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Common Aperture DSLR Camera Design Approach with Diffractive Lens

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Anahtar Kelimeler

Sayısal Tek Mercek Yansımalı Kamera
Optik Sistem Tasarm
Kırınımlı Optik Eleman

Graphical/Tabular Abstract (Grafik Özet)

Digital Single-Lens Reflex (DSLR) cameras are widely used across various fields; however, their dependence on eyepieces imposes functional limitations. To overcome this constraint, this study introduces a comprehensive optical system approach incorporating specialized diffractive optical elements, enabling simultaneous focusing on both the viewfinder and the image sensor (Figure A). / Sayısal Tek Lensli Refleks (DSLR) kameralar çeşitli alanlarda yaygın olarak kullanılır; ancak, göz merceklerine olan bağımlılıkları işlevsel sınırlamalar getirir. Bu kısıtlamanın üstesinden gelmek için, bu çalışma, hem vizöre hem de görüntü sensörüne aynı anda odaklanmayı sağlayan özel kırınımlı optik elemanları içeren kapsamlı bir optik sistem yaklaşımı sunar (Figür A).

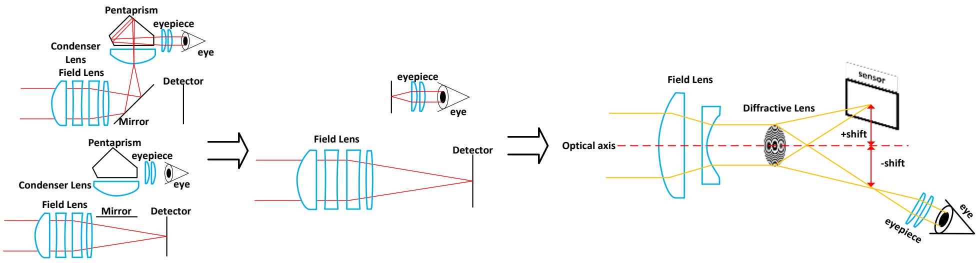

***Figure A**: General Structure of DSLR cameras and the proposed structure / DSLR kameraların genel yapısı ve önerilen yapı*

Highlights (Önemli noktalar)

- *Diffractive optical element design that can focus the secene radiation on two different points on the focal plane simultaneously / Sahne ışınımını aynı anda odak düzlemindeki iki farklı noktaya odaklayabilen kırınımlı optik eleman tasarımı.*
- *Validation of the two-regional diffractive lens design by comparison with equivalent ideal lenses. / İki bölgeli kırınımlı mercek tasarımının, eşdeğer ideal merceklerle karşılaştırılarak doğrulanması*
- *A new DSLR camera structure that uses two-regional diffractive optical element. / İki bölgeli kırınımlı optik eleman kullanan yeni bir DSLR kamera yapısı.*

Aim (Amaç): *In this study, it is aimed to design a diffractive optical element that can simultaneously transmit the scene radiation to both the sensor and the eyepiece for use in DSLR cameras. / Bu çalışmada, DSLR kameralarında kullanılmak üzere sahne ışınımını eş zamanlı olarak hem sensöre hem de göz merceğine iletebilen kırınımlı bir optik elemanın tasarlanması amaçlanmıştır.*

Originality (Özgünlük): *A new design methodology for DSLR cameras is presented using a two regional diffractive optical element for the first time. / DSLR fotoğraf makineleri için ilk kez iki bölgeli kırınımlı optik eleman kullanan yeni bir tasarım metodolojisi sunulmaktadır.*

Results (Bulgular): *Intensity distributions generated using optical wave propagation simulations have shown that the two regional diffractive optical element can focus scene radiation on both the sensor and the eyepiece simultaneously. / Optik dalga yayılım simülasyonları kullanılarak oluşturulan şiddet dağılımları, iki bölgesel kırınımlı optik elemanın sahne radyasyonunu aynı anda hem sensöre hem de göz merceğine odaklayabileceğini göstermiştir.*

Conclusion (Sonuç): *The innovative optical design method for DSLR cameras proposed in this study eliminates the need for complex lens systems traditionally used in eyepieces, offering a novel alternative. The effectiveness of the proposed designs was validated through comparisons with ideal lenses possessing similar optical parameters./ Bu çalışmada önerilen DSLR kameralar için yenilikçi optik tasarım yöntemi, geleneksel olarak göz merceklerinde kullanılan karmaşık lens sistemlerine olan ihtiyacı ortadan kaldırarak yeni bir alternatif sunar. Önerilen tasarımların etkinliği, benzer optik parametrelere sahip ideal lenslerle yapılan karşılaştırmalar yoluyla doğrulanmıştır.*

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Abstract

Digital Single-Lens Reflex (DSLR) cameras have widespread applications across various fields. Yet, their reliance on eyepieces poses limitations on their functionality. To address this constraint, a comprehensive optical system approach utilizing specialized diffractive optical elements, enabling concurrent focusing on both the viewfinder and the image sensor has been developed in this study. The effectiveness of this innovative design approach has been verified through comparative analysis with conventional separated ideal lenses. The outcome of the simulations was shared, and this study is expected to pave the way for advanced optical system designs and inspire novel approaches in camera technology development.

