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# Strategies to Boost the Performance of Eco-Friendly Light-Emitting Diodes, Quantum Dots Size versus Plasmonic Layer

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**ABSTRACT**

This study explores the enhancement of light-emitting diode (LED) performance through the integration of quantum dots (QDs) and plasmonic layers. Simulations were conducted using Lumerical software to analyze the effects of QD size (2, 5, and 10 nm) and plasmonic layer thickness on emitted light intensity and wavelength variations. The results demonstrate that the plasmonic layer significantly enhances the electromagnetic field near the QDs, leading to increased emission light intensity. Changing the QD size influences both the emission wavelength and intensity: smaller QDs shift the emission toward shorter wavelengths and exhibit higher intensity, while larger QDs shift it toward longer wavelengths with lower intensity. This combined approach offers an effective strategy for optimizing LED efficiency, enabling precise wavelength control and improved energy performance. The findings contribute to advancements in LED technology, high-quality displays, and energy-efficient nanoscale light sources, and also suggest promising directions for future research.

## 1. Introduction

Light-emitting diodes (LEDs) are recognized as one of the most crucial optical devices in the modern world. This technology plays a significant role in various fields, including lighting, displays and optical communications. With the extensive advancements in nanotechnology and materials science, the LED simulations, particularly quantum dot-based LEDs (QD-LEDs), has become a significant research topic [1]. Quantum dots (QDs), are semiconductor nanoparticles that exhibit unique capabilities in light emission and wavelength tunability. These properties arise from quantum effects and size reduction, altering the energy levels of electrons and allowing the emitted light wavelength to be tunable [2,3]. Plasmonic layers, composed of thin metallic structures placed near quantum dots, can enhance the intensity and efficiency of LED emissions. These layers generate localized electromagnetic fields, which interact with the emitted light from quantum dots, thus enhancing the optical characteristics of the diodes [4, 5]. In this context, numerical and computational simulations serve as key tools for understanding the optical behavior of these systems and optimizing their design. Optical interactions and the optoelectronic properties of materials, facilitating overall performance improvement [6].

This research aims to provide a deeper understanding of how plasmonic layers can be utilized to enhance the design and performance of QD-LEDs [7]. The first challenge in this area is selecting the appropriate material for quantum dots. QDs can be synthesized using different semiconductor elements, and their optical properties are significantly influenced by their composition and nanoparticle size. Thus, determining the optimal chemical composition to achieve the desired emission wavelength is a crucial requirement [8].

Apart from material selection, optical interference and diffraction phenomena arising from the presence of plasmonic layers can substantially impact LED performance. Therefore, accurate simulations are required

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to model these effects and provide reliable predictions [9]. Another critical aspect is the optimization of the geometric parameters and plasmonic layer geometry and thickness. The size of the nanoparticles and their distance from the plasmonic surface should also be examined to maximize optical efficiency [10]. Addressing these challenges necessitates complex and precise simulations to model the intricate interactions among these elements. The development of QD-based light-emitting diodes (QD-LEDs) electrically driven electroluminescent devices—presents a promising approach to maximizing the benefits of quantum dots. These advantages include energy efficiency, an ultra-wide color spectrum, and fabrication potential. Given that a significant portion of global energy consumption is dedicated to lighting applications, QD-LEDs are considered one of the most promising candidates for next-generation low-power displays and solid-state lighting. To date, most research on QDs for LEDs has focused on cadmium-based materials such as CdSe/CdS, CdSe/ZnS, and ZnSe/CdSe. However, these materials contain heavy metals, raising concerns regarding their toxicity and potential environmental and health risks, including chronic diseases and carcinogenic effects. Therefore, developing cadmium-free QD-LEDs is crucial for achieving safer and more sustainable display and lighting applications. In addition to exploring alternative, non-toxic QD materials, our study aims to enhance the efficiency of cadmium-free QD-LEDs by incorporating a plasmonic nano-island layer. This integration is expected to improve light extraction efficiency and optimize device performance, paving the way for the next generation of high-performance, environmentally friendly QD-LEDs [11].

## 2. Research Methodology

The geometry and structure of a light-emitting diode (LED) includes the following layers: Substrate layer, which is made of glass with a thickness of 200 nm and serves to provides mechanical support and minimizes light loss. Anode layer, made of indium tin oxide (ITO) with a thickness of 50 nm, and has a high transparency for light transmission and hole injection into the LED structure featuring high transparency to enable light transmission and hole injection.

Hole Injection Layer (HIL), composed of PEDOT:PSS with a thickness of 40 nm, and has the role of improving the transfer of holes to the active layers and reducing electrical resistance facilitates hole transport to active layers while reducing electrical resistance. Hole Transport Layer (HTL), made of TPD with a thickness of 50 nm, and has the role of prevents electron leakage toward the anode and enhances hole injection efficiency.

