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RESEARCH ARTICLE

REVISED Optimizing direct-modulated laser LiFi systems for hospital environments through simulation-driven analysis of BER, SNR, and Q-factor performance

[version 3; peer review: 3 approved, 1 approved with reservations]

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Abstract

Background Modern hospital environments require wireless communication systems that ensure electromagnetic interference (EMI) compliance, privacy, and high throughput for mission-critical applications, such as telemetry, medical imaging, and Electronic Health Record (EHR) synchronization. Traditional RF-based wireless systems are susceptible to EMI, limited spectrum availability, and security issues. Direct-Modulated Laser (DML)-based Light Fidelity (LiFi) offers a promising alternative by leveraging the visible spectrum for high-speed, interference-free communication in terms of intended optical emissions. Methods The optimized configuration achieves BER well below the commonly cited analytical reliability benchmark ($BER < 10 - 9$), $SNR \approx 74.94$ dB, and $Q \approx 18.84$ at 25 m, under idealized detector-noise-limited assumptions. Launch powers $\geq$ +5 dBm are required beyond ~15 m, modulation indices of 0.8–1.0 yield higher Q across distances, narrow beam divergences (1–2 mrad) maintain stronger SNR, and receiver apertures of 4–6 mm provide a balance between light collection and noise. Results The optimized configuration achieves BER well below the analytical benchmark ($BER < 10^{-9}$), $SNR \approx 74.94$ dB, and $Q \approx 18.84$ at 25 m, demonstrating a substantial analytical performance margin in a best-case, well-aligned line-of-sight configuration. Launch powers = +5 dBm are required beyond ~15 m, modulation indices of 0.8–1.0 yield higher Q across distances, narrow beam divergences (1–2 mrad) maintain stronger SNR, and receiver apertures of 4–6 mm provide a balance between

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light collection and noise. Conclusions This paper introduces a four-parameter DML-LiFi optimization framework tailored to hospital environments, which offers a theoretical explanation of link-budget feasibility and parameter sensitivity to idealized indoor environment. These results indicate an upper-bound performance study, and not a demonstration of deployment-ready reliability, and are meant to be used in future experimental and system-level studies that focus on mobility, line-of-sight blockage, ambient-light-induced shot noise, electromagnetic interference pickup, and eye-safety constraints in hospital settings.

Plain language summary

Fast, secure, and reliable communication systems have become essential in modern hospitals to assist in the provision of critical healthcare services. These are real-time monitoring of patients, high-resolution medical imaging, distantly held consultations, and electronic health records transfer. Nowadays, the majority of this communication is based on Wi-Fi and other radio mechanisms. Nonetheless, radio waves have the potential to disrupt sensitive medical equipment, like MRI machines and pacemakers, and they are able to pass through walls, which is why they can be easily compromised in security terms.

LiFi is the future form of wireless technology, which involves the use of light rays rather than radio waves to convey information. It is very high speed, has better security and zero electromagnetic interference, and thus it is suitable in hospital settings. This paper has discussed how Direct-Modulated Lasers (DML) can be used to develop a LiFi system specific to a hospital. These lasers can transmit information at a gigabit-per-second rate with visible light in a small and low-energy-consuming format.

To explore the effects of four technical factors on data quality and reliability, we simulated with the help of advanced simulation tools (OptiSystem and MATLAB) the influence of the following factors on this issue: transmit power, modulation index, beam divergence, and receiver aperture size. The four parameters were optimized to develop an extremely low error rate and a robust and stable connection across the distances typical of hospitals (e.g., between patient rooms and wards).

We have established that LiFi using DML can offer hospitals secure high-speed communication that is free of interference, eliminating most of the drawbacks of the existing Wi-Fi networks. The speed and safety of sharing data through medical devices could be achieved faster and more safely through this technology.

Keywords

LiFi; Direct-Modulated Laser (DML); Hospital Communication; Bit Error Rate (BER); Signal-to-Noise Ratio (SNR); Q-Factor; Optical Wireless Communication

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REVISED **Amendments from Version 2**

The updated edition of this article features significant advances in the clarity, methodological transparency, and locating in scholarly space based on the critique of the reviewers. The greatest change is related to the way of how the optimization process is framed. The previous version referred to the four-parameter tuning as being optimized without stating how. The updated paper version makes it clear that the reported configuration is obtained by a systematic parametric sweep and sensitivity analysis, but not the official multi-objective optimization algorithm. It clearly indicates that the solution being described is an analytically desirable configuration of the parameter space being considered under idealized detector-noise-limited conditions, but not a global optimum.

The assertions about reliability have been moderated all over the manuscript. Such statements suggesting deployment-level robustness have been substituted with wording that focuses on theoretical feasibility and high-level analytical performance when the line-of-sight is well-aligned. Restrictions to mobility, blockage, shot-noise due to ambient lighting, electromagnetic pickup and eye protection are now properly recognized.

The literature review has been enhanced to offer a better positioning as compared to LED based LiFi, VCSEL array systems and hybrid LiFi-RF architectures. The comparative discussion has been broadened to define the trade-offs in bandwidth, coverage and sensitivity to the position of the aim of presentation of balanced state of the art.

Mathematical notation is standardized and variables are formatted in italic and proper equation structures have been fixed. The legends have also been adjusted to enhance the clarity of the figures and the overlapping data annotations have been removed. Altogether, this updated edition is a more strictly constructed, properly placed, and scholarly mature work on the analysis of hospital-based DML-LiFi systems.

Any further responses from the reviewers can be found at the end of the article

Introduction

The extensive rise in wireless communication speed and security requirements has led to major advancements in optical wireless technologies, specifically light fidelity (LiFi). LiFi uses the visible-light spectrum to deliver wireless connectivity and complements traditional RF methods in certain scenarios. Because LiFi exploits the wide, license-free optical spectrum, it can offer higher throughput, lower latency, and better energy efficiency than RF under favorable channel and alignment conditions, with energy efficiency depending strongly on coverage area, link geometry, and implementation. In healthcare, the need for interference-free, cyber-resilient links has intensified with digital transformation (telemetry, imaging, EHRs).[1]

Electromagnetic interference (EMI) immunity is a key reason LiFi can outperform RF in hospitals. Hospital settings demand EMI-free communication because RF signals from Wi-Fi and Bluetooth, along with other wireless devices, can interfere with MRI scanners, pacemakers, and patient-monitoring systems.[2] Unlike RF, optical signals do not penetrate walls appreciably, reducing eavesdropping risk.[3] It is, however, observed that in practice LiFi receivers could continue to be vulnerable to EMI pickup via photodetectors and front-end electronics, and this must be taken into account when designing on the system level.

A modern LiFi system can be implemented with a Direct-Modulated Laser (DML), which provides compact, high-energy efficiency operation at gigabit-per-second (Gbps) speeds while using single integrated devices without external modulators. Compared with LED-based LiFi, DMLs offer higher modulation bandwidth (up to multi-GHz), better linearity, and lower noise, enabling stable high-rate links in dense, time-critical hospital networks (e.g., telemetry, imaging, robotic/remote procedures, and AI-assisted diagnostics).[4]

Directly modulated laser sources allow a modern LiFi system to be built with compact transmitter architecture and high modulation bandwidths whilst avoiding external modulators. Although DMLs support bandwidths that are higher than LEDs, theoretical and practical stability in hospital settings also requires alignment robustness, the nature of receiver noise, ambient light, and mobility.

Recent studies support DML-LiFi's suitability for clinical environments, with 500-nm DML links achieving BER $< 10^{-10}$ at >20 m[5]. These outcomes reflect the ability to perform a link-budget when conditions are perfect, and lines-of-sight are maintained, instead of the performance of reliable deployment. These findings motivate further system-level analysis and parameter optimization for indoor hospital scenarios.

Building on our prior optical-wireless research, we modeled snow-induced penalties with ANN-based BER prediction for FSO links,[5] designed inter-building FSO backbones with RF redundancy,[6] explored Li-Fi/IoT integration toward 6G architectures,[7] and developed simulation-driven FSO performance models.[8] We also analyzed optical-wireless links

using Fresnel-lens collection under diverse atmospheric conditions[9] and investigated Gaussian-beam propagation effects for FSO system performance.[10,11] Together, these studies establish a methodology of environment- and device-aware modeling for optical wireless networks. However, they also reveal a remaining gap: the indoor, EMI-safe optimization of direct-modulated-laser (DML) LiFi in hospital rooms and wards—where device-level parameters (launch power, modulation index, beam divergence, receiver aperture), rather than outdoor weather, dominate reliability, security, and throughput. The current paper bridges this gap with the creation of a hospital-specific DML-LiFi model and a 4-parameter optimization model, which offers a theoretical understanding of how the four parameters affect BER, SNR, and Q-factor under idealistic indoor conditions.

However, a hospital-specific optimization of DML-LiFi—covering transmit power, modulation index, beam divergence, and receiver aperture—remains under-reported. This paper addresses that gap by developing a simulation-driven model (OptiSystem + MATLAB) and quantifying how these four parameters jointly shape BER, SNR, and Q-factor at clinically relevant distances. The aim is to examine theoretical link-budget feasibility and parameter sensitivities of DML-LiFi in hospital-scale indoor DML-LiFi applications. It is the contribution of the four-parameter optimization study that sets the upper-bound performance trends, and not the validation of deployment-ready reliability or the resolution of mobility, blockage or eye-safety constraints.

Literature review

LiFi Fundamentals and Healthcare Applications: The research group led by Haas *et al.*[12] introduced LiFi, which has since matured from concept to deployed technology; recent demonstrations report 100 Gbps speeds through wavelength-division multiplexing. Kavipriya *et al.*[1] validated LiFi's medical potential via real-time hospital trials that met EMI requirements. Mosaif and Rakrak[3] showed LiFi's suitability for secure, high-resolution telemedicine imaging and data transfer. These experiments prove to be feasible but at the same time point to practical limitations in the areas of coverage, alignment and noise on the environment.