Kırınımlı Lens ile Ortak Açıklık DSLR Kamera Tasarım Yaklaşımı

Makale Bilgisi

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Öz

Sayısal Tek Mercek Yansımalı (DSLR) kameralar çeşitli alanlarda yaygın uygulamalara sahiptir. Ancak göz merceklerine olan bağımlılıkları, işlevselliklerine sınırlamalar getirmektedir. Bu kısıtlamayı gidermek için, bu çalışmada hem vizöre hem de görüntü sensörüne eşzamanlı odaklanmayı mümkün kılan, özel kırınımlı optik elemanları kullanan kapsamlı bir optik sistem yaklaşımı geliştirilmiştir. Bu yenilikçi tasarım yaklaşımının etkinliği, geleneksel ayrılmış ideal merceklerle karşılaştırmalı analiz yoluyla doğrulanmıştır. Simülasyon sonuçlarının paylaşıldığı bu çalışmanın, ileri optik sistem tasarımlarının önünü açması ve kamera teknolojisi geliştirmede yeni yaklaşımlara ilham vermesi beklenmektedir.

1. INTRODUCTION (GİRİŞ)

Technological progress has introduced new possibilities in camera design. The evolution has seen a transition from traditional single-lens reflex cameras to digital versions (DSLRs), with a current shift toward mirrorless models. Despite this evolution, the unique capability of interchangeable lenses continues to make DSLR cameras indispensable in both scientific and industrial applications.

The core design of DSLR cameras incorporated a mirror system that enabled users to view scenes directly through an eyepiece before redirecting light to the image sensor. While this traditional design had limitations, particularly for video capture, the advent of mirrorless systems offered a solution by providing simultaneous scene capture and digital preview capabilities. However, despite the advantages of mirrorless technology, it has not entirely replaced mirror-based systems.

Though eliminating the mirror simplifies the DSLR camera structure, it presents new challenges. Digital previews cannot perfectly replicate the optical viewing scene, with limitations in conveying scene characteristics such as contrast accurately. Additionally, mirrorless systems face difficulties in viewing in bright sunlight. These limitations highlight the need for an innovative optical solution that combines the benefits of mirrorless design while maintaining true optical viewing capabilities [1-6].

Diffractive optical elements have begun to be used in many applications due to their design freedoms and advantages over refractive lenses. It is expected to replace refractive optics in the future. Diffractive optics in common aperture optical systems have begun to be designed and - have the potential to

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create solutions for many electro-optical systems soon. DSLR camera design is a well-known common aperture design problem in the literature. Although optical structures such as beam splitters or mirrors are used in common aperture designs, better solutions may be produced with the advantages of diffractive optics [7-12].

Based on the literature, Bauer et al. [1] explored the design of electronic viewfinders using freeform optics, focusing on a mirrorless configuration with an OLED-based (organic light-emitting diode) display. In a follow-up study, Bauer et al. [2] developed a similar viewfinder with an OLED-based display and five reflective surfaces, also in a mirrorless configuration. Hamed et al. [6] examined optical viewfinders, presenting a detailed table of the limitations of digital optical viewfinders. Lim et al. [13] investigated mechanical mirror systems aimed at improving mirror speed. Additionally, Yoon et al. [14] compared DSLRs and digital cameras, analyzing image capture through mirrored structures versus faster digital systems. While both mirrorless and mirrored approaches have their respective advantages and drawbacks, a gap exists in the literature. This study aims to address that gap by proposing a design approach that combines the fast scene-capturing capability of mirrorless DSLRs with the ability to produce an exact image of the scene, without conversion, as seen in mirrored DSLRs.In this study, a novel DSLR camera design approach is proposed, using a common aperture with a diffractive optical element. With this proposed design approach, a mirrorless DSLR camera with an eyepiece design has been developed without any mirror or OLED components.

2. THEORETICAL BACKGROUND (TEORİK ALTYAPI)

Fresnel Zone Plates (FZPs) consist of alternating opaque and transparent concentric rings. When designed precisely, each ring contributes to achieving the desired focus, enabling FZPs to operate similarly to refractive lenses. FZPs can be classified as Phase FZPs (PFZPs) and Amplitude FZPs (AFZPs) depending on how these concentric rings interact at the focal point. Because they have a higher diffraction efficiency than amplitude types, PFZPs are favored in many applications and are good substitutes for conventional refractive lenses. A 2-level PFZP was chosen for this study due to its higher diffraction efficiency and less computational time [8-12].

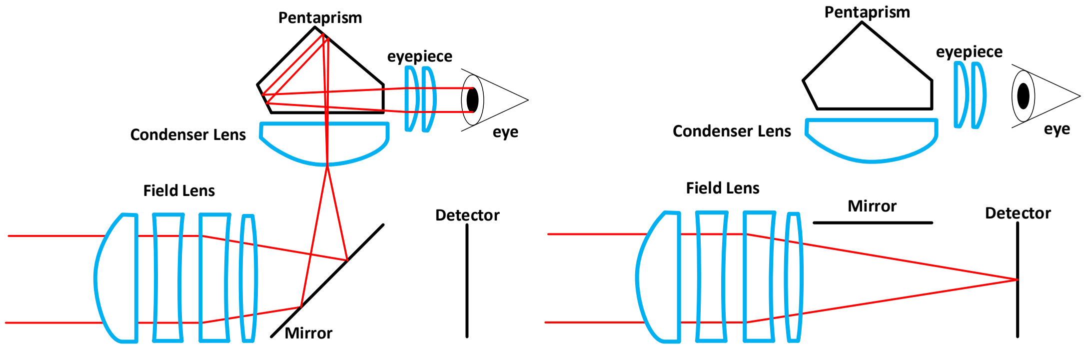
The simple working principle of a DSLR camera is shown in Figure 1. The scene is common in both the eyepiece and sensor. While taking a photograph, the mirror closes the eyepiece and the radiation coming from the scene directly falls onto the sensor. The picture of the scene seen by the eye is captured on the sensor.