**Table 1.** Specifications of different layers of the light-emitting diode (LED)

| Layer | Thickness (nm) | Refractive Index | Electrical Conductivity (S/cm) |
|---|---|---|---|
| **Al (Aluminum)** | 200 | 1.0 | $3.7 \times 10^7$ |
| **ZnO Film** | 30 | 2.0 | 1000 |
| **Plasmonic (Au)** | 14 | 0.47 | $10^7$ |
| **QDs (InP)** | 20 (2-5-10) | 2.5 | - |
| **Poly-TPD** | 50 | 1.8 | - |
| **PEDOT:PSS** | 40 | 3.0 | - |
| **ITO** | 50 | 1.9 | 5000 |

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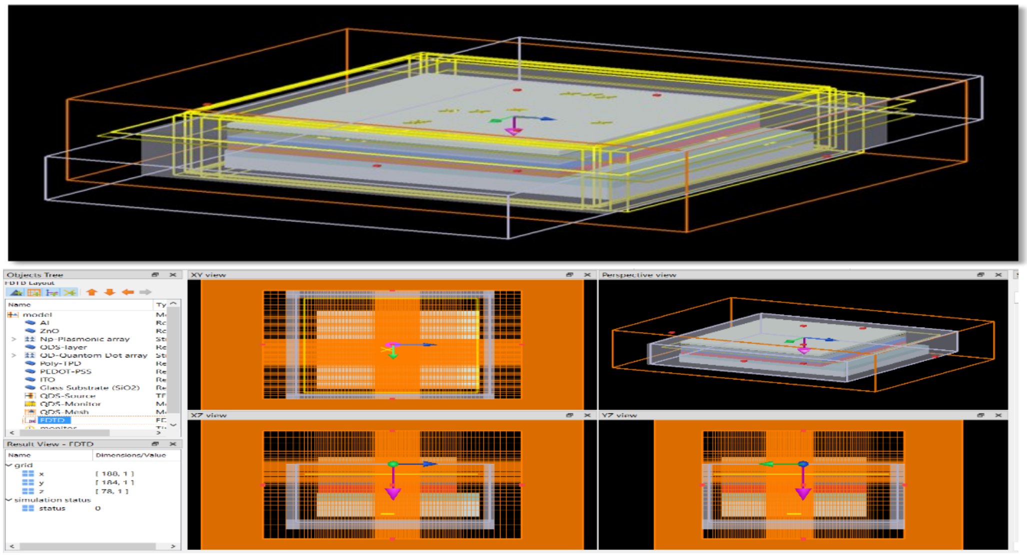


**Fig. 1.** The 3D image of the layers of the light-emitting diode

Emission Layer (EML), consisting of indium phosphide quantum dots (InP QDs) with a thickness of 20 nm. The QDs have diameters of 2 nm, 5 nm, and 10 nm, and their role is to produce light through electron-hole recombination. Electron Transport Layer (ETL) or plasmonic layer, made of ZnO with a thickness of 30 nm. Its functions include blocking hole transport to the cathode, enhancing electron mobility, and enabling localized surface plasmon enhancement. Plasmonic Nanoparticles, composed of gold (Au) with a diameter of 14 nm, and used to enhance electromagnetic field intensity and boost external quantum efficiency (EQE). Cathode or electron injection layer, made of aluminum (Al) with a thickness of 200 nm, responsible for electron injection and establishing electrical contact. The specific properties of these layers are summarized in Table 1, while a visual representation of the three-dimensional model is provided in Fig. 1. Table 1 lists the thickness, refractive index, and electrical conductivity of all layers used in the LED architecture.

## 3. Results and Discussion

In this study, the simulation of the LED structure was conducted using Lumerical by following several key steps. First, the geometry and materials of the system were defined, including the substrate, quantum dot (QD) layer, plasmonic layer, and optoelectronic contacts. Each layer from the substrate to the optoelectronic contacts was then modeled to ensure accurate structural representation. The refractive indices and material loss coefficients were defined based on either experimental data or built-in models within Lumerical. Additionally, appropriate light sources were defined, with a dipole source used to simulate the radiation of the quantum dots and a plane wave source for analyzing plasmonic interactions. Electromagnetic field sensors were then placed within the structure to monitor light propagation and intensity, and spectral monitors were used to extract emission and absorption spectra. Perfectly Matched Layer (PML) boundary conditions were applied to suppress light reflection at the simulation domain edges, and the mesh was optimized for high precision in the regions of the quantum dots and plasmonic layers. Once the simulation setup was complete, the next phase involved executing the simulation and extracting key results. This included calculating the emission intensity, output spectra, electromagnetic field distribution, and quantum efficiency using Lumerical's numerical processor. Furthermore, the influence of parameters such as plasmonic layer thickness, quantum dot size, and structural arrangement on overall LED performance was systematically investigated. The spectral analysis is limited to the range of 400-800 nm. Finally, the model approximates the influence of nanoparticle spacing on electromagnetic field intensity, interactions.

