delay spread (up to 9.9%), ensuring greater consistency in performance despite challenges such as ambient light interference and multipath dispersion.
- Hybridization and increased variable count: This study highlights the advantages of combining optimization algorithms while expanding the number of adjustable variables. This approach enhances the adaptability of diffuse spots, allowing them to dynamically adjust to environmental conditions, ultimately boosting overall system efficiency and communication reliability.

Final Implications:

These results affirm the importance of strategic optimization in optical wireless systems, demonstrating how adaptive placement and intensity control can significantly improve SNR stability, delay spread management, and signal transmission quality. Future research could further refine hybrid algorithm approaches to enhance real-time adaptability, ensuring robust high-speed communication in diverse indoor environments.

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References

1. Agiwal, M.; Roy, A.; Saxena, N. Next generation 5G wireless networks: A comprehensive survey. *IEEE Commun. Surv. Tutor.* **2016**, *18*, 1617–1655. [CrossRef]
2. Alsulami, O.; Hussein, A.T.; Alresheedi, M.T.; Elmirghani, J.M.H. Optical wireless communication systems: A survey. *arXiv* **2018**, arXiv:1812.11544. [CrossRef]
3. Arfaoui, M.A.; Soltani, M.D.; Tavakkolnia, I.; Ghayeb, A. Measurements-based channel models for indoor LiFi systems. *IEEE Access* **2020**, *20*, 827–842. [CrossRef]
4. Chowdhury, M.Z.; Shahjalal, M.; Hasan, M.K.; Jang, Y.M. The Role of Optical Wireless Communication Technologies in 5G/6G and IoT Solutions: Prospects, Directions, and Challenges. *Appl. Sci.* **2019**, *9*, 4367. [CrossRef]
5. Javaid, F.; Wang, A.; Sana, M.U.; Husain, A.; Ashraf, I. Characteristic study of visible light communication and influence of coal dust particles in underground coal mines. *Electronics* **2021**, *10*, 883. [CrossRef]
6. Khalighi, M.A.; Ghassemlooy, Z.; Alouini, M.S.; Hranilovic, S.; Zvanovec, S. Optical wireless communications for emerging connectivity requirements. *IEEE Open J. Commun. Soc.* **2021**, *2*, 82–86. [CrossRef]
7. Kirrbach, R.; Faulwasser, M.; Jakob, B.; Schneider, T.; Noack, A. Li-Fi for augmented reality glasses: A proof of concept. In Proceedings of the 2019 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct), Beijing, China, 10–18 October 2019; pp. 263–268.
8. Lebaka, M. Optimization of spot pattern in indoor diffused optical wireless systems. *IEEE Photonics Technol. Lett.* **2006**. Available online: <https://home.iitk.ac.in/~yensingh/mtech/lmadhu.pdf> (accessed on 9 August 2025).
9. Manousiadis, P.; Yoshida, K.; Turnbull, G.A.; Ifor, D.W.; Samuel, I.D.W. Organic semiconductors for visible light communications. *Phil. Trans. R. Soc. A.* **2020**, *378*, 20190186. [CrossRef] [PubMed]
10. Alves, L.N.; Khalighi, M. Optimization and design of a diffuse optical wireless sensor network. *Appl. Opt.* **2022**, *61*, 6599–6608. Available online: <https://opg.optica.org/ao/abstract.cfm?uri=ao-61-22-6599> (accessed on 9 August 2025). [CrossRef] [PubMed]
11. Eltokhey, M.W.; Mahmoud, K.R.; Ghassemlooy, Z.; Obayya, S.S.A. Optimization of intensities and locations of diffuse spots in indoor optical wireless communications. *Opt. Switch. Netw.* **2019**, *33*, 177–183. [CrossRef]
12. Wong, D.W.K.; Chen, G.C.K. Optimization of spot pattern in indoor diffuse optical wireless local area networks. *Opt. Express* **2005**, *13*, 3000–3014. [CrossRef] [PubMed]
13. Wu, X.; Soltani, M.D.; Zhou, L.; Safari, M.; Haas, H. Hybrid LiFi and WiFi networks: A survey. *IEEE Trans. Wirel. Commun.* **2020**, *23*, 1398–1420. [CrossRef]
14. Chen, X.; Li, C.; Chen, L.; Wang, H.; Zang, Y.; Yao, W. Influence of different structure and specification parameters on the propagation characteristics of optical signals generated by GIL partial discharge. *Energies* **2020**, *13*, 3241. [CrossRef]
15. Zhou, H.; Chabory, A. An Extraction Method for the Multipath Characteristics of Simulated Tropospheric Propagation Channels. *IEEE Trans. Aerosp. Electron. Syst.* **2025**, *61*, 14401–14413. [CrossRef]

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