The mirror configuration can be redesigned by using the two regional diffractive optical elements. The two regional behaviors of the diffractive lens make it possible to focus the scene into two different paths. With this method, scene radiation will be able to reach both the sensor and the eye at the same time. The application of this method offers a new design approach for DSLR cameras [5, 6].

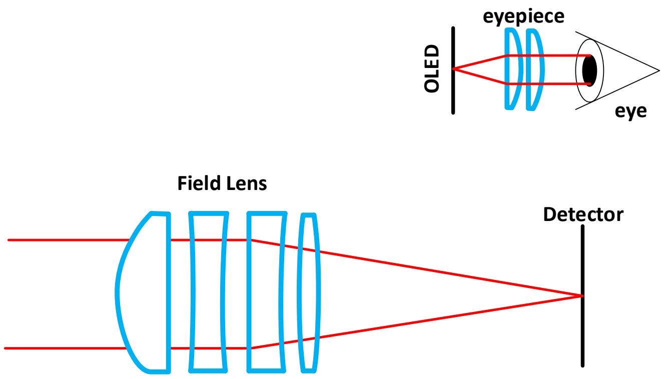
2.1. Optical Model Of DSLR Design Approach
(DSLR Tasarım Yaklaşımının Optik Modeli)

The proposed design approach modifies the traditional DSLR camera configuration in several key ways. The first is the pentaprism and mirror are removed. Second, the diffractive lens is inserted into the optical system. The advantages of the new design modification offer several benefits. First, it eliminates the need for complex optical elements like the pentaprism and second, it removes design constraints associated with the traditional mirror structure in DSLR cameras.

The new configuration maintains similar functionality to a standard DSLR camera while potentially offering a more streamlined and simplified design. By replacing conventional optical components with diffractive optical elements, the approach may lead to more compact or efficient camera systems. The simplified working diagram is shown in Figure 2.



a) DSLR camera structure with mirror (Aynalı DSLR kamera yapısı)



b) DSLR camera structure with OLED (OLEDli DSLR kamera yapısı)

Figure 1. Optical configuration of the DSLR camera. Scene radiation falls directly onto the mirror after passing the field lens. According to the position of the mirror, the radiation falls on the sensor or eyepiece. By the moving mirror, the field seen by the eye is directly saved on the sensor. Based on the mirror's position in the system, the left in a) image represents the scene as viewed through the viewfinder, while the right image in a) represents the scene as captured by the sensor. b) depicts the mirrorless DSLR configuration. The scene is generated digitally on the OLED display and seen by the eye with the eyepiece. (DSLR kameranın optik yapılandırması. Sahne radyasyonu, alan merceğinden geçtikten sonra doğrudan aynaya düşer. Aynanın konumuna göre radyasyon, sensör veya göz merceğine düşer. Hareket eden ayna sayesinde, gözün gördüğü alan doğrudan sensöre kaydedilir. Sistemdeki aynanın konumuna bağlı olarak, a)'daki soldaki görüntü, vizörden görülen sahneyi temsil ederken, a)'daki sağdaki görüntü, sensör tarafından yakalanan sahneyi temsil eder. b) aynasız DSLR yapılandırmasını tasvir eder. Sahne, OLED ekranda dijital olarak üretilir ve göz merceğiyle göz tarafından görülür.)

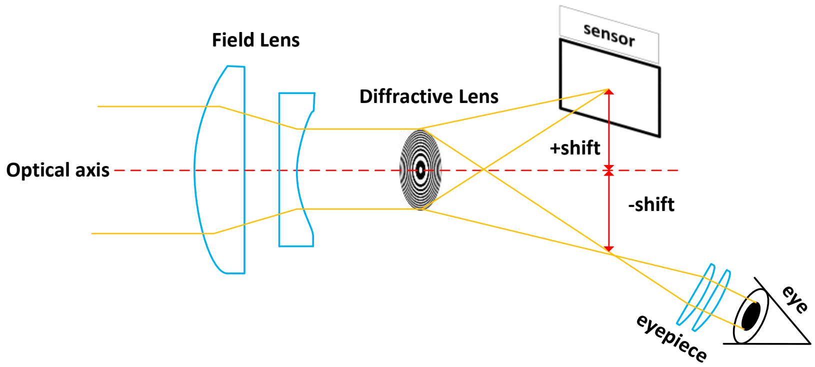


Figure 2. Working principle of the proposed DSLR camera design approach with two regional diffractive lens. The scene radiation directly falls on the field lens. After passing the field lens the radiation falls directly on the diffractive lens. The diffractive lens splits the beam in two ways. One directly falls on the sensor. The second way falls directly on the eye. By this method, the beam is split into two ways. The diffractive lens behaves like a focusing beam splitter.(Önerilen iki bölgesel kırınımlı lensli DSLR kamera tasarım yaklaşımının çalışma prensibi. Sahne radyasyonu doğrudan alan lensine düşer. Alan lensini geçtikten sonra radyasyon doğrudan

kırınımlı lense düşer. Kırınımlı lens ışını iki şekilde böler. Biri doğrudan sensöre düşer. İkinci yol doğrudan göze düşer. Bu yöntemle ışın iki şekilde bölünür. Kırınımlı lens odaklama ışın ayırıcı gibi davranır.)