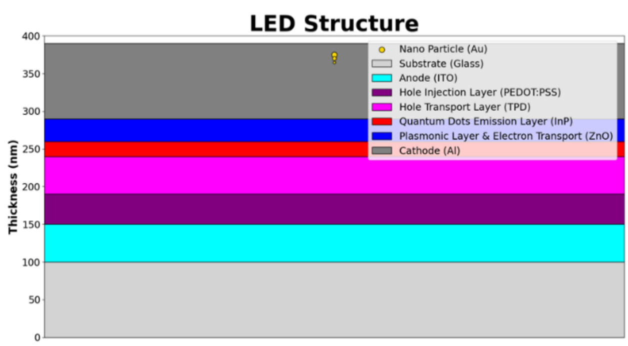



**Fig. 2 .** LED structure

### 3.1. Optical Properties of Quantum Dots

The emission and absorption spectra of quantum dots were analyzed to understand their optical behavior in LEDs. Simulations using Lumerical software showed the absorption and emission characteristics are influenced by quantum dot size and the presence of a plasmonic layer. Smaller quantum dots (e.g., 2 nm) absorb at shorter wavelengths, while larger ones (e.g., 10 nm) absorb at longer wavelengths. The inclusion of a plasmonic layer leads to an overall increase in spectral intensity across various wavelengths, whereas its absence results in considerably weaker spectral features. These results highlight the essential contribution of the plasmonic layer to enhancing the optical performance of the LED.

### 3.2. Effect of Plasmonic Layer on Emission Wavelength

Plasmons are generated through the excitation of surface electrons on noble metals such as silver or gold, and amplify the local electromagnetic field via resonant interactions with free electrons. These Surface plasmon waves can absorb the radiant energy from the quantum dots and convert it into enhanced radiative emission. As a result, the presence of a plasmonic layer increases the emission intensity and improves the efficiency of the LED. The interaction between the plasmonic field and the excitons of the quantum dots is simulated using Maxwell's equations and quantum models.

$$I = I_0 \cdot (1 + k \cdot E_{local}) + I_0 \cdot (\eta_r - \eta_{\{0\}}) \quad (1)$$

This formula shows that the total emission intensity is affected by two important factors: the first factor, the enhancement of the local electromagnetic field caused by the gold nanoparticles and the second factor, the increase in the radiative recombination efficiency. These two factors simultaneously increase the emission intensity in the output spectrum. Temperature causes a decrease in optical efficiency by increasing energy, phonon generation, and energy dissipation. This effect is due to the physical nature of semiconductor materials and plasmonic interactions in the presence of gold layers and quantum dots.

Formula for the decrease in optical efficiency with increasing temperature:

To express the relationship between temperature and optical efficiency, we can use a simple linear model. Let us assume that the optical efficiency (η) is dependent on temperature (T) and decreases with increasing temperature. This relationship can be expressed as:

$$\eta(T)=\eta\_0-k(T-T\_0) \quad (2)$$

where:
η: Optical efficiency at temperature T
η_0: Base optical efficiency at reference temperature T0
T, T0: Temperature in degrees Celsius (°C)

K: Rate of decrease in optical efficiency per unit temperature increase (mW/°C)

The effect of quantum dot size and composition on emission wavelength was analyzed using Lumerical simulations. The results indicate that smaller quantum dots (e.g., 2 nm) emit at shorter wavelengths, while larger dots (e.g., 10 nm) emit at longer wavelengths due to quantum confinement effects and bandgap variations. When quantum dots are combined with a plasmonic layer, significant changes in emission wavelengths are observed. The plasmonic enhancement shifts emission towards higher energy regions, increasing emission intensity in specific spectral ranges.

Graph of the effect of quantum dot size and composition on emission wavelength is shown in Fig. 3.

### *3.3. Comparison of Quantum Dot Properties and Its Impact on LED Efficiency*

This section examines how the size and composition of quantum dots affect LED performance. Simulations with Lumerical software reveal that quantum dot properties, such as emission wavelength and light intensity, play a key role in LED efficiency. Quantum dots enable a wider range of colors, producing up to a billion colors, unlike conventional LEDs. Larger quantum dots experience more scattering and internal interference, reducing light intensity. Plasmonic layers near quantum dots enhance light emission, especially for smaller dots, significantly improving LED efficiency by transferring radiative energy. With plasmonic layers, quantum dots produce higher intensity light and more optimized wavelengths, improving LED performance. While increasing quantum dot size reduces intensity, plasmonic layers help mitigate this decrease, improving overall LED efficiency. Table 2 compares LED efficiency for different quantum dot sizes.

The plasmonic layer plays a crucial role in enhancing the optical properties and efficiency of quantum dot-based LEDs. It is typically made of metals like gold or silver, which exhibit strong plasmonic behavior. These metals interact effectively with electromagnetic waves, particularly in the visible and near-infrared regions, amplifying light amplifying light emission from quantum dots. In this study, gold nanoparticles were used to optimize energy transfer.