DML Advancements and Performance Optimization: Recent DML research demonstrates gigabit-per-second transmission speeds through advanced modulation innovations (Zhu *et al.*[4]). Nonlinear distortion remains a key challenge; pre-distortion and compensation techniques can mitigate it (Dimitrov and Haas[12]). Channel and device parameters also matter: Al-Khaffaf and Hujijo[13] reported that narrowing beam divergence improved SNR by ~15 dB at 20 m, while Li and Sang[14] showed receiver-aperture sizing trades off BER and thermal noise, requiring careful detection/noise-suppression design. These are works that focus on the sensitivity of parameters but typically take idealized or controlled conditions. Hybrid Systems and Adaptive Techniques: Abejide *et al.*[15] combine LiFi (for secure patient-data transfer) with Wi-Fi (for mobile services on handhelds). Zaki Rashed *et al.*[16] use transmission coding to improve BER under fluctuating conditions. Fernandes *et al.*[17] recommend visible/IR LiFi operation to reduce alignment sensitivity in hospitals. These methods using standalone optical links can emphasize the point that complementary methods might be needed to overcome blockage and mobility. Security and Environmental Robustness: The physical confinement of LiFi hampers eavesdropping; security can be further enhanced with physical-layer encryption (Rahaim and Little[18]). EMI-management protocols for critical care (Lapinsky and Easty[2]) provide operational guidance complementary to LiFi deployment. However, EMI pickup at the receiver side and the shot noise caused by ambient light are still pertinent concerns in a real system. Remaining Challenges: Despite these advances, optimizing DML-LiFi specifically for hospital rooms/wards is underexplored. For high data rates, the relationship between modulation index and laser linearity requires systematic study.[19] Field evidence for hybrid tracking/alignment in dynamic clinical spaces remains limited.[20] Other inside wireless optical solutions have also been suggested, such as LED-based LiFi, MIMO LiFi, and VCSEL array transmitters, to improve coverage and robustness, with bandwidth, spatial confinement, and alignment sensitivity trade-offs.

This paper addresses that gap by developing a hospital-specific DML-LiFi model (OptiSystem + MATLAB) and quantifying how joint tuning of transmit power (-5 to 5 dBm), modulation index (0.4–1.0), beam divergence (1–4 mrad), and receiver aperture (2–8 mm) impacts BER, SNR, and Q-factor. The findings offer theoretical instructions on the parameter sensitivity and upper-bound link performance in idealized indoor circumstances. In order to place the proposed LiFi system in the larger research context, a comparison between the main performance indicators and design features thereof with the existing studies should be drawn. Most of the literature has concentrated on optimizing individual parameters (i.e. BER, SNR, or modulation format), though few have also analyzed the same parameters simultaneously in the context of hospital conditions where energy saving, EMI safety and data integrity are essential. A comparative summary of LiFi system investigations that were chosen is presented in Table 1 and indicates variations in the wavelength selection, modulation methods, and application. This analogy encourages the current study as one of the theoretical investigations about the optimization of DML-LiFi parameters, not as an ultimate means to overcome the the challenges of indoor hospital communication.

Table 1. Comparison of LiFi system studies and the proposed DML design.

Study/ Reference	Environment Focus	Device Type	Parameters Investigated	Reported Metrics	Key Limitations
Kavipriya *et al.* (2022)[1]	Hospital (general trials)	LED-based LiFi	Launch power only	BER	Did not address EMI-sensitive zones or multi-parameter tuning
Mosaif & Rakrak (2019)[3]	Hospital surveillance	LED-based LiFi	Range & data rate	BER, imaging quality	Limited to surveillance, no physical-layer modeling
Zhu *et al.* (2017)[4]	Laboratory	DML	Modulation techniques	Data rate, bandwidth	No hospital-specific constraints or BER/SNR/Q study
Al-Khaffaf & Hujijo (2018)[13]	Indoor (generic)	Optical wireless	Beam divergence	SNR	Studied divergence alone, not integrated with other parameters
Li & Sang (2017)[14]	Outdoor	Laser link	Receiver aperture	BER, SNR	Focused on atmospheric noise, not indoor EMI-safe environments
Fernandes *et al.* (2023)[17]	Hospital	Visible/IR LiFi	Alignment robustness	BER	Did not provide quantitative tuning rules
Rahaim & Little (2017)[18]	Generic indoor	Optical wireless	Security	Interference metrics	Did not model BER/SNR/Q or hospital constraints
This Study (Ajay Sharma *et al.*, 2025)	**Hospital rooms/wards (EMI-sensitive)**	**Direct-Modulated Laser (DML)**	**Launch power, modulation index, beam divergence, receiver aperture (joint)**	**BER, SNR, Q-factor (simulated and modeled)**	

Directly modulated lasers are also higher bandwidth compared to LED-based LiFi systems which generally have broad spatial coverage capabilities but with lower modulation bandwidth. VCSEL array methods enhance the strength of alignment but add another degree of complexity to the system. The suggested framework does not purport itself to be superior over all deployment scenarios but offers an organized hospital-based parameter sensitivity line with a controlled indoor assumption.

Novelty and innovation

This paper makes several original contributions that distinguish it from previous studies on optical wireless communication and LiFi systems:

Hospital-Specific Optimization Framework

The current LiFi literature deals with generic indoor environments, or local-scale experiments, without considering the high electromagnetic interference (EMI) limits, privacy concerns, and dependability needs of hospital settings. A hospital-centred framework of DML-LiFi optimization proposed in this paper pays specific attention to EMI-sensitive conditions and privacy limitations of the physical layer. The framework will be used to examine theoretically whether links can work under ideal indoor conditions, but not purport that it can work in real hospital networks under interference-free or deployment-ready conditions.

Multi-Parameter Joint Optimization

Previous studies have examined modulation index, beam divergence, or launch power individually in isolation. Conversely, this paper simultaneously optimizes four parameters of the device-level launch power, modulation index, beam divergence, and receiver aperture, and measures their interactive effect on BER, SNR, and Q-factor, as a multi-dimensional design guide to the system engineer. This combined analysis offers multi-dimensional design knowledge of the sensitivities and trade-offs of the parameters of the system in the detector-noise-limited scenario and does not resolve in every practical system impairment.

The hardware design of transmitters and receivers is not new in principle. The novelty of the work is in the collaborative four-parameter sensitivity model that is optimized to the conditions of a hospital-scale indoor system, where various device-level parameters are optimally adjusted and mapped to BER, SNR, and Q-factor under the EMI-sensitive conditions.

Integration of OptiSystem and MATLAB Simulation

The current study introduces a reproducible simulation workflow, which combines OptiSystem to model an optical system and MATLAB to analyze it, allowing them to perform parametric sweeps and sensitivity mapping over clinically-relevant distances. In this case, internal consistency between the analytical trends and simulation outputs has been used as validation, as opposed to benchmarking experimental results or field validation. This integrated workflow supports systematic exploration of design parameters under controlled and idealized assumptions.

Quantitative Design Guidelines for Clinical Deployment

Unlike other previous studies, which mainly present individual performance measures, the current paper generates quantitative design recommendations such as $\geq +5$ dBm in distances of more than 15 m, modulation index 0.8–1.0, beam divergence 1–2 mrad, and receiver apertures 4–6 mm. Such tangible principles enable hospital information technology strategists to create stable and EMI-compliant LiFi connections to vital telemetry and medical imaging information.

Positioning DML-LiFi as a Superior Alternative

This paper establishes DML-based LiFi as a high-bandwidth optical wireless solution, which has a high physical-layer confinement and symbol-rate capability when the line-of-sight is well-aligned. Instead of purportedly addressing reliability or safety issues inherent in hospital wireless systems, the work emphasizes the theoretical benefits of DML-LiFi and outlines its drawbacks compared to RF, LED-based LiFi, MIMO LiFi and VCSEL-array solutions, especially on coverage, alignment, mobility and eye-safety issues.

The contributions offer an upper-bound performance baseline and parameter insight in a structured form that can be used to guide experimental validation in the future, hybrid architecture, and systems design with a reliability concern in clinical communication networks.

Methodology

The research method follows a systematic process for designing, simulating, and analyzing a DML-based LiFi system for hospital spaces. The research methodology combines virtual optical system simulation and mathematical modeling with parametric analysis to measure the essential BER, SNR, and Q-factor performance metrics. It is designed to evaluate theoretical link-budget feasibility and parameter sensitivity in controlled and idealized indoor environments, rather than to assess deployment-level reliability in operational hospital environments.

A LiFi system uses a direct-modulated laser (DML) operating at 500 nm to transmit data at 1 Gb/s using on–off keying (OOK) (Figure 1 and Figure 2).[21–23] An electrical/receiver front-end bandwidth of ~5 GHz is used to preserve pulse shape at 1 Gb/s under idealized receiver bandwidth assumptions.

In order to model an idealized high-gain receiver front end, a 10 dB optical amplification stage with a proposed noise figure of 4 dB is added. This noise figure is a simplified detector-noise-limited assumption that fails to describe frequency-dependent noise behaviour of transimpedance amplifiers (TIA). The simulation uses an optimized line-of-sight (LOS) channel model, including free-space path loss, beam-divergence-driven geometric coupling, and additive receiver noise. The LOS model reflects perfectly aligned indoor link and lacks active misalignment, obstruction and

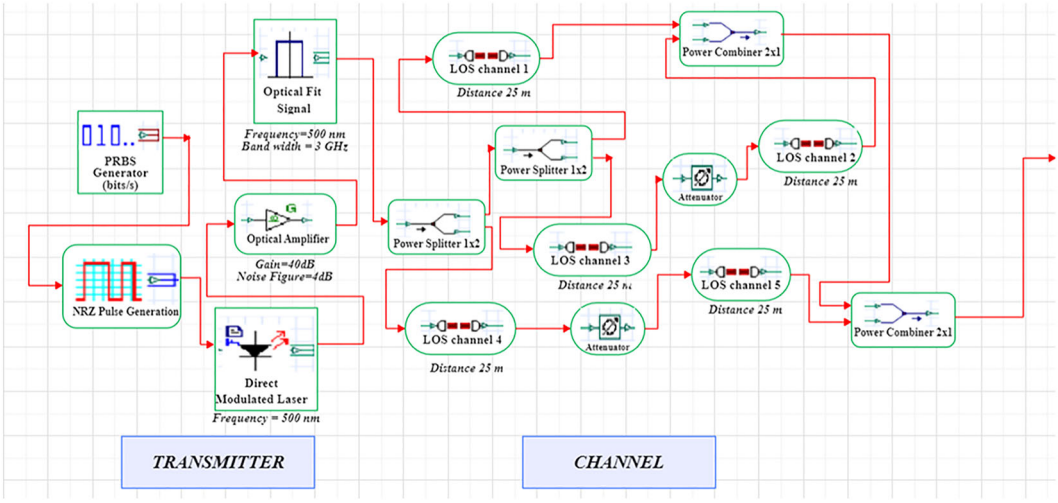


Figure 1. **LiFi Transmitter and Channel Model with DM Laser at data rate of 1 GHz.**