2.2. Optical Model of Diffractive Lens

(Kırınımlı Lensin Optik Modeli)

Scalar diffraction theory offers two key approximations, Fresnel and Fraunhofer which are widely applicable across various optical systems. These approximations provide analytical and numerical methods for studying wave distributions in both near-field (Fresnel) and far-field conditions (Fraunhofer). The mathematical foundation for these analyses is the Huygens-Fresnel integral, which can be expressed in terms of a Fourier Transform when using the Fresnel approximation. The approximation is defined as follows [7, 20].

$$I(x,y)=\frac{e^{ikd}}{i\lambda d}e^{i\pi\frac{x^2+y^2}{\lambda d}}\Im\left\{I'(x',y')e^{i\frac{\pi}{\lambda d}\left((x')^2+(y')^2\right)}\right\} \quad (1)$$

In the case of uniform plane wave illumination, the amplitude distribution remains the same between the source plane and the lens plane, with only a phase difference present. Over typical propagation distances, this phase difference becomes insignificant as the wave travels through and before the lens plane. The propagation geometry is shown in Figure 3 with source, lens, and image planes [19,20].

The thickness of each phase level corresponds roughly to the wavelength of the light. This property allows for a simplified calculation method using an aperture function, enabling a one-step propagation approach. Mathematically, this can be expressed using the Fourier Transform and the diffractive optical element's aperture function [21].

By applying this one-step propagation method to the optical system's geometry, we can efficiently calculate both the amplitude distribution in the image plane (using the Fresnel approximation) and its corresponding angular spectrum.

$$I(x,y)=\frac{1}{i\lambda d}\Im^{-1}\left[\Im\{A(x',y')\}e^{ikd\sqrt{1-(\lambda x')^2-(\lambda y')^2}}\right] \quad (2)$$

The Huygens-Fresnel integral operates within specific constraints defined by the Fresnel approximation. The applicability of this approximation is determined by the Fresnel number, which serves as a quantitative measure for the validity range of the approximation in optical wave propagation scenarios [7, 11, 22].

$$N_F=\frac{a^2}{\lambda d} \quad (3)$$

The applicability of the Fresnel approximation is determined by the Fresnel number. A Fresnel number below 1 indicates ideal conditions for applying the approximation. However, the approximation remains reliable for Fresnel numbers as high as 20 or 30. The phase Fresnel zone plate is designed with varying material thicknesses in different regions. These thicknesses can be calculated using the following formula and the structure of the phase Fresnel zone is defined in Figure 4 [7, 11].

$$t_l=\frac{(l-1/2)}{L}\frac{\lambda}{(n-1)} \quad (4)$$

In equations 1, 2, 3, and 4, the following symbols are used.

$\Im\{\ \}$	: 2D Fourier Transform
$I'(x',y')$	: amplitude distribution in the source plane
$I(x,y)$	: amplitude distribution in the image plane
d	: distance between source and image plane
λ	: wavelength
N_F	: Fresnel number
a	: radius of a circular lens aperture
t_l	: lth level thickness
n	: refractive index of the material
l	: phase Fresnel subzone level
L	: total level of the phase Fresnel zone plate

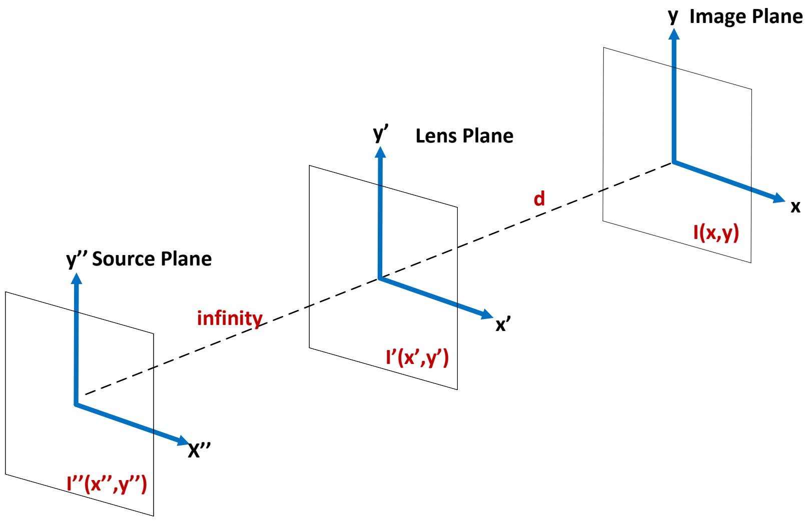


Figure 3. Optical wave propagation geometry. The geometry is the two step wave propagation geometry. In the first propagation, the beam propagates from the source plane to the lens plane. In the second propagation, the beam propagates from the lens plane to the image plane. $I(x,y)$, $I'(x',y')$, and $I''(x'',y'')$ are the amplitude distribution in the image plane, in the lens plane, and in the source plane respectively. (Optik dalga yayılım geometrisi. Geometri iki adımlı dalga yayılım geometrisidir. İlk yayılımda, ışın kaynak düzleminden mercek düzlemine doğru yayılır. İkinci yayılımda, ışın mercek düzleminden görüntü düzlemine doğru yayılır. $I(x,y)$, $I'(x',y')$, ve $I''(x'',y'')$ sırasıyla görüntü düzlemindeki, mercek düzlemindeki ve kaynak düzlemindeki genlik dağılımıdır.)