Gold is chosen for its high refractive index and excellent plasmonic properties at the nanoscale. Its ability to absorb and emit electromagnetic waves efficiently makes it ideal for boosting quantum dot emissions. This enhances light intensity and improves overall LED performance. By incorporating a plasmonic layer, the LED benefits from stronger energy transfer and enhanced light emission. Surface plasmonic layer waves help convert absorbed radiation into higher light output. As a result, the LED at metal-dielectric interfaces and amplify light emission through energy transfer. Plasmonic layer in metals like gold or silver strengthen electromagnetic waves by interacting with free electrons.

### *3.4. Effect of Distance Between Quantum Dots and the Plasmonic Layer*

The distance between quantum dots and the plasmonic layer is crucial for optimizing LED performance. It significantly affects energy transfer and plasmonic layer interactions. Simulations using Lumerical indicate that increasing this distance reduces light intensity due to weaker electromagnetic fields. An optimal separation exists for maximizing LED efficiency. Tests on distances from 5 nm to 50 nm show that LED efficiency drops as the gap increases, with the highest efficiency observed at distances below 10 nm. The Fig. 4(a) illustrates these effects, highlighting the importance of precise design in quantum dot-based LEDs.

### *3.5. Comparison with Structures Without a Plasmonic Layer*

Structures with a plasmonic layer show significant improvements in LED performance compared to those without it. The plasmonic layer enhances light emission and efficiency by facilitating stronger interactions between quantum dots and surface plasmons. Simulations using Lumerical software confirm that LEDs with a plasmonic layer achieve higher efficiency, especially for smaller quantum dots (2 nm), which interact more effectively with plasmonic layer. Overall, incorporating a plasmonic layer significantly boosts LED efficiency, particularly for small quantum dots, by enhancing optical interactions and energy transfer. Comparison of Structures with and without a Plasmonic Layer can be seen in Fig. 4 (b).

### *3.6. LED Emission Spectrum and Performance Analysis*

The emission spectrum of quantum dot-based LEDs is crucial for their optical performance. Simulations show that increasing quantum dot size (2, 5, and 10 nm) shifts the emission wavelength toward longer values due to the reduction in the bandgap. Additionally, incorporating a plasmonic layer slightly shifts the emission peak and enhances intensity due to plasmonic layer -light interactions. Smaller quantum dots benefit more from the plasmonic layer enhancement, leading to higher emission intensities. The intensity and uniformity of emitted light are vital for LED efficiency. The plasmonic layer further increases light intensity by enhancing the electromagnetic field and boosting radiative recombination rates. Moreover, the plasmonic layer improves light uniformity by reducing hotspots, creating a more evenly distributed emission compared to structures without a plasmonic layer. These findings suggest that optimizing quantum dot size and integrating a plasmonic layer can significantly enhance LED performance. Table 3 summarizes the simulation results for light intensity and uniformity.

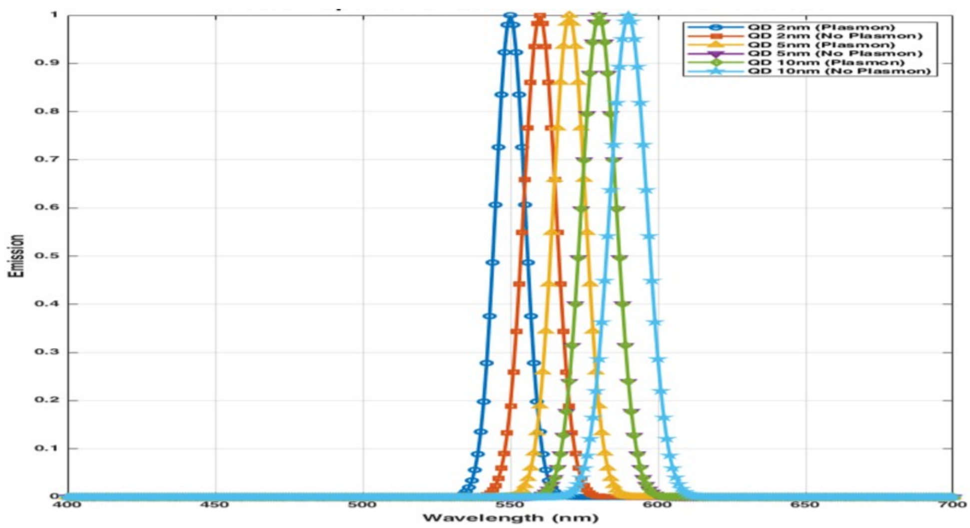
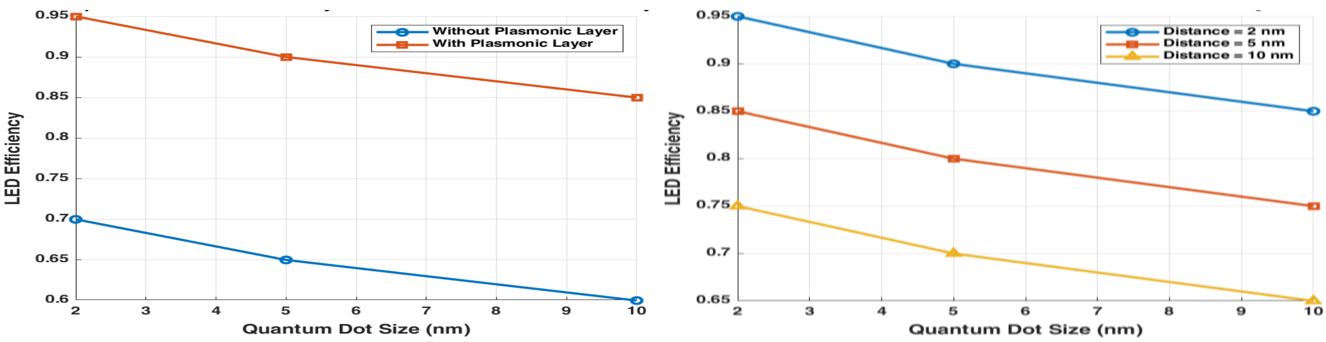