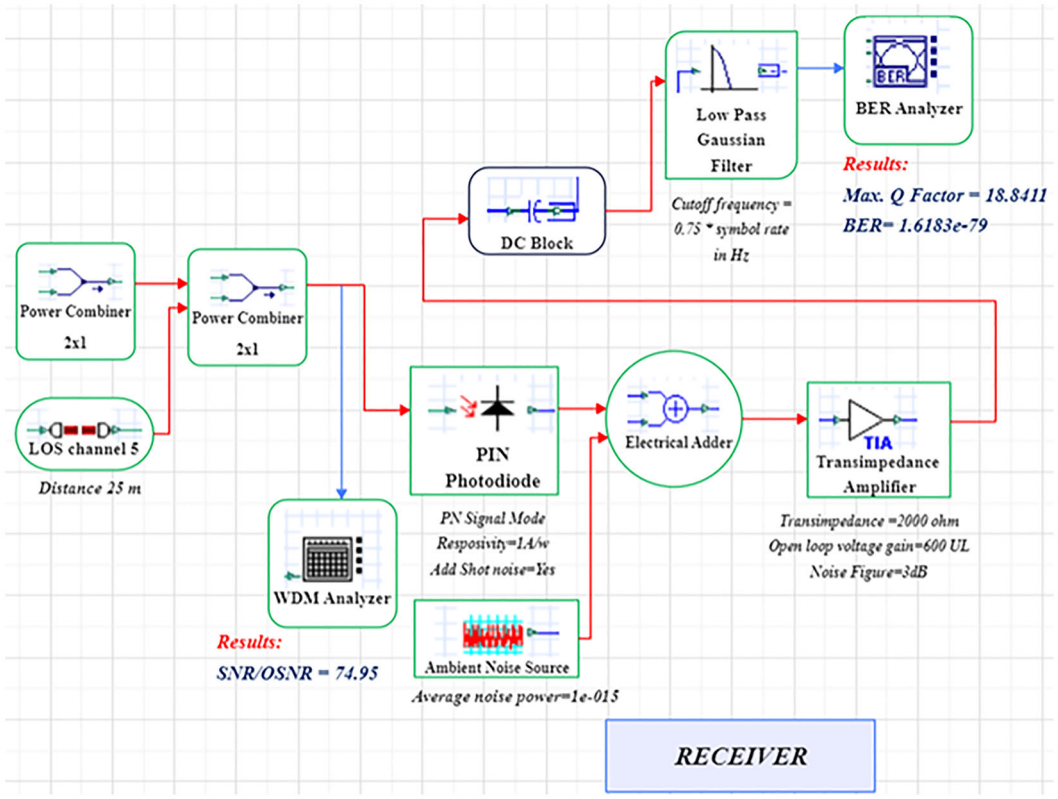


Figure 2. **LiFi Receiver Model with DM Laser at data rate of 1 GHz.**

fading as a result of movement. The signal conversion from optical to electrical takes place through a PIN photodiode (responsivity = 0.8 A/W) at the receiver, while the receiver aperture size (2–8 mm) is swept to determine light-collection efficiency and its noise trade-offs. The simulation uses a 25 m reference link representative of inter-bed/room distances in hospitals.

The system is modelled in OptiSystem (version 22.0) using a structured workflow, and data post-processing is carried out in MATLAB R2024b (GNU Octave open-source alternative). OptiSystem is a proprietary optical simulator, and

equivalent results can be reproduced using the mathematical framework described below. In the transmitter module, the DML is configured with input power levels ranging from -5 dBm to +5 dBm in 2 dB increments and modulation indices spanning 0.4–1.0. Beam-spread effects are captured by varying beam divergence between 1–4 mrad. The PIN photodiode uses electrical filters to lower inter-symbol interference, and a receiver front-end noise figure of 4 dB. These parameter ranges are selected to study sensitivity trends rather than represent fully deployed configurations.

The PIN photodiode uses electrical filters to reduce inter-symbol interference, although residual ISI effects at very low BER are not explicitly modeled. For each parameter combination, BER, SNR, and Q-factor are computed at the decision point; Q is estimated as (μ1–μ0)/(σ1+σ0), and BER follows the standard $\frac{1}{2}erfc\left(Q/\sqrt{2}\right)$ approximation, while SNR is derived from signal and noise powers at the sampler. The BER formulation based on erfc assumes additive white Gaussian noise and becomes inaccurate for very high Q values. Based on this, values of BER obtained in very low error rates must be considered as analytic lower limits as opposed to forecasts about operational reliability. This workflow uses sensitivity maps to establish the relationship between device-level parameters (power, modulation index, divergence and aperture) and analytical reliability criteria (e.g., $BER < 10^{-9}$, $Q > 6$) in idealized optical conditions, with noise at the detector.

All component parameters and analysis scripts are documented for reproducibility. Equivalent analysis can be replicated using GNU Octave without requiring proprietary software. Reproducibility in this context means numerical stability of the analytical and simulation model as opposed to experimental or field validation.

The term optimization in this work is used to refer to a systematic parametric search and sensitivity study within predefined parameters of launch power, modulation index, beam divergence and receiver aperture. There was no formal nonlinear or multi-objective optimization algorithm (genetic algorithms or particle swarm optimization) used. The configuration reported is the optimum parameter combination in the parameter space covered which meets analytical reliability criteria in the idealized detector-noise-limited scenario. It does not assert a mathematically certain world optimum.

Mathematical modeling

The optical wireless communication theoretical approach to the LiFi channel and receiver performance uses standard analytical models commonly adopted in optical wireless communication literature. These models are used to give a tractable first-order understanding of link-budget feasibility and parameter sensitivity under idealised indoor conditions, as opposed to a complete representation of all physical impairments of realistic LiFi systems.

To calculate the received optical power P_r at the detector, one uses the line-of-sight (LOS) Lambertian model:

$$P_r = P_t \frac{(m+1)A_r}{2\pi d^2} cos^{-m}(\Phi) T_s(\psi) g(\psi) cos(\psi) \tag{1}$$

where P_t is the transmitted optical power, A_r is the receiver aperture area, d is the link distance, and m is the Lambertian emission order defined by

$$m = -\frac{ln(2)}{ln(cos(\Phi_{1/2}))} \tag{2}$$

Lambertian LOS model is a model which is also well-aligned with the indoor optical link and does not take into consideration the dynamic misalignment, shadowing, and the effects of mobility.

The electrical signal-to-noise ratio (SNR) is expressed as

$$SNR = \frac{(RP_r)^2}{\sigma_{shot}^2 + \sigma_{thermal}^2} \tag{3}$$

where R is the photodiode responsivity, and σ_{shot}^2 and $\sigma_{thermal}^2$ denote shot and thermal noise variances, respectively. The noise terms have been modeled in this work as additive Gaussian noise, and they are used to model noise limited to the detector; ambient-light-noise of shots, pickup electromagnetic interference, and frequency-dependent receiver noise are not explicitly modeled. To predict the performance of systems through the analytical relationships of distance, received power and signal quality parameters, the following models are used. Each model relates a key performance measure (BER, Q-factor or SNR) with transmission distance or signal quality to provide support to both theoretical and simulation outcomes.

BER Vs. Distance

The bit error rate (BER) is a measure of the reliability of the link, and it increases with the distance when the received optical power decreases because of the free-space attenuation. BER and distance are represented by a power-law relationship:

$$BER(d) = BER_{ref} \times \left(\frac{d}{d_{ref}}\right)^{n} \tag{4}$$

Such relationships are meant to be trend models to assist in interpretation and are not designs of real physical descriptions of indoor LiFi channels, where BER_{ref} at d_{ref} = 25 m, d is the transmission distance, and n is the distance exponent. This term is applied only as an empirical trend model to demonstrate the distance sensitivity on the assumption of detector-noise-limited. It is not aimed at substituting strict error-function-based BER formulations in the case of very low error probabilities.[14,24,25]

Q-Factor Vs. Distance

Q-factor is the quality of the signal at the receiver, which is negatively proportional to the distance due to cumulative attenuation and noise. Q-factor vs distance is a model of power law form, which is defined as:

$$Q(d) = Q_{ref} \times \left(\frac{d_{ref}}{d}\right)^{m} \tag{5}$$

The parameter m depends on the modulation index as well as beam divergence when Q_{ref} equals 18.84 (reference Q-factor at d_{ref} = 25 m). Relevant research from DML optimization studies shows that m takes the value 2 for this quadratic relation.[4,5]

SNR Vs. Distance

Signal-to-noise ratio (SNR) is the ratio between the power of the received signal and the total power of noise. It obeys the inverse-square law of the free-space optical channels, where SNR is rapidly decreasing with distance. The mathematical expression is in the form of:

$$SNR(d) = SNR_{ref} \times \left(\frac{d_{ref}}{d}\right)^{k} \tag{6}$$

Where SNR_{ref} = 74.94 dB (reference SNR at d_{ref} = 25 m), and k = 2 (distance attenuation factor). The inverse-square law emerges from free-space optical propagation models according to references.[14,24,25] This relation encodes the dependence of the first order distance and fails to consider frequency selective noise or bandwidth limited receiver effects.

SNR Vs. BER

The correlation between SNR and BER establishes the correlation between signal quality and error performance in LiFi communication. In the case of on-off keying (OOK) modulation, the analytical expression of the relationship between these parameters is:

$$\text{Assuming } Q = \sqrt{SNR}$$

$$BER = \frac{1}{2} erfc\left(\sqrt{\frac{SNR}{2}}\right) \tag{7}$$

The theoretical framework exhibits wide use in optical communication systems while researchers both theoretically and analytically validate optical signal quality metrics.[12,26,27]

Results

Distance Vs. BER

The result in Figure 3 indicates that BER increases with distance due to path loss and reduced received optical power, but higher launch power reduces BER. At short range (1–10 m), all tested power settings achieve similarly low BER, yet beyond ~15 m, the low-power cases (–5 dBm and 0 dBm) no longer sustain the target error floor. Launch power is found to be a prevailing parameter in analytical BER trends when the detector-noise-limited hypotheses are taken (e.g. $BER < 10^{-9}$ as a reference criterion). To achieve reliable patient data transmission at longer distances, hospital LiFi systems should operate at ≥ +5 dBm. These findings demonstrate theoretical link-budget viability as opposed to assured working reliability. In practice, real-world applications benefit from adaptive power control (APC) that increases launch power as range and coupling losses grow, while backing off at short range to limit energy use and eye-safety exposure.

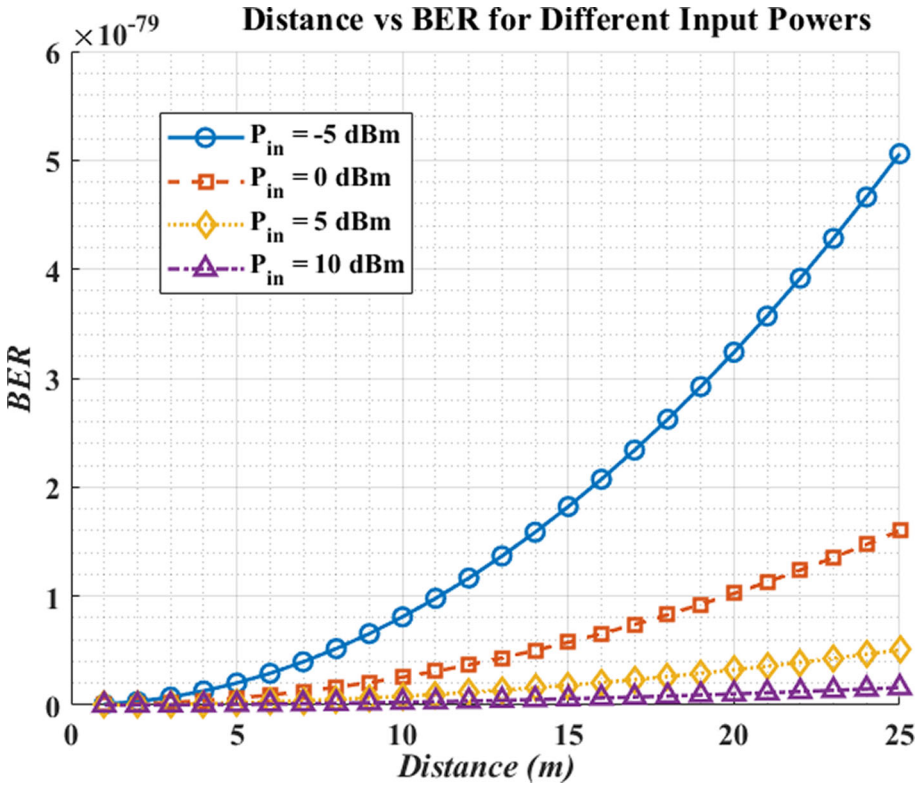


Figure 3. Distance vs BER for different input powers.