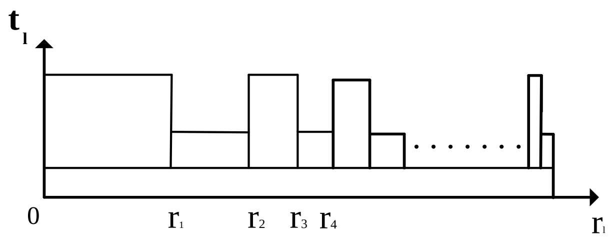


Figure 4. 2-Level Phase Fresnel zone plate material structure. The structure has been showed on a substrate material. (2-Seviyeli Faz Fresnel bölge plaka malzeme yapısı. Yapı bir alttaş malzemesinde gösterilmiştir.)

2.3. Optical Model Of Combined Diffractive Lens

(Birleştirilmiş Kırınımlı Lensin Optik Modeli)

The regional diffractive lens consists of two separate regions: a central region corresponding to the sensor and an outer region corresponding to the eye. Each region requires distinct parameter calculations to define its aperture function. These parameters depend on the specific focal lengths, wavelengths, and the number of phase Fresnel zones and subzones. Consequently, the overall aperture function is obtained by combining the individual aperture functions of the central and outer regions. The mathematical expressions for the aperture functions of these regions are presented in Equations 5 and 6.

In the equations 5 and 6, the following symbols are used.

$A_{central}(x',y')$	: aperture function of the central region
$A_{outer}(x',y')$	: aperture function of the outer region
S	: total number of phase Fresnel zones of the outer region
N	: total number of phase Fresnel zones of the central region
$shift$	: focus shift in the x direction
r_l	: l^{th} phase Fresnel zone radius
r_{l-1}	: (l-1)th phase Fresnel zone radius
D_{out}	: diameter of the outer region
D_{cen}	: diameter of the central region
$circ(x',y')$	: circular function [10,11]

$$A_{central}(x',y') = \left[\sum_{l=1}^{N*L}\exp\left(-i2\pi\frac{l-1/2}{L}\right)\left\{circ\left(\frac{x'+shift}{r_l},\frac{y'}{r_l}\right) - circ\left(\frac{x'+shift}{r_{l-1}},\frac{y'}{r_{l-1}}\right)\right\}\right].\left[circ\left(\frac{x'}{D_{cen}/2},\frac{y'}{D_{cen}/2}\right)\right] \quad (5)$$

$$A_{outer}(x',y') = \left[\sum_{l=N*L}^{S*L}\exp\left(-i2\pi\frac{l-1/2}{L}\right)\left\{circ\left(\frac{x'-shift}{r_l},\frac{y'}{r_l}\right) - circ\left(\frac{x'-shift}{r_{l-1}},\frac{y'}{r_{l-1}}\right)\right\}\right].\left[circ\left(\frac{x'}{D_{out}/2},\frac{y'}{D_{out}/2}\right) - circ\left(\frac{x'}{D_{cen}/2},\frac{y'}{D_{cen}/2}\right)\right] \quad (6)$$

3.SIMULATIONS AND RESULTS
(SİMÜLASYONLAR ve BULGULAR)

The analysis of two regional (central and outer) diffractive optical elements was conducted using MATLAB software, employing optical wave propagation techniques. Rather than using a two-step wave propagation approach, the simulation applied propagation methods directly to the lens structures. The investigation was limited to a single wavelength for verification purposes. Tables 1 and 2 provide a comparison between the diffractive optical lens parameters and their equivalent ideal lens counterparts.

The sampling parameters were carefully selected to comply with the Nyquist sampling criteria, ensuring appropriate sampling parameters in both the spatial domain for the lens and the spatial frequency domain for the image planes. To evaluate the effectiveness of the design, comparisons were made between the proposed approach and discrete ideal lenses with matching optical characteristics. The simulation results are shown in Figure 5 and Figure 6.