**Fig. 3.** Effect of quantum dot size and composition on emission wavelength

**Table 2.** LED efficiency for different quantum dot sizes

| Parameter | 2 nm (with plasmon) | 2 nm (without plasmon) | 5 nm (with plasmon) | 5 nm (without plasmon) | 10 nm (with plasmon) | 10 nm (without plasmon) |
|---|---|---|---|---|---|---|
| **Emission Wavelength (nm)** | 530-570 | 540-580 | 550-590 | 560-600 | 560-600 | 570-610 |
| **Emission Intensity** | Very High | Medium | High | Medium | Medium | Weaker |
| **LED Efficiency** | 95% | 75% | 85% | 70% | 80% | 65% |
| **Plasmon Effect** | Strong Enhancement | - | Moderate Enhancement | - | Low Enhancement | - |




(a) (b)

**Fig. 4.** (a) Graph of the effect of distance between quantum dots and the plasmonic layer, and (b) Comparison of structures with and without a plasmonic layer

**Table 3.** Summary of simulation results for light intensity and uniformity

| Quantum Dot Size (nm) | Light Intensity without Plasmon (a.u.) | Light Intensity with Plasmon (a.u.) | Light Uniformity Increase (%) |
|---|---|---|---|
| 2 | 1.0 | 1.4 | 30% |
| 5 | 0.8 | 1.1 | 25% |
| 10 | 0.6 | 0.9 | 20% |

**Table 4.** Simulation results of optical efficiency

| Quantum Dot Size (nm) | Thickness 10 (nm) | Thickness 20 (nm) | Thickness 30 (nm) | Thickness 40 (nm) |
|---|---|---|---|---|
| **Random Arrangement** | 45% | 72% | 68% | 50% |
| **Ordered Arrangement** | 50% | 78% | 74% | 55% |

Table 3 shows that adding plasmonic layers increases light uniformity (e.g., for 2 nm quantum dots, light uniformity with plasmon is 30% higher than without plasmon), although the light intensity decreases.

### *3.7. Effect of Quantum Dot Layer Thickness and Arrangement on Optical Efficiency*

In this section, the impact of quantum dot layer thickness and arrangement on the optical efficiency of Light Emitting Diodes (LEDs) is analyzed through simulations in Lumerical software. The thickness of the quantum dot layer influences both light intensity and uniformity. For thicknesses less than 10 nm, fewer quantum dots lead to lower radiative recombination rates, resulting in decreased light intensity. As the thickness increases to around 20-30 nm, optical efficiency reaches its peak due to optimal quantum dot distribution and maximum radiative recombination. However, with thicknesses exceeding 40 nm, the optical efficiency decreases due to increased non-radiative recombination and photon reabsorption. The arrangement of quantum dots also affects LED performance. A random arrangement improves light output uniformity but reduces optical efficiency slightly. On the other hand, an ordered (grid) arrangement increases optical efficiency, though it results in reduced light uniformity. These findings highlight how both the thickness and arrangement of quantum dots play a crucial role in optimizing LED performance. The Simulation results of optical efficiency can be seen in Table 4. To determine the most suitable thickness for different quantum dot sizes, it's essential to consider how their size interacts with the layer thickness. Smaller quantum dots (2 nm) exhibit strong quantum characteristics, so thinner layers (10 nm and 20 nm) are more suitable. For medium-sized quantum dots (5 nm), both thin and thick layers work, but medium thicknesses (20 nm and 30 nm) are optimal for efficiency.

Larger quantum dots (10 nm) perform better with thicker layers (30 nm and 40 nm). The 10 nm thickness is best suited for 2 nm quantum dots due to their strong quantum characteristics, which are better supported by thinner layers. For 5 nm quantum dots, the ideal layer thickness is 20 nm, as it offers the best efficiency. In the case of 30 nm thickness, it is suitable for both 5 nm and 10 nm quantum dots, providing optimal performance for these sizes. Finally, the 40 nm thickness is most appropriate for 10 nm quantum dots, as their larger size benefits from the enhanced properties of thicker layers.