Distance Vs. Q-Factor

Figure 4 plots Q-factor versus distance for multiple modulation-index settings, highlighting how signal quality evolves with range. As expected, Q decreases as distance increases due to path loss and accumulated noise/jitter, while higher modulation indices (0.8–1.0) consistently yield larger Q across all distances; reducing the index to 0.4 lowers Q.

At the 25 m baseline, $Q \approx 18.84$, demonstrating a substantial margin over the $Q = 6$ error-free threshold. This margin corresponds to best-case performance based on the assumption of Gaussian noise instead of reliability at deployment levels. The figure's y-axis scaling emphasizes the relative Q variations with distance, making the impact of modulation index immediately visible. Practically, keeping the modulation index ≥ 0.8 preserves high signal quality over the tested ranges, whereas low-index operation (~0.4) risks approaching the Q = 6 boundary sooner.

Implication for hospital links: selecting a sufficiently high modulation index—while remaining within the DML's linear region—provides an effective lever to maintain distance-robust performance. This supports the overall optimization strategy in terms of analytical reliability benchmarks ($BER < 10^{-9}$, $Q > 6$) under idealized conditions.

Distance Vs. SNR

Figure 5 shows SNR versus distance for beam divergences of 1, 2, 3, and 4 mrad. SNR decreases approximately with the inverse square of distance due to geometric spreading and path loss, and smaller divergences maintain higher SNR by concentrating optical power on the receiver aperture. The MATLAB analysis computes SNR(d) for each divergence, confirming that larger divergences broaden the spot and accelerate SNR degradation as range increases.

At the 25 m baseline, SNR ≈ 74.94 dB. Beyond ~25 m, high-divergence beams (3–4 mrad) exhibit a faster SNR decline than narrow beams (1–2 mrad); conversely, limiting divergence (≈1–2 mrad) preserves stronger SNR over longer distances. Design implication for hospital links: use narrower beam divergence to enhance SNR at room-to-ward scales, subject to alignment tolerance, mobility, and eye-safety considerations that are not explicitly modeled here.

SNR Vs. BER

Figure 6 shows the relationship between SNR and BER for the proposed DML-LiFi link. As expected, BER decreases rapidly (quasi-exponentially) as SNR increases, consistent with the OOK/AWGN relation $BER \approx \frac{1}{2} erfc\left(Q/\sqrt{2}\right)$ with Q increasing with SNR.

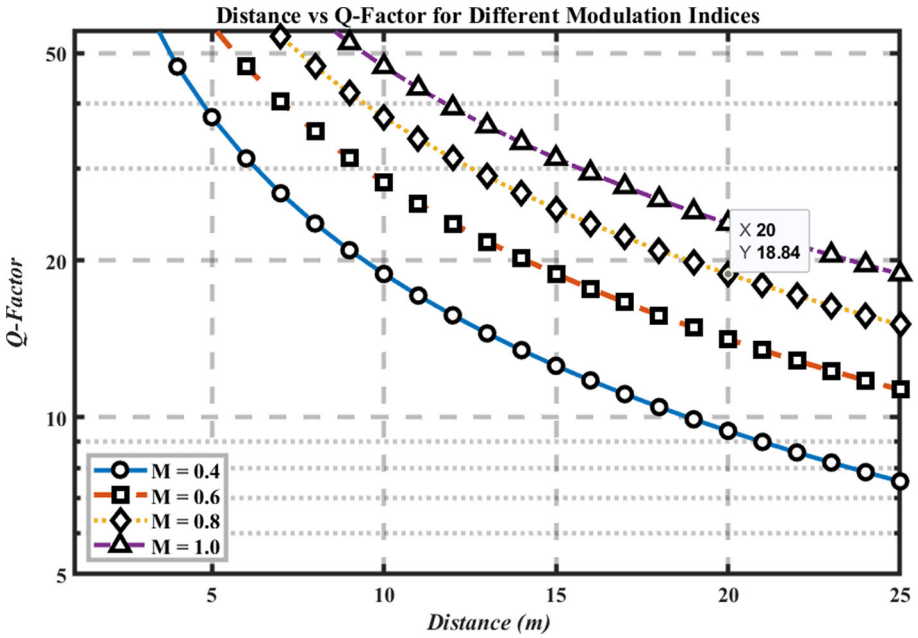


Figure 4. **Distance vs Q-factor for different modulation indices.**

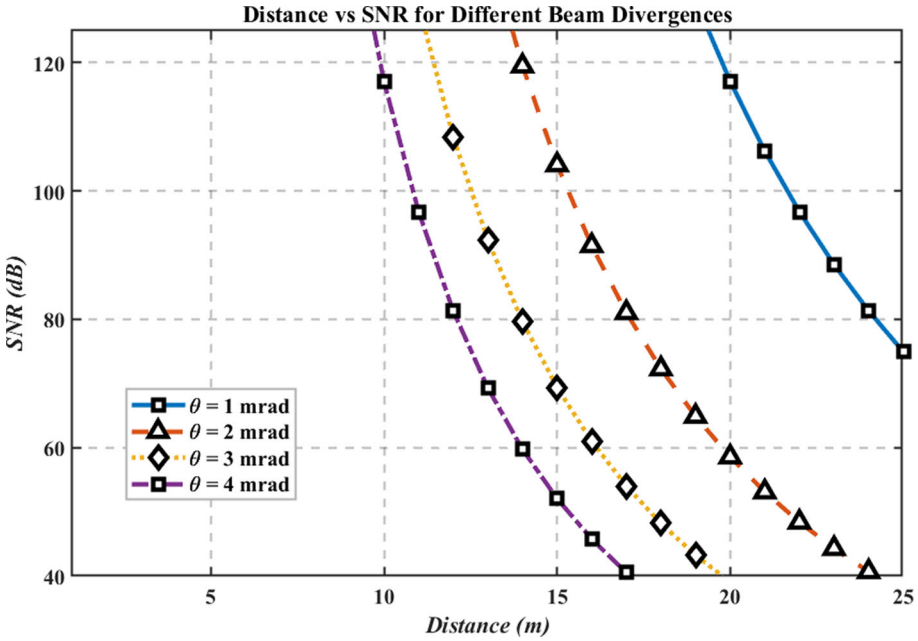


Figure 5. **Distance vs SNR for different beam divergences.**

Aperture size affects the operating SNR by trading optical collection (signal) against added ambient/shot noise: increasing the aperture generally shifts the link to a higher SNR region up to a practical optimum; at the same SNR, however, BER is essentially identical regardless of aperture—the difference is that aperture changes where on the SNR curve the system operates.

Thus, there is a design trade-off: apertures that are too small under-collect signal, while excessively large apertures admit more background light and jitter; an intermediate aperture (e.g., ~4–6 mm in our sweeps) offers a good balance.

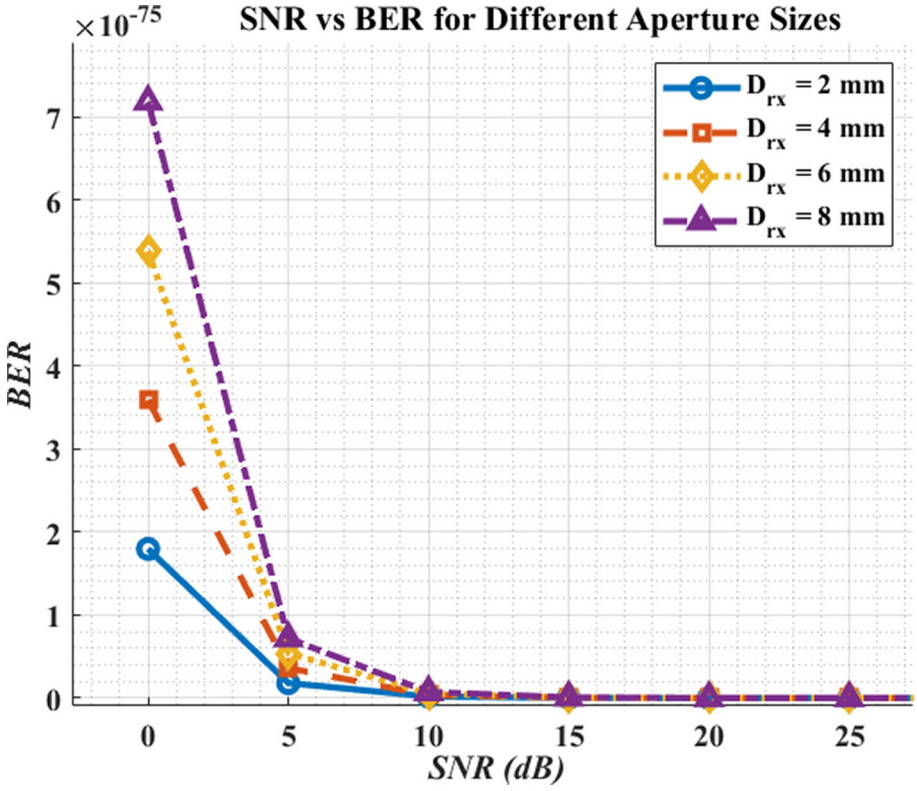


Figure 6. SNR vs BER for different aperture sizes.

Figure 5 further confirms the expected monotonic relationship: BER falls near-exponentially as SNR increases. Within the tested aperture sweep (2–8 mm), BER improved progressively with larger apertures because more optical power reached the detector, moving the operating point to a higher SNR region. These curves agree with the analytical OOK/AWGN model and our MATLAB/OptiSystem predictions, validating that the system behaves as theory anticipates. In practice, fixed receivers can leverage larger apertures (≈6–8 mm) for maximum margin, whereas compact/mobile clinical devices benefit from mid-range apertures (≈4–6 mm) to limit background-light capture. Overall, appropriate tuning of launch power, beam divergence, modulation index, and aperture enables DML-LiFi to meet hospital-grade targets ($BER < 10^{-9}$; $Q > 6$) with a comfortable SNR margin.