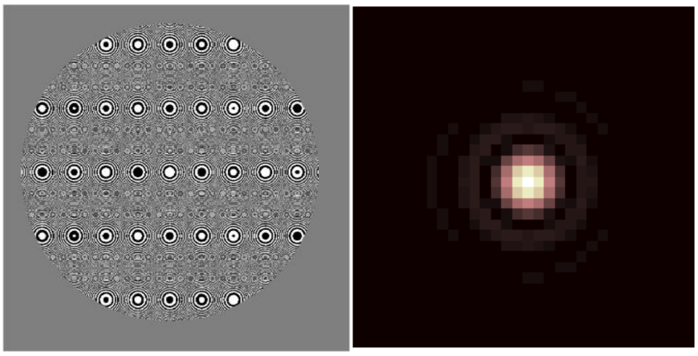
Table 1. Optical parameters of the central region with equivalent ideal lens (Eşdeğer ideal mercek ile merkezi bölgenin optik parametreleri)

	Parameters	Value
Central Region	Focal length (f)	100 mm
	Wavelength (λ)	550 nm
	Distance (d)	100 mm
	Fresnel Number (N_F)	454
	Number of Phase Fresnel Zones (N)	1536
	shift	8 mm
Ideal Lens	Focal length (f)	100 mm
	Wavelength (λ)	550 nm
	Distance (d)	100 mm
	Diameter (D_{cen})	10 mm

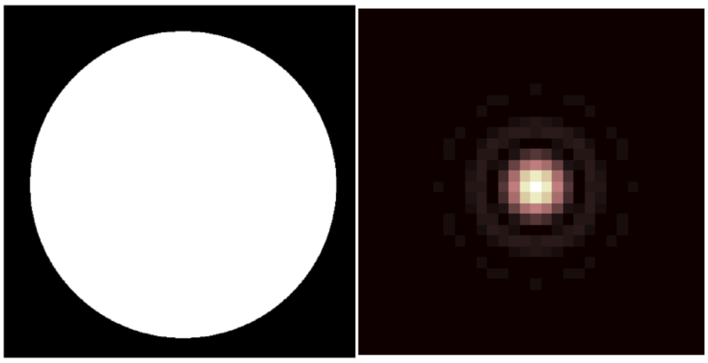
Table 2. Optical parameters of the outer region with equivalent ideal lens (Eşdeğer ideal mercek ile dış bölgenin optik parametreleri)

	Parameters	Value
Outer Region	Focal length (f)	100 mm
	Wavelength (λ)	550 nm
	Distance (d)	100 mm

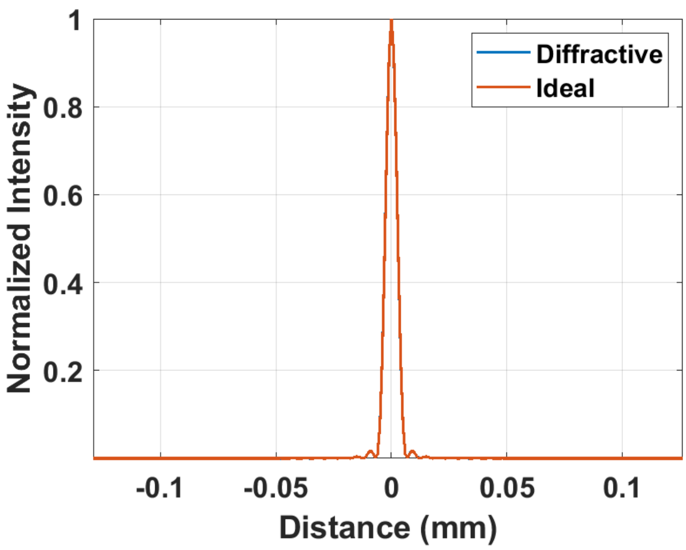
	Fresnel Number (N_F)	891
	Number of Phase Fresnel Zones (S)	2045
	shift	-8 mm
Ideal Lens	Focal length (f)	100 mm
	Wavelength (λ)	550 nm
	Distance (d)	100 mm
	Diameter (D_{out})	14 mm



a) The aperture function of the central region and its shifted focus. (Merkezi bölgenin açıklık fonksiyonu ve kaydırılmış odak noktası.)

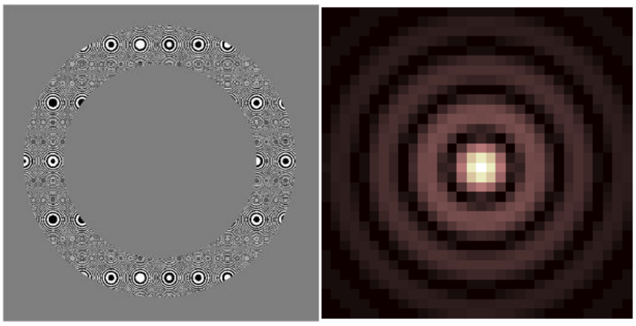


b) The aperture function of the equivalent ideal lens and its on axis focus. (Eşdeğer ideal merceğin açıklık fonksiyonu ve eksen üzerindeki odak noktası.)

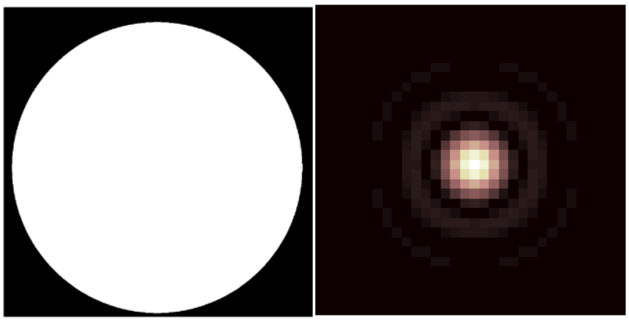


c) Comparison of the 1D intensity distributions of the diffractive lens and its equivalent ideal lens. (Kırınımlı mercek ve eşdeğer ideal merceğin 1D yoğunluk dağılımlarının karşılaştırılması.)