A regular arrangement of quantum dots enhances optical gain by creating resonance at specific wavelengths, enabling efficient light interaction. This alignment ensures in-phase emission, leading to constructive interference and amplified intensity.

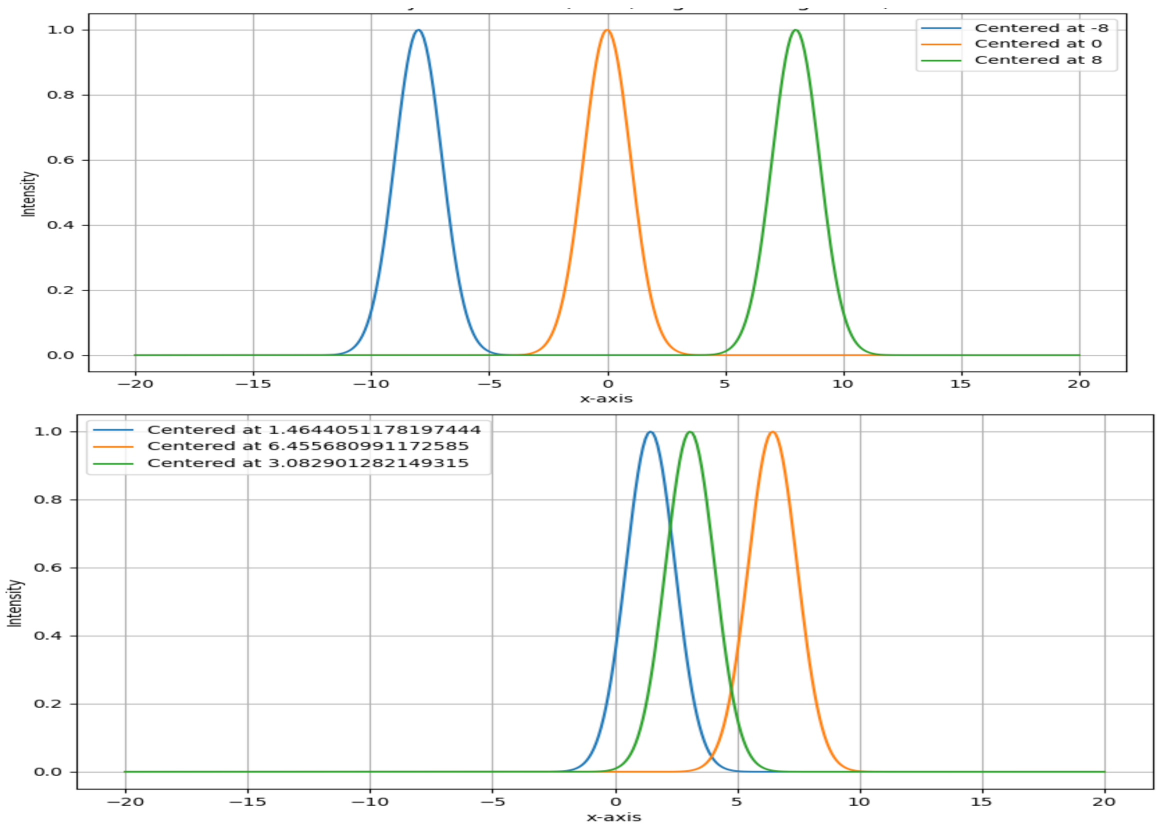



**Fig. 5.** (a) Intensity distribution for 10 nanometer quantum dots, regular arrangement, and (b) Intensity distribution for 10 nanometer quantum qots, random arrangement

In contrast, a random arrangement disrupts resonance and reduces constructive interference, lowering optical gain and emission efficiency. In Fig. 5 (a), the intensity distribution for the 10 nm quantum dots in a regular arrangement likely demonstrates more uniformity and a stronger, more focused light emission due to resonance effects and constructive interference, as previously mentioned.

On the other hand, Fig. 5 (b) shows the intensity distribution for the 10 nm quantum dots in a random arrangement. This distribution is likely less uniform, with weaker and more scattered emission due to the lack of resonance and interference, resulting in lower optical gain compared to the regular arrangement. The diagram illustrating the impact of plasmonic resonance on light emission is shown in Fig. 6.