Discussion

The four distinct graphs in the simulation results demonstrate how various performance factors affect the operation of Direct-Modulated Laser (DML)-based LiFi systems within hospital environments. The achieved findings demonstrate the operational trade-offs among signal quality, power consumption, noise, and an optimized line-of sight and detector-noise-limited conditions, while accounting for hospital environmental limitations.

Distance Vs. BER

The initial graph illustrates that Bit Error Rate (BER) increases because signal attenuation happens when the communication distance expands. The system offers reliable communication during proximity because all power levels generate comparable low BER measurements between 1 to 10 meters. The BER rises dramatically beyond 15-meter distances for those power input levels below -5 dBm or 0 dBm, which stresses the need to use proper power levels for long-distance communication. In the simulated and idealized conditions, the launch powers of about +5 dBm are necessary to sustain analytical levels of BER at the distance of over 15 meters. The research findings indicate adaptive power control represents a practical capability to optimize power usage through real-time distance monitoring and environmental factor assessment, thus increasing operating efficiency with preserved communications integrity, even though here not expressly modeled are the aspects of implementation, e.g., eye safety, mobility and the changes in ambient light.

Distance vs Q-Factor

Signal quality becomes inferior as the transmission distance extends because of increasing attenuation rates based on the Q-factor measurement. The Q-factors reach their maximum levels when using M = 0.8 or M = 1.0 modulation indices, while observing higher Q-factors primarily at extended distances. The evaluation shows that the modulation index dictates how signal quality is maintained while transmitting over longer distances. The performance optimization depends greatly on the selection of an appropriate modulation index because systems using higher modulation indices consistently deliver superior signal quality irrespective of tested distances. Precise laser linearity becomes necessary when operating with higher modulation indices to achieve better signal quality, since this process demands precise laser linearityand this need can be a limitation in real-world operation beyond an ideal laboratory environment or simulations.

Distance vs SNR

The third graph demonstrates that the Signal-to-Noise Ratio (SNR) exhibits quadratic reduction with distance due to the inverse square law behavior. A reduction in beam divergence ranging from 1 to 2 mrad yields superior SNR readings compared to the 3–4 mrad values since narrower beams concentrate their energy more precisely, thus maintaining better signal fidelity and less noise interference. The data shown in the graph validates the need to select narrow beam divergences when hospitals want to achieve dependable communication systems with high signal-to-noise ratios. Accurate placement and alignment of narrow beams remain essential, yet these designs are easily affected by disruptions that occur from equipment motions or alignment problems. Hybrid tracking systems used for alignment maintenance would improve the system's operational effectiveness by addressing this issue though these mechanisms cannot be the subject of the current theoretical research.

SNR vs BER

The final plot establishes that increasing SNR results in a significant BER reduction. An established principle shows that higher signal quality (SNR) delivers better communication reliability. Receiver aperture size strongly affects BER at any predetermined SNR level according to the graphical analysis. The combination of improved SNR through larger apertures comes at the expense of increased noise, which diminishes BER performance. The essential trade-off must be considered during LiFi system design for hospitals because it directly affects the reliability of data transmission through BER performance. Achieving maximum efficiency in light reception requires optimization of receiver aperture diameter. Hospital LiFi systems should use apertures measuring between 4–6 millimeters to obtain maximum effectiveness between BER reduction and noise management,with the assumptions of controlled indoor lighting and detector-noise-limited. Design choices need special attention because they determine how well errors can be minimized and how the communication system stability can be enhanced.

The evaluation of four performance graphs confirms that design parameters, including input power along with modulation index and beam divergence, and aperture size, define the optimum operation of DML-based LiFi systems used within hospital spaces. The system's key metrics of BER, Q-factor, and SNR depend on the mutual effects between all parameters. The research shows hospitals must achieve equilibrium between system component adjustments to satisfy hospital requirements, which involve maintaining strong reliability and electromagnetic compatibility, and patient data security compliance, at an analytical level of performance. Table 1 summarizes the comparative context of previous LiFi studies and highlights how this research advances beyond them through multi-parameter optimization and a theoretical design analysis of EMI sensitivity based on a hospital. Three technology enhancements, including adaptive power control methods alongside hybrid beam alignment systems and optimized aperture dimensions, will enhance LiFi system reliability in dynamic hospital installations,to be validated by experiments in the future and by integrating hybrid systems.

The findings are supposed to be considered as analytical upper-bound trends that assume a detector-noise-limited and well-aligned line-of-sight assumption.

System Resilience and Fail-Safe Communication Architecture

Hybrid LiFi–RF Communication for Fail-Safe Operation

Although Direct-Modulated Laser (DML)-based LiFi offers high throughput, electromagnetic interference (EMI) immunity and physical-layer security in typical hospital operations, optical wireless connections are very vulnerable to misalignment, obstruction, and power outage in extreme conditions like potentially damaging earthquakes or structural damage. Pure use of an optical connection can thus interfere with communication continuity during an emergency situation.

To alleviate this risk, a hybrid LiFi-RF architecture will be introduced in which LiFi will be used as the main high-capacity and EMI-safe communication layer, and a low-speed, ruggedized RF backup will ensure that the connectivity remains fail-safe in case of interference in the optical path. The RF layer is not designed to match the performance of LiFi, but it will ensure the bare minimum of connections to sustain life-critical data and control signaling. LiFi and RF Hybrid operation has demonstrated the ability to greatly increase the availability and strength of the network by dynamically switching to handover and load balancing, especially in the case of blockage or mobile conditions, which is perfectly appropriate in mission-critical hospital applications.[28]

On-Premise Network Independence through Edge Computing

There is a need to keep hospitals in the event of an external telecommunication infrastructure failure. In this regard, the proposed DML-LiFi system is expected to work in conjunction with on-premises edge computing capabilities and provide the hospital with the opportunity to act as an autonomous information island in the event of external network disruptions.

In this design, LiFi connections between interconnected clinical devices and interconnected local servers, the data processing, storage, and clinical decision support are processed on the local level. This provides a guarantee of continued connectivity to the telemetry of patients, medical imaging, and electronic health records with a lower latency and without reliance on cloud connectivity. Earlier research has established that these distributed edge-based architectures enhance robustness, fault tolerance, and data availability in critical infrastructure systems to a large extent.[29]

Optical Wireless Backhaul for Disaster Recovery

Inter-building connectivity can also be achieved with the help of optical wireless technologies in case fiber connections are broken. The free-space optical (FSO) communication has received considerable research attention as a license-free, high-speed backhaul system that can be deployed quickly to supply the high-capacity connections among important infrastructure devices in the wake of disaster-related scenarios.[30]

The suggested DML-LiFi system is a constituent in a resilient optical wireless ecosystem, with LiFi and FSO enhancement of indoor clinical communication and emergency inter-building backhaul, respectively, in the event of terrestrial infrastructure degradation.

Conclusion

This work set out to optimize a hospital-grade DML-LiFi link and quantify how launch power, modulation index, beam divergence, and receiver aperture jointly shape BER, SNR, and Q-factor. In general, with proper tuning of the launch power, beam divergence, modulation index, and aperture, DML-LiFi is capable of meeting the criterion of analytical reliability ($BER < 10^{-9}$, $Q > 6$) under idealized conditions, $SNR \approx 74.94$ dB, and $Q \approx 18.84$, at optimized line-of-sight and detector-noise-limited conditions for clinical traffic.

Superiority over existing options: Compared with RF-only links, the proposed DML-LiFi design is intrinsically EMI-safe, confines propagation to rooms for stronger physical-layer privacy, and exploits the license-free optical spectrum for higher usable capacity. Relative to LED-LiFi, direct-modulated lasers provide GHz-class bandwidth with better,modulation capability, albeit with narrower coverage and increased alignment sensitivity, enabling high-rate links under well-aligned line-of-sight conditions in dense clinical spaces. This work offers a hospital-oriented optimization framework, which also looks at four paramount optical parameters and correlates them to the main performance measures (BER, SNR, Q-factor) as opposed to the previous LiFi literature that generally studied these parameters separately. Actionable design rules (problems addressed): To overcome distance-induced loss and maintain hospital-grade reliability ($BER < 10^{-9}$; $Q > 6$): use $\geq +5$ dBm beyond ~15 m with adaptive power control; keep the modulation index ≈ 0.8–1.0 while remaining in the DML's linear region; prefer narrow divergence ($\approx$1–2 mrad) with proper mounting/lightweight tracking to tolerate motion; select mid-range apertures (~4–6 mm) for mobile devices (balancing collection vs. background light), with larger (~6–8 mm) feasible for fixed receivers. These guidelines are theoretical operating ranges calculated under simplistic assumptions as opposed to prescriptive deployment considerations.

Objective, contribution, and significance: The objective was a hospital-specific optimization of DML-LiFi. The contribution is a reproducible simulation-based OptiSystem+MATLAB framework that yields four-parameter (launch power, modulation index, beam divergence, and receiver aperture) deployment guidelines tied to BER/SNR/Q targets. Although DML-LiFi has proven to be a better choice in terms of EMI-sensitive and high-throughput clinical

communication, at a theoretical performance level, practical implementation in hospital setups would be best realized when deployed as part of a robust hybrid architecture with resilience and fail-safe back-up connectivity, as discussed in the previous section. The significance lies not only in the achieved performance but in offering the first reproducible and parameterized blueprint for EMI-safe, high-throughput indoor LiFi systems that can inform future experimental validation and system-level reliability studies in hospital environments.

Future scope

The study also paves the way for future work in several critical areas, including further testing in actual hospital environments with surgical lights and moving equipment, which will form a key basis for upcoming research activities. A hybrid communication network that links LiFi systems to Wi-Fi technology using machine learning methods enables smooth network transfers between multiple pathways for healthcare capabilities.

Further research will also expand the current two-dimensional sensitivity analysis to three-dimensional response-surface models and formal multi-objective systems, such as Pareto-front exploration to help a systematic analysis of trade-offs between BER, SNR, and Q-factor.

Ethics and consent

Ethical approval and consent were not required for this study as it did not involve human participants, animals, or sensitive personal data.

Data availability

No external datasets were generated or analyzed in this study. All data used in this paper were generated internally through OptiSystem 22.0 and MATLAB R2024b simulations. OptiSystem is a third-party, proprietary optical system simulator used for link modelling. Where possible, the mathematical procedures are described so that equivalent simulations can be reproduced. MATLAB R2024b was used for post-processing and plotting; an open-source alternative, GNU Octave, can be used to run the analysis scripts. Due to licensing restrictions associated with the proprietary OptiSystem software and institutional policies governing third-party simulation tools, the complete simulation project files and raw output datasets cannot be publicly deposited.

No ethical or institutional review board (IRB) approval was required for this study, and no restrictions on data sharing were imposed by an IRB or equivalent body, as the work did not involve human participants, animals, or sensitive personal data.