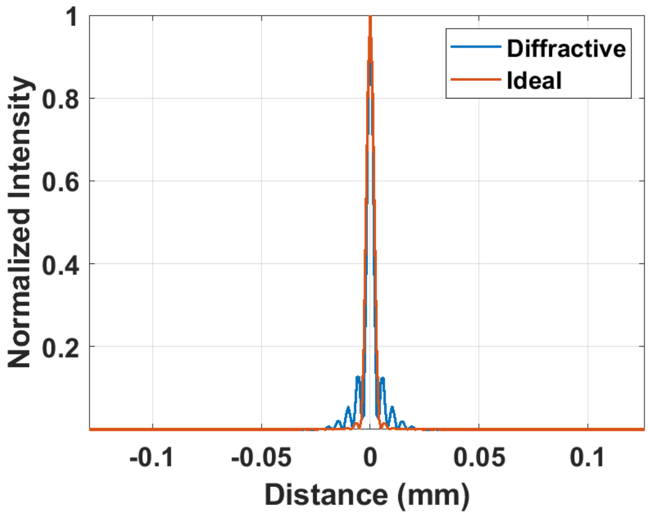
Figure 5. Simulation results of the central region and its equivalent on axis ideal lens. The ideal lens parameters were taken similarly with the diffractive lens in order to make a reasonable comparison as shown in Table 1. (Merkez bölgenin ve eksen üzerindeki ideal eşdeğer merceğin simülasyon sonuçları. İdeal mercek parametreleri, Tablo 1'de gösterildiği gibi makul bir karşılaştırma yapmak için kırınımlı mercek ile benzer şekilde alındı.)



a) Aperture function of the outer region and its focus. (Dış bölgenin açıklık fonksiyonu ve odağı.)



b) Aperture function of the equivalent ideal lens and its on axis focus. (Eşdeğer ideal merceğin açıklık fonksiyonu ve eksen üzerindeki odak noktası)



c) Comparison of the 1D intensity distributions of the diffractive lens and its equivalent ideal lens. (Kırınımlı mercek ve eşdeğer ideal merceğin 1D şiddet dağılımlarının karşılaştırılması)

Figure 6. Simulation results of the outer region with equivalent ideal lens. The ideal lens parameters were taken similarly with the diffractive lens in order to make a reasonable comparison as shown in Table 2. (Eşdeğer ideal mercek ile dış bölgenin simülasyon sonuçları. İdeal mercek parametreleri, Tablo 2'de gösterildiği gibi makul bir karşılaştırma yapmak için kırınımlı mercekle benzer şekilde alındı.)

4. DISCUSSION (TARTIŞMA)

Simulation results are presented in two figures: one depicting the central sensor focus region of the DSLR camera design, and another showing the outer eyepiece region (Figures 5 and 6 respectively)

Analysis reveals that the diffractive lens's central region performs comparably to an ideal lens with similar characteristics. However, the outer region exhibits different behavior, notably an increase in secondary maxima within the intensity distribution pattern. This divergence can be attributed to the circular obstruction present in the lens design, which amplifies these secondary maxima effects. The spatial resolution of both the sensor and the eye-view component of the optical system can be determined using the Rayleigh resolution criterion [15]. The radius of the airy disc sets the spatial resolution limit of an electro-optical system, as expressed by the following formula.

$$r_R = 1.22\lambda F_{\#} \tag{7}$$

Using the equation, the spatial resolution of the inner part of the DOE at the focal point is 6.7 µm, while the outer part achieves a spatial resolution of 4.8 µm. The spatial resolution is directly related to the F# of the DOE. To achieve lower spatial resolution, either the diameter of the DOE can be increased, or the focal length can be reduced. The parameters in this study are determined to validate the accuracy of the proposed design approach for this novel DSLR camera. Additionally, adjustments can be made for different sensor sizes or spatial resolutions by modifying the "shift" parameters listed in Tables 1 and 2 accordingly and F#. For high-resolution sensors, such as those with a pixel size of 2–3 µm, an F# of 3 or 4 can be achieved by increasing the diameter to approximately 30 mm or decreasing the focal length to 30 mm as an example. Therefore the parameters of the diffractive lens can be adjusted according to the sensor.

The research focused on demonstrating the viability of a common aperture DSLR design using just one wavelength as a simplified test case. While this initial proof of concept was limited to a single wavelength, the optical system can be adjusted and enhanced for different wavelengths across the visible spectrum. The same design principles with optimization techniques could be applied to accommodate other visible wavelengths [23-25]. In this research, it is chosen to verify the design approach with only one wavelength to reduce complexity and provide a clear initial validation.

The methodology developed in this research extends beyond DSLR cameras to potentially benefit various devices, including smartphones, ultimately enhancing user experience. Although the verification process specifically focused on DSLR cameras, the principles can be adapted for any optical system requiring an eyepiece. Besides these, the common aperture design proposed here can also be generalized for applications where different spectral bands are used together [26].

This study successfully validated a novel design approach for DSLR cameras incorporating diffractive optical elements, overcoming previous limitations. The versatility of this design methodology makes it applicable to a broad range of electro-optical systems that utilize eyepieces, demonstrating its potential impact beyond just camera technology.