**Table 5.** Points of maximum and minimum electromagnetic field intensity

| Quantum Dot Size (nm) | Location of Maximum Field Intensity (nm) | Location of Minimum Field Intensity (nm) | Relative Field Intensity at Maximum (%) |
|---|---|---|---|
| **2** | 5 (near plasmonic layer) | 20 (inside the active layer) | 180 |
| **5** | 10 (middle of the active layer) | 25 (far from the plasmonic layer) | 140 |
| **10** | 15 (inside LED structure) | 30 (center of the active layer) | 100 |

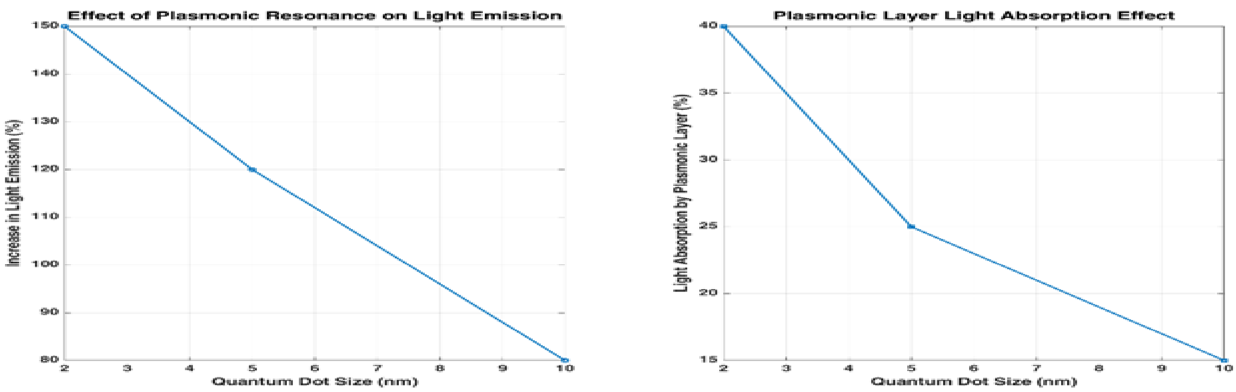



**Fig. 6.** Impact of plasmonic resonance on light emission

**Table 6. C**omparing the current research with previous research

| Improvement Technique | Device Configuration | Improvement Criteria | Articles |
|---|---|---|---|
| Integration of sputtered gold nanoparticles. | ITO/Au NPs/ZnMgO/QDs/TFB/PEDOT:PSS/Al | Luminescence increased by 1.41 times, current efficiency improved by 1.29 times. | Perveen et al, 2018. Chinese Physics B. [12]. |
| Gold-doped PEDOT:PSS hole injection layer. | ZnCdSe/ZnS QDs emission layer, gold-doped PEDOT:PSS hole injection layer. | ٪۸۰ improvement in brightness, EQE of 8.2%, current efficiency of 29.1 cd/A. | Chen et al, 2016. Nanoscale Research Letters. [13]. |
| Multi-size/space gold nanounits with thin aluminum oxide layer. | Multi-sized gold nanoparticles with Al2O3 layer, coated with quantum dots. | Approximately one order of magnitude increase in photoluminescence. | Kosger et al, 2023. Journal of Physics D: Applied Physics. [14]. |
| Integration of 2D plasmonic nanograting structure on the electrode. | Colloidal quantum dots, metal-dielectric plasmonic bridge, nanograting structure. | Electroluminescence intensity increased by 34.72%; photoluminescence increased by 32.63%. | Bhave et al, 2015. Nanotechnology. [15]. |
| Using lithographically defined plasmonic nanostructures on GaAs active substrates. | Gold tips on GaAs substrates with adjacent self-assembled InGaAs quantum dots. | This paper reports a 60% reduction in the luminescence signal of quantum dots with decreasing the spacing between the dots. | Bracher et al, 2014. [16]. |
| Coating CdSe/ZnS QDs and silver nanoparticles on gallium-containing ZnO interlayer. | CdSe/ZnS QDs, InGaN/GaN QWs, silver nanoparticles, gallium-doped ZnO. | The QD emission intensity is enhanced through SP coupling; consistent with LED performance. | Lin et al, 2018. Optics Express. [17]. |
| Using indium phosphide quantum dots for non-toxic quantum dot LEDs and increasing efficiency with gold plasmonic layer | Indium phosphide quantum dots with plasmonic layers (gold nanoparticles). | Increase light intensity by up to 150% and quantum efficiency by up to 38%. | Current research |

The results indicate that for optimizing the optical gain of quantum dot-based LEDs, both the thickness and arrangement of the quantum dots must be carefully adjusted. This ensures both high optical gain and appropriate uniformity in the light output.

### *3.8. Analysis of Plasmonic Resonance and Its Effect on Light Emission Enhancement*

This section investigates the impact of plasmonic resonances on the enhancement of light emission in quantum dot-based light-emitting diodes (LEDs) with plasmonic layers. Simulations were conducted using the Lumerical software, and the effect of quantum dot size on light emission intensity and quantum efficiency was evaluated. The simulation results show that plasmonic resonances can enhance the radiative recombination rate, leading to an increase in light emission intensity. This effect is strongly dependent on the size of the quantum dots and their distance from the plasmonic layer.