However, the simulation parameter sets, MATLAB analysis scripts, and supporting numerical results can be made available for academic and non-commercial research purposes upon reasonable request, subject to compliance with the relevant software licensing conditions.

Access requests can be directed to Lalit Garg (lalit.garg@um.edu.mt) or Ajay Sharma (ajay.sharma@um.edu.mt).

Acknowledgements

The authors acknowledge the support of the Department of Computer Information Systems, Faculty of Information and Communication Technology at the University of Malta, for facilitating the simulation work.

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Open Peer Review

Current Peer Review Status: ? ✓ ✓ ✓

Version 3

Reviewer Report 30 April 2026

https://doi.org/10.21956/openreseurope.25447.r72770

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✓ **Urvashi Chaudhary**
COPELABS, Universidade Lusófona, Lisboa, Portugal

This report provides an evaluation of the research article titled "**Optimizing direct-modulated laser LiFi systems for hospital environments through simulation-driven analysis of BER, SNR, and Q-factor performance**".

Article Summary

The study proposes a four-parameter optimization framework for Direct-Modulated Laser (DML)-based LiFi systems specifically tailored for hospital settings. Using OptiSystem and MATLAB, the authors simulated the joint effects of launch power, modulation index, beam divergence, and receiver aperture on performance metrics like Bit Error Rate (BER), Signal-to-Noise Ratio (SNR), and Q-factor. The research identifies theoretical "upper-bound" performance trends, suggesting that DML-LiFi can meet high reliability standards (BER < 10^{-9}) under idealized, well-aligned line-of-sight conditions in EMI-sensitive environments.

Presented accurately and cites current literature?
Partly
The literature review was enhanced in Version 3 to include hybrid LiFi/RF systems and FSO-based recovery. However, reviewers noted initial gaps in comparing it to LED-based or VCSEL systems.

Study design appropriate and academic merit?
Yes
The study design is considered appropriate for a theoretical/simulation-based analysis. It offers merit by exploring multi-parameter joint effects rather than isolated variables.

Sufficient methodology for replication?
Partly
While the mathematical procedures and simulation workflow (OptiSystem/MATLAB) are described, proprietary licensing prevents the sharing of raw project files.

Statistical analysis appropriate?
Yes
The analysis follows established OOK/AWGN models, and the simulation results are internally consistent with analytical trends.

Source data available for reproducibility?
Partly
No external datasets were used; data was generated internally. Full project files are not public due to institutional policies and proprietary software restrictions.

Conclusions supported by results?
Partly
Earlier versions overclaimed reliability (e.g., BER of 10^{-79}). While Version 3 moderates these to "theoretical feasibility," they remain based on "best-case" scenarios.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Wireless Communication

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Author Response 30 Apr 2026

Ajay Sharma

Dear Reviewer, Thank you very much for your valuable feedback and for approving our manuscript. We appreciate your constructive comments and the time you have taken to evaluate our work. Kind regards,

Competing Interests: No competing interests were disclosed.

Reviewer Report 28 April 2026

https://doi.org/10.21956/openreseurope.25447.r72653

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Jean-Paul Linnartz
Eindhoven University of Technology, Eindhoven, The Netherlands

I thank the authors for taking my previous comments carefully into account. The paper is much more mature now.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Wireless Communication

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 23 April 2026

https://doi.org/10.21956/openreseurope.25447.r72654

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Chun Sing Lai
Tianjin University, Tianjin, Tianjin, China

I have no further comment.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Devices and Circuits, Smart Cities, Energy Systems

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

Reviewer Report 05 March 2026

https://doi.org/10.21956/openreseurope.25041.r70529

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Chun Sing Lai
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[2] Tianjin University, Tianjin, Tianjin, China

The authors claimed that “The four parameters were optimized to develop an extremely low error rate and a robust and stable connection across the distances typical of hospitals (e.g., between patient rooms and wards).” For this highly nonlinear and multi-objective problem, please explain how the proposed technique can achieve the optimal solution, i.e., how do the authors know that the soultion is optimal? Which optimization algorithm is used?

Figures 1 and 2 present the transmitter and receiver models, however, it is not clear what is the state of the art and how it is innovative as compared to previous models. The authors may make a comparison figure or add clear annotations on where the innovation is.

For a multidimensional problem, i.e., BER, SNR, and Q-factor, it may be more appropriate to plot 3-dimensional plots or overlapped figures of the plots to identify the optimal configuration of the system, by identifying how do the four parameters affect the system performance.

There is a lack of comparison with the state of the art methods and different device type. Some quantitative comparisons would add value to the work.

Minor comments:
The symbols for equations should be properly formatted, please check the italic fonts for consistency.
The figures must be properly made to ensure results are presented clearly. For example, Fig. 5’s legend hides some results. Fig. 4 the databox hides the line.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?

Yes

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Devices and Circuits, Smart Cities, Energy Systems

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 25 Mar 2026

Ajay Sharma

We are grateful to the reviewer for the elaborate and constructive feedback. The feedback has helped us enhance the clarity, rigour, and placement of the manuscript. Point-by-point, we respond below.

Reviewer Comment *"The authors claimed that "The four parameters were optimized to develop an extremely low error rate and a robust and stable connection across the distances typical of hospitals (e.g., between patient rooms and wards)." For this highly nonlinear and multi-objective problem, please explain how the proposed technique can achieve the optimal solution, i.e., how do the authors know that the soultion is optimal? Which optimization algorithm is used."*

Author Response: In the modified document, we explain that the term optimized refers to a systematic parametric search and sensitivity analysis over predefined intervals of launch power, modulation index, beam divergence, and receiver aperture. No mathematical nonlinear or multi-objective optimization (e.g., genetic algorithm, particle swarm optimization, convex optimization) algorithm was used. The configuration that performs best within the explored parametric space can be defined as optimal and is the parameter set that achieves the highest level of analytical reliability (e.g., BER < 10^{-9} and Q > 6) and has robust SNR margins under idealised detector-noise-limited assumptions. We now make it quite clear that this does not imply a mathematically global optimum. Instead, it is an analytically preferable upper-bound design in the explored design space. The paper has also been edited to prevent overstatement.

Reviewer Comment *"Figures 1 and 2 present the transmitter and receiver models, however, it is not clear what is the state of the art and how it is innovative as compared to previous models. The authors may make a comparison figure or add clear annotations on where the innovation is."*

Author Response: The updated document now makes it clear that the transmitter and receiver hardware blocks are not inherently new architectures. This work has been

innovative in terms of the structured joint four-parameter sensitivity framework that has been specifically designed to suit hospital sized indoor environment. In contrast to other literature that examine individual parameters independently, this paper will combine joint tuning of launch power, modulation index, beam divergence, and receiver aperture and map the combined effect on BER, SNR, and Q-factor with hospital-based limitations. Table 1 has been reinforced to make a more distinct comparison with the previous studies, showing the difference in parameter range, type of devices used, and no hospital specific multi-parameter analysis in previous research.

Reviewer Comment *"For a multidimensional problem, i.e., BER, SNR, and Q-factor, it may be more appropriate to plot 3-dimensional plots or overlapped figures of the plots to identify the optimal configuration of the system, by identifying how do the four parameters affect the system performance."*

Author Response: This is a helpful recommendation by the reviewer. The present research uses the structured two-dimensional sensitivity plots to isolate and interpret the influencing effect of the specific parameters when the other parameters are under controlled assumptions. We concur that multi-objective visualization of Pareto-fronts and three-dimensional response surfaces would be more useful in understanding trade-offs. We have included in the revised manuscript a statement in the Future Scope section that will say that future work will consider:

- Three-dimensional response-surface analysis,
- Multi-objective optimization by Pareto-fronts,
- Strict evolutionary optimization algorithms.

The current study forms a first-order analysis foundation, which can be expanded in the future in multidimensional optimization research.

Reviewer Comment *"There is a lack of comparison with the state of the art methods and different device type. Some quantitative comparisons would add value to the work."*

Author Response In the updated manuscript, quantitative and qualitative comparison has been made clearer and is now included:

- LED-based LiFi systems (wider coverage but lower modulation bandwidth),
- Direct-modulated lasers (higher bandwidth but narrower coverage),
- VCSEL array approaches (alignment mitigation but increased complexity),
- Hybrid LiFi–RF systems for resilience.

We have made clear that the suggested DML-based frame does not have any implied universal superiority but rather offers a parameterized analytical baseline in idealized conditions of the indoor of a hospital.

Reviewer Comment *"The symbols for equations should be properly formatted. Please check the italic fonts for consistency."*

Author Response All equations have been reformatted with consistent italicized variables and corrected fraction structures.

Reviewer Comment *"The figures must be properly made to ensure results are presented clearly. For example, Fig. 5's legend hides some results. Fig. 4 the databox hides the line."*

Author Response All figures have been revised to improve clarity.

Evaluation Summary
Questions Comment *Is the work clearly and accurately presented and does it cite the current literature?*
Partly
Response: To make sure correct presentation, the literature review has been enlarged, comparative positioning has been made clear, and claims have been moderated.

Comment *Are sufficient details of methods and analysis provided to allow replication by others?*
Partly

Response: The paper has now explained the methodology of the parametric sweep, assumptions of analysis, the scope of the noise model and conditions of reproducibility. In the optimization procedure, the details are provided in a manner that enables one to independently reproduce the analytical trends in MATLAB.

Comment *Are all the source data underlying the results available to ensure full reproducibility?*
Partly

Response: We made it clear that proprietary OptiSystem project files may not be publicly deposited as a result of licensing restrictions, but that parameter sets, mathematical formulae, and MATLAB scripts can be made available on reasonable academic request.

Comment *Are the conclusions drawn adequately supported by the results?*
Partly
Response: All claims have been moderated. The conclusions have now been made clearer in the Discussion section to report that they represent upper-bound analytical performance in idealized conditions and not the reliability of deployment. The aspects of practical implementation are already recognized as future work.

Closing Statement The reviewer has written very constructive and technically insightful remarks, for which we thank him. The paper has undergone significant revisions to help explain optimization methodology, enhance comparative positioning, enhance the quality of figures, and tone down claims. In our opinion, the revisions enhance the clarity of the work and its academic rigor in a major way.

Competing Interests: No competing interests were disclosed.

Version 1

Reviewer Report 06 February 2026

https://doi.org/10.21956/openreseurope.23373.r68125

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Jean-Paul Linnartz
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Direct modulation of a laser can be an attractive approach to allow a cost down and miniaturization of optical wireless systems. That makes the work interesting and relevant.

However in the present form, the paper overclaims to an unacceptable degree. Most importantly, the scientific community in LiFi must not advise health care providers to adopt LiFi in hospitals, solely based on the findings in this report. The paper seems to suggest that the results are a breakthrough and that the reliability of optical links is flawless (10^-79). This strong claim is not sufficiently substantiated.

It seems like an overclaim to conclude “”this paper makes DML-based LiFi a practically viable”” if the study is (only) a simplified theoretical model. The idea of DML is interesting and the theoretical analysis has merit, but the overall claim that authors made a breakthrough in making LiFi in hospitals feasible is unsufficiently supported. In any revision, claims should be limited to something like
"in theory, in a well-aligned line-for-sight link, the link budget and SNR for a directly modulated laser of a few mWatt seems more than sufficient to support OOK at 1 Gbit/s over 25 meter if the beam divergence is below a millirad".

The authors must realize that claiming a BER of 10^-79 may be interpreted by many readers (including myself) a sign of a lack of a maturity in reliability engineering: A BER of 10^-79 suggests that not a single bit error would have occurred in any instance of billions of such systems in parallel that all started transmitting since to beginning of the universe. Engineers educated in reliability of systems understand that many more aspects need to be considered to achieve a typical 5 nines (99,999 %) reliability of a link. Relying on an excessive SNR is not adequate.

Deep gaussian tails (certainly Q>18) are notoriously inaccurate as an error model. Extrapolating a BER versus SNR curve based on Gaussian assumptions (!?) to claim exorbitant reliability sounds a bit naïve. I am afraid that such numbers put the trustworthiness of the paper into question, already once reading the abstract. (at least that was my feeling after reading just the abstract).

Surprisingly, the section after: “”Building on our prior optical-wireless research, ..”” reveals that the authors have a much more mature perspective on these various aspects than shown in the current paper.

Statements such as:
“”A modern LiFi system can be implemented with a Direct-Modulated Laser (DML), which provides compact, high-energy efficiency operation at gigabit-per-second (Gbps) speeds while using single integrated devices without external modulators.”” needs a justification. These do not follow from results in this paper. References are needed about power efficiency (relative to radio, to LEDs, ?). If the SNR (Q) is so excessive, then much lower power would also suffice!? Secondly, the low power relies on covering a just single client device in small area of a few tens of cm's.

I am not convinced that there are no EMI challenges in LiFi: photodetectors are notoriously sensitive in picking up RF signals, and modulating currents into low impedance lasers often leads to unwanted emissions in the radio spectrum. I am not too convinced with a paper claiming absence of EMI without studying these effects explicitly and only relying on the fact that the intended (!) emissions are not in the radio spectrum. Receiver noise caused by picking up RF signals (man-made noise, non-Gaussian) is usually orders of magnitude larger than additive noise in the amplifier. Even reaching 10^-12 is hard in a practical setting, for EMI reasons.

Shot noise highly depends on the environmental light. This effect is not quantified except for mentioning some precautions of optical shielding. 500 nm is in the visible range of hospital illumination, thus environmental light causes significant shot noise.

The assumed noise figure of 4 dB needs justification when used as a transimpedance amplifier for an optical system. the use of this as a noise model (borrowing assumptions of 50 Ohm terminations in RF signal amplification?) requires further elaboration for TIA connected to photo diodes.

I do not understand how in (4) the BER can be a function of distance to the power n, rather than via the erfc(distance ^ n) . How are the error function (erfc) expressions used, if eq. (4) seems to model BER in a different manner.
Eq 4 seems a misuse of Turbulence-limited FSO channels and not appropriate for detector-noise limited indoor channels. ISI is not modelled, and certain at low BER these effects become a limiting factor.

Is the noise white as assumed in the models? Typical detectors have a low-pass response. Correcting this response in a TIA usually results in enhanced noise power densities that increase with frequency. (the only gentle roll off above 1 GHz seems to accept a lot of noise enhancements)
In particular, the use of a Lambertian sensitivity model for the photo diode detector implies the use of relatively large (naked) dye area (no lenses), thus high capacitances. It is unclear what the aspect of angle of arrival is brought into the model, as this aspect of misalignment is not described.

“”current study introduces a validated simulation workflow””. But how is it validated?

Regarding: “”This solves the reliability and safety issues of wireless systems that have been in place in the healthcare setting.””
1) I do not read how the authors resolved the blockage of a line of sight, which is the most frequently heard objection against LiFi.
2) I do not read about whether or not moving / portable devices need to supported in hospital

settings. Would doctors or nurses want to calibrate the directivity of a laser while preparing to a medical intervention?
3) I do not read how the authors resolved eye-safety issues with lasers at 500 nm, this in the visible range.

Compared to studies with LEDs, similar bit rates have been achieved but with much wider coverage (10 m2) than the laser spot (1 mrad at 25 m illuminates only a small spot). LED give comparable bit/s per watt/m^2 and wide coverage seems more appropriate for the application.

The references seem a bit biased towards FSO and lack links to paper on providing reliable LiFi coverage indoors, including MIMO to resolve l.o.s. blockage issues, including solutions based on (ITU or IEEE) standards for which interfacing electronics ICs are available.

There is also quite some literature on using arrays of VSCELS. These can also be seen as directly modulated lasers, and bring a solution to the issue of aligning the beam direction. I am not convinced that the work advances the state of art if benchmarked against published work on VCSEL arrays.

Because of these considerations I cannot recommend exposure of the paper in its current form to the readers.

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Partly

Are the conclusions drawn adequately supported by the results?
No

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I have published many papers in the field of LiFi

I confirm that I have read this submission and believe that I have an appropriate level of expertise to state that I do not consider it to be of an acceptable scientific standard, for reasons outlined above.

Author Response 09 Feb 2026

Ajay Sharma

Response to Reviewer 2 Comments

We are grateful to the reviewer, who has examined, in detail and rigorously and constructively, the subject. We are grateful to the reviewer that he has read so carefully, and we admit that some of the assertions in the original manuscript are exaggerated. We have, in turn, significantly amended the manuscript in order to capture scope, redress exaggeration, and make all conclusions within the framework of the theoretical and simulation-based nature of the study. Each comment is reproduced below and explained how it has been met.

Reviewer Comment *"Direct modulation of a laser can be an attractive approach to allow a cost down and miniaturization of optical wireless systems. That makes the work interesting and relevant. However, in the present form, the paper overclaims to an unacceptable degree. Most importantly, the scientific community in LiFi must not advise health care providers to adopt LiFi in hospitals solely based on the findings in this report."*
Author Response: We fully agree. The manuscript has been updated all over (Abstract, Introduction, Novelty, Results, Discussion, and Conclusion) to clearly indicate that the manuscript offers upper-bound performance analysis based on theory and simulations only. Anything that hints at the adoption of a hospital or deployment preparedness has been eliminated.

Reviewer Comment *"The paper seems to suggest that the results are a breakthrough and that the reliability of optical links is flawless (10^-79). This strong claim is not sufficiently substantiated."*
Author Response: This is an issue that is completely dealt with. The Abstract, Results, Discussion, Mathematical Modeling and Conclusion have been cleared of all signs of BER $\approx 10^{-9}$. BER is now always defined as well below the analytical level (e.g., BER $< 10^{-9}$), and it is clearly identified as an analytical lower limit based on Gaussian-noise modelling, and not operational reliability.

Reviewer Comment *"It seems like an overclaim to conclude 'this paper makes DML-based LiFi a practically viable' if the study is (only) a simplified theoretical model."*
Author Response: We agree. All expressions that purported to be viable in practice, deployable, or a solution to hospital reliability have been eliminated or weakened. The rewritten text makes many attempts to explain that the paper only judges on the theoretical feasibility in idealized conditions of line-of-sight and detector-noise-limited.

Reviewer Comment *"In any revision, claims should be limited to something like 'in theory, in a well-aligned line-for-sight link...'"*
Author Response This very framing has been utilized across the edited text. The Abstract, Methodology, Results, Discussion, and Conclusion now clearly express themselves using the terminology of in theory, under idealized assumptions, and upper-bound analytical performance.

Reviewer Comment *"The authors must realize that claiming a BER of 10^-79 may be*

interpreted … as a sign of a lack of maturity in reliability engineering."
Author Response We do consider this fact and completely agree with it. The updated manuscript acknowledges clearly the shortcomings of Gaussian tail extrapolation at large Q-factors, and the values of BER are no longer regarded as reliability measures, but rather as analytical ones. Claims of reliability engineering are eliminated.

Reviewer Comment *"Deep gaussian tails (certainly Q>18) are notoriously inaccurate as an error model."*
Author Response This weakness is now clearly mentioned in the Methodology section as well as in the Mathematical Modeling section. It is explicitly stated that the erfc-based formulation of the BER is an approximation that becomes less valid at large Q, and the results are put in context.

Reviewer Comment *"Statements such as 'A modern LiFi system can be implemented with a Direct-Modulated Laser (DML)…' needs a justification."*
Author Response This is an updated sentence. There are no longer careless claims of energy efficiency, EMI immunity, and better than RF or LEDs, and literature has been included to support the claims. This study could not make justification to some extent, and hence this claim was eliminated.

Reviewer Comment *"I am not convinced that there are no EMI challenges in LiFi…"*
Author Response We agree. Any alleged claims of the operation being free of EMI have now changed to "EMI-safe in terms of intended optical emissions". The updated version takes explicit responsibility for EMI pickup in photodetectors and front-end electronics as a significant pragmatic constraint that is not represented in this work.

Reviewer Comment *"Shot noise highly depends on the environmental light… 500 nm is in the visible range…"*
Author Response This is a limitation that is now clearly stated. It is indicated clearly that the noise model is detector-noise-limited, and the effect of ambient-light-induced shot noise is not in-scope, and needs to be studied in the future.

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Author Response The noise figure is no longer used as a realistic TIA model, but rather as a simplified or idealistic assumption. The manuscript explains that the frequency-dependent noise and the practical TIA behaviour are not modelled.

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Author Response It has been reinterpreted as equation (4) and is clearly stated as an empirical trend model, rather than a law of physical BER. This has been represented by a clear separation in the manuscript between the expressions of erfc-based BER and distance-dependent trend fitting that are only utilized to aid in the interpretation of the results of the simulations.

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Author Response This has now clearly mentioned in the Methodology and Mathematical Modeling sections.

Reviewer Comment *"'current study introduces a validated simulation workflow'. But how is it validated?"*
Author Response The term "validated" has been replaced with "reproducible" throughout the manuscript. Validation is now defined strictly as internal consistency between analytical trends and simulation outputs, not experimental verification.

Reviewer Comment *"I do not read how the authors resolved the blockage of a line of sight… moving / portable devices… eye-safety issues…"*
Author Response We concur that they are essential matters. The updated Discussion and Conclusion clearly indicate that line-of-sight blockage, mobility, and eye safety are not resolved in this study and need to be addressed in hybrid architectures and experimental studies in the future.

Reviewer Comment *"Compared to studies with LEDs… VCSEL arrays…"*
Author Response Literature Review and Discussion have been extended to note LED-based LiFi, MIMO LiFi, and VCSEL array designs, and explain that DML-LiFi is a single design point of many, each with trade-offs.

Reviewer Comment *"Because of these considerations, I cannot recommend exposure of the paper in its current form to the readers."*
Author Response: We appreciate such an honest evaluation by the reviewer. The manuscript has been revised on a large scale to accommodate all issues of concern. Exaggerated assertions have been eliminated, scope has been defined, constraints have been clearly stated, and conclusions are now fully substantiated by the theoretical analysis provided.

Reviewer Summary Questions

- *Is the work clearly and accurately presented, and does it cite the current literature?*
  Revised to address gaps and balance citations.
- *Is the study design appropriate, and does the work have academic merit?*
  Clarified as a theoretical and simulation-based study.
- *Are sufficient details provided for replication?*
  Clarified as numerical reproducibility, not experimental validation.
- *Are the conclusions supported by the results?*
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We sincerely thank the reviewer for highlighting critical issues related to reliability engineering, modeling assumptions, and scientific responsibility. The revised manuscript reflects a more mature, careful, and accurate presentation of the work, and we believe it is now suitable for consideration as a theoretical and simulation-based contribution to LiFi research.

Competing Interests: No competing interests were disclosed.

Author Response 23 Feb 2026

Ajay Sharma

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Competing Interests: No competing interests were disclosed.

Reviewer Report 28 January 2026

https://doi.org/10.21956/openreseurope.23373.r68130

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1. Executive Summary
The article presents a robust simulation of Direct-Modulated Laser (DML) LiFi systems for clinical settings, demonstrating superior BER (10^{-79}) and SNR performance. However, the report

identifies a significant real-world gap: the system's reliance on precise optical alignment and complex maintenance makes it vulnerable during "Black Swan" events (natural disasters or conflict). To be scientifically and practically sound for critical infrastructure, the work must address system redundancy and independence from external premises.

2. Points Must Be Addressed (Required for Soundness)

A. Resilience and Disaster Recovery (The "Critique" Point)

The authors argue for LiFi as a replacement or primary system. However, in a hospital environment during a disaster (e.g., earthquake or war-time structural damage), laser-based LiFi is highly susceptible to misalignment and power failure.

- **Correction Required:** The authors must discuss or model a **Hybrid LiFi-RF (Radio Frequency) handover**. While LiFi handles high-speed/EMI-sensitive data during normal operations, a simple, ruggedized RF backup (such as Sub-GHz radio) must be integrated to ensure "fail-safe" communication when the optical link is disrupted.

B. On-Premise Independence

The current model assumes a functioning backhaul. If external infrastructure is destroyed, a hospital must function as an "information island."

- **Correction Required:** The authors should specify how the system maintains 100% independence from outer-premise maintenance. This includes the use of Local Edge Computing to process data internally via LiFi even when external telecommunications are severed.

3. Detailed Assessment

- **Methods:** The use of OptiSystem and MATLAB is technically sound for establishing the "Best Case" performance metrics of DML-LiFi.
- **Results:** The optimization of launch power ($\ge +5$ dBm) and modulation index ($0.8–1.0$) provides clear engineering guidelines.
- **Conclusions:** The conclusion that DML-LiFi is a "complete" solution is currently overstated. It is a superior *performance* solution but a fragile *resilience* solution unless coupled with legacy radio systems.

4. Supporting References & Literature (Addressing Resilience)

To support the requirement for hybrid systems and independent hospital networks in critical scenarios, the following literature is recommended for inclusion:

1. On Hybrid LiFi/RF Resilience:

This study demonstrates that while LiFi provides speed, RF provides the "coverage and reliability" necessary when the optical path is blocked or the system is under stress.

- **Reference:** Wu, X., et al. (2021). "Dynamic Load Balancing for Hybrid LiFi and Wi-Fi Networks."
- **DOI:** 10.1109/TCOMM.2019.2962434

2. On Critical Infrastructure Independence:

Discusses the necessity of localized "Edge" networks in hospitals to ensure that life-saving data remains accessible even if the external "outer premise" network fails.

- **Reference:** Sahni, Y., et al. (2017). "Edge Mesh: A New Paradigm to Enable Distributed Intelligence in IoT." (Relevant to hospital independent comms).
- **DOI:** 10.1109/ACCESS.2017.2739804

3. On FSO for Disaster Recovery:

Using Free Space Optics (FSO) as a ruggedized, independent backhaul for hospitals when fiber

lines are cut during natural disasters.

- **Reference:** Khalighi, M. A., & Uysal, M. (2014). "Survey on Free Space Optical Communication: A Communication Theory Perspective."
- **DOI:** 10.1109/COMST.2014.2329501

Final Recommendation: Partly Accept. The article is technically excellent regarding laser physics but requires a "System Resilience" section to be viable for hospital policy implementation. Incorporating a Hybrid RF-Radio backup strategy will make the research significantly more powerful.

References

1. Sahni Y, Cao J, Zhang S, Yang L: Edge Mesh: A New Paradigm to Enable Distributed Intelligence in Internet of Things. *IEEE Access*. 2017; **5**: 16441-16458 Publisher Full Text
2. Wu X, Haas H: Load Balancing for Hybrid LiFi and WiFi Networks: To Tackle User Mobility and Light-Path Blockage. *IEEE Transactions on Communications*. 2020; **68** (3): 1675-1683 Publisher Full Text
3. Khalighi M, Uysal M: Survey on Free Space Optical Communication: A Communication Theory Perspective. *IEEE Communications Surveys & Tutorials*. 2014; **16** (4): 2231-2258 Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: I am an agricultural entomologist specializing in multidisciplinary research that integrates the principles of physics and chemistry with the life sciences to evaluate system performance in high-stakes environments. My expertise lies in the "Practical Application Validation" of emerging technologies, specifically assessing how complex systems—from biological ecosystems to optical communication networks—function under extreme stress, such as natural disasters or conflict-induced infrastructure failure. My research focuses on building resilient, "fail-safe" architectures that ensure decentralized independence and operational continuity in mission-critical settings, bridging the gap between theoretical laboratory findings

and rugged, real-world survival

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 09 Feb 2026

Ajay Sharma

Response to Reviewer 1 Comments

We are grateful to the reviewer for critically analysing our manuscript and providing positive feedback, which strengthened our work scientifically and practically. The revised manuscript has taken into consideration all the suggestions as explained below.

Comment 1: Executive Summary Reviewer Comment:

The manuscript presents strong simulation results but identifies a real-world gap related to system fragility during “Black Swan” events. The work must address redundancy and independence from external premises.

Response:

We concur with the evaluation of the reviewer. We have, in order to close this gap, placed a new dedicated section, namely “System Resilience and Fail-Safe Communication Architecture” **(Section 8).** This part will specifically address system-level resiliency, redundancy, and operational independence, thus making the proposed DML-LiFi system reasonable to support critical infrastructure in hospitals under other than the best-case conditions.

Comment 2A: Resilience and Disaster Recovery (The “Critique” Point) Reviewer Comment:

LiFi is susceptible to misalignment and power failure during disasters. A Hybrid LiFi–RF handover must be discussed to ensure fail-safe communication.

Response:

Section 8.1 has discussed this point in detail. The revised manuscript has very clearly placed DML-LiFi as the main high-performance and EMI-safe communication layer, and a low-rate and rugged RF backup to maintain fail-safe operation in case the optical link is broken. The suggested literature on hybrid LiFi/RF supports the discussion **[Wu & Haas]**

Comment 2B: On-Premise Independence Reviewer Comment:

The system must maintain independence from external infrastructure so that the hospital can function as an “information island.”

Response:

This has been covered in **Section 8.2**, in which it is explicitly assumed that the system is deployed together with on-premise edge computing resources. This guarantees that critical clinical data processing, storage, and access capabilities are still accessible in the case of unavailability of external telecommunications, as had been previously done on edge-based critical infrastructure networks **[Sahni et al.]**.

Comment 3: Conclusions Reviewer Comment:

The conclusion that DML-LiFi is a “complete” solution is overstated unless coupled with legacy radio systems.
Response:
We concur and have amended the Conclusion (it has become Section 9). The absolute statements have been diluted, and the conclusion now clearly states that DML-LiFi is best adopted when embedded into a robust hybrid architecture, including a reliable backup connection that is fail-safe, as explained in Section 8.

Comment 4: Supporting References & Literature Reviewer Comment:
Hybrid LiFi/RF systems, critical infrastructure independence, and FSO-based disaster recovery literature should be included.
Response:
Section 8 has included all the recommended references and cited them.

- Hybrid LiFi/RF resilience **[Wu & Haas]**
- Edge-based independent hospital networks **[Sahni et al.]**
- FSO for disaster recovery backhaul **[Khalighi & Uysal]**

The reviewer is once again thanked for the feedback, which has substantially enhanced the relevance and applicability of the manuscript at the system level and for its application to hospital policy and deployment.

Competing Interests: No competing interests were disclosed.

Author Response 23 Feb 2026

Ajay Sharma

We are grateful to the reviewer who critically analyzed our manuscript and provided positive feedback, which made our work scientifically and practically sound. The revised manuscript has taken into consideration all the suggestions as explained below. **Comment 1: Executive Summary Reviewer Comment:**
The manuscript presents strong simulation results but identifies a real-world gap related to system fragility during “Black Swan” events. The work must address redundancy and independence from external premises. **Response:**
We concur with the evaluation of the reviewer. We have, in order to close this gap, placed a new dedicated section, namely “System Resilience and Fail-Safe Communication Architecture” **(Section 8).** This part will specifically address system-level resiliency, redundancy, and operational independence, thus making the proposed DML-LiFi system reasonable to support critical infrastructure in hospitals under other than the best-case conditions. **Comment 2A: Resilience and Disaster Recovery (The “Critique” Point) Reviewer Comment:**
LiFi is susceptible to misalignment and power failure during disasters. A Hybrid LiFi–RF handover must be discussed to ensure fail-safe communication. **Response:**
Section 8.1 has discussed this point in detail. The revised manuscript has very clearly placed DML-LiFi as the main high-performance and EMI-safe communication layer, and a low-rate and rugged RF backup to maintain fail-safe operation in case the optical link is broken. The suggested literature on hybrid LiFi/RF supports the discussion **[Wu & Haas] Comment 2B:**

On-Premise Independence Reviewer Comment:
The system must maintain independence from external infrastructure so that the hospital can function as an "information island." **Response:**
This has been covered in **Section 8.2**, in which it is explicitly assumed that the system is deployed together with on-premise edge computing resources. This guarantees that critical clinical data processing, storage, and access capabilities are still accessible in the case of unavailability of external telecommunications, as had been previously done on edge-based critical infrastructure networks **[Sahni et al.]**. **Comment 3: Conclusions Reviewer Comment:**
The conclusion that DML-LiFi is a "complete" solution is overstated unless coupled with legacy radio systems. **Response:**
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The reviewer is once again thanked for the feedback, which has substantially enhanced the relevance and applicability of the manuscript at the system level and for its application to hospital policy and deployment.

Competing Interests: No competing interests were disclosed.