5. CONCLUSION (SONUÇ)

The novel optical design method for Digital Single Lens Reflex Camera (DSLR) introduced in this research removes the need for complicated lens systems typically associated with eyepieces, presenting an innovative alternative. The results of the designs were verified by comparing them with ideal lenses with similar optical parameters.

The proposed design approach eliminates the drawbacks of mirrored and digital structures that recreate the image used in eyepieces.

DECLARATION OF ETHICAL STANDARDS (ETİK STANDARTLARIN BEYANI)

The author of this article declares that the materials and methods they use in their work do not require ethical committee approval and/or legal-specific permission.

Bu makalenin yazarı çalışmalarında kullandıkları materyal ve yöntemlerin etik kurul izni ve/veya yasal-özel bir izin gerektirmediğini beyan ederler.

AUTHORS' CONTRIBUTIONS (YAZARLARIN KATKILARI)

***Ahmet ÜNAL*:** He conducted the simulations, analyzed the results and performed the writing process.

Simülasyonları yapmış, sonuçlarını analiz etmiş ve maklenin yazım işlemini gerçekleştirmiştir.

CONFLICT OF INTEREST (ÇIKAR ÇATIŞMASI)

There is no conflict of interest in this study.

Bu çalışmada herhangi bir çıkar çatışması yoktur.

REFERENCES (KAYNAKLAR)

[1] A. Bauer and J. P. Rolland, "Design of a freeform electronic viewfinder coupled to aberration fields of freeform optics," (2015), Opt. Express 23, 28141-28153 https://doi.org/10.1364/OE.23.028141

[2] A. Bauer, M. Pesch, J. Muschaweck, F. Leupelt, and J. P. Rolland, (2019), "All-reflective electronic viewfinder enabled by freeform optics," Opt. Express 27, 30597-30605 https://doi.org/10.1364/OE.27.030597

[3] A. Bauer and J. P. Rolland, (2014), "Visual space assessment of two all-reflective, freeform, optical see-through head-worn displays," Opt. Express 22, 13155-13163 https://doi.org/10.1364/OE.22.013155

[4] A. H. Incekara, D. Z. Seker, A. Delen, and A. Acar, Investigating The Suitability Of Mirrorless Cameras In Terrestrial Photogrammetric Applications, (2017), “ISPRS Annals of the Photogrammetry”, Remote Sensing and Spatial Information Sciences, IV-4/W4, 259--262, DOI 10.5194/isprs-annals-IV-4-W4-259-2017

[5] J. M. Ryu, G. M. Gang, H. K. Lee, K. Lee, M. Heu, and J. H. Jo, (2015), "Optical Design and Fabrication of a Large Telephoto Zoom Lens with Fixed f/2.8 and Light Autofocus Lens", J. Opt. Soc. Korea 19, 629-637, https://opg.optica.org/josk/abstract.cfm?URI=josk-19-6-629

[6] S. Hamed, M. J. A. A. Salama, and M. M. M. Hassan, (2022), “Developments of the viewfinder system in digital photographic cameras”, 7, 4, 834-849, Arab Association for Islamic Civilization and Art, DOI : 10.21608/mjaf.2021.91869.2464

[7] A. Ünal, (2023), "Frequency selective diffractive optical element (FSDOE)", Proc. SPIE 12518, Window and Dome Technologies and Materials XVII, 125180C; https://doi.org/10.1117/12.2657048

[8] A. Ünal, (2024), “Analytical and numerical fresnel models of phase diffractive optical elements for imaging applications.”, Opt Quant Electron 56, 960 https://doi.org/10.1007/s11082-024-06906-6

[9] A. Ünal, (2024), “Electro-optical system, imaging infrared and laser range finder, design with dual squinted combined lens for aerial targets”. J Opt. https://doi.org/10.1007/s12596-024-02057-9

[10] A. Ünal, (2023), “Semi-active laser seeker design with combined diffractive optical element (CDOE)”. J Opt 52, 956–968 https://doi.org/10.1007/s12596-022-00954-5

[11] A. Ünal, (2023), “Laser seeker design with multi-focal diffractive lens”, Eng. Res. Express 5 045014, DOI 10.1088/2631-8695/ad0024

[12] A. Ünal, (2024), “Dual mode, imaging infrared and semi-active laser, seeker design with squinted combined diffractive optical element”. J Opt https://doi.org/10.1007/s12596-024-01657-9

[13] S. Lim, B. H. Ko, K. S. Park, et al. (2012), “Design of mirror system in digital single lens reflex camera for high-speed continuous shooting”, Microsyst Technol 18, 1487–1496. https://doi.org/10.1007/s00542-012-1578-x

[14] B. S. Yoon, and T.R. Anderson, (2014), "Comparison of Technological Performance between Digital Single-Lens Reflex Cameras and Mirrorless Cameras", Advances in Business and Management Forecasting (Advances in Business and Management Forecasting, Vol. 10), Emerald Group Publishing Limited, Leeds, pp. 55-71, https://doi.org/10.1108/S1477-407020140000010015

[15] D. Atwood, (2000) Soft X-Rays and Extreme Ultraviolet, Cambridge University Press

[16] L. N. Hazra, Y. Han, C.A. Delisle, Kinoform lenses: (1995), “Sweatt model and phase function”, Optics Communications, Volume 117, Issues 1–2, Pages 31-36, https://doi.org