Regarding the distribution of electromagnetic field intensity, the results show that for small quantum dots (2 nm), the maximum intensity is near the plasmonic layer, while the minimum is in the active layer, farther from the plasmonic surface. For medium-sized quantum dots (5 nm), the maximum intensity is at a balanced distance from the plasmonic layer, improving the radiative recombination rate, while the minimum intensity remains farther from the active layer. For large quantum dots (10 nm), the intensity distribution becomes more uniform, with a reduced difference between maximum and minimum points. The maximum field intensity is deeper within the structure compared to smaller quantum dots. Table 5 presents the points of maximum and minimum electromagnetic field intensity. Fig. 7 displays the graph of maximum and minimum field intensities.

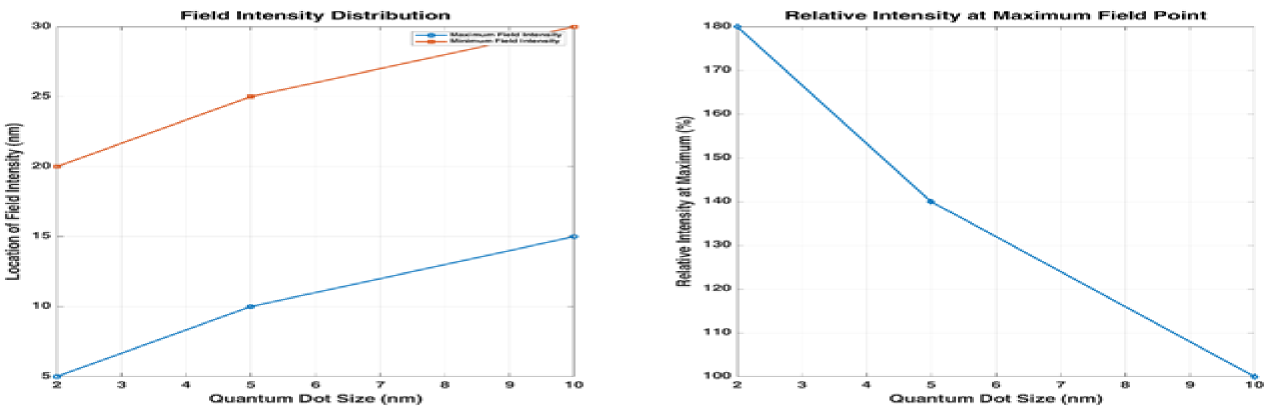



**Fig. 7.** Maximum and minimum field intensities

It can be concluded from the table and figure that for 2 nm quantum dots, the maximum intensity occurs at 5 nm near the plasmonic layer, with a relative field intensity of 180%, while the minimum intensity is observed at 20 nm, inside the active layer. For 5 nm quantum dots, the maximum intensity is at 10 nm in the middle of the active layer, with a relative intensity of 140%, and the minimum intensity is at 25 nm, farther from the plasmonic layer. For 10 nm quantum dots, the maximum intensity is at 15 nm inside the LED structure, with a relative intensity of 100%, and the minimum intensity occurs at 30 nm, at the center of the active layer.

### *3.9. Comparison of Results with Previous Research*

In this section, the results obtained from Lumerical simulations are compared with experimental and theoretical data presented in previous research. This comparison helps assess the accuracy and reliability of the simulated model and highlights the improvements brought by the use of quantum dots and plasmonic layers in light-emitting diodes (LEDs). Table 6 presents a comparison between the simulation results and past research.

## 4. Conclusions

The main objective of this research was to investigate the impact of plasmonic layers and quantum dot size on the intensity and wavelength of light emitted from the diode, and to optimize these parameters for maximum light efficiency. The results obtained from simulations confirmed the hypotheses and demonstrated that design parameters play a significant role in the performance of light-emitting diodes (LEDs). Key findings of this study include the following: Quantum dot size and plasmonic layer thickness were identified as critical parameters in optimizing LEDs. Numerical analyses showed that changing the quantum dot size led to shifts in the emission wavelength and changes in light output intensity. Additionally, the thickness and optical properties of the plasmonic layer directly affected the enhancement of the local electromagnetic field, thus improving light efficiency. The presence of the plasmonic layer effectively enhanced the electromagnetic field, resulting in a significant increase in light emission, attributed to surface plasmon resonance. Moreover, proper design choices were found to improve the efficiency of LEDs compared to traditional diodes. A comparison of this research with past studies revealed that the optimized design incorporating plasmonic layers and quantum dot size offered better performance than conventional diodes. This performance improvement is crucial for the development of more efficient LEDs for display, lighting, and optical communication applications. In conclusion, the use of plasmonic layers and the optimal selection of quantum dot size can significantly improve the intensity and wavelength of light emitted from "LEDs". This research provides valuable guidance for the design of quantum dot-based LEDs and paves the way for the development of highly efficient light sources in photonics and nanophotonic.

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## Conflicts of interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

## Authors contribution statement

P. Amiri: Simulation, Writing – Original Draft. A. Jamshidi Zavaraki: Supervision, Writing – Review & Editing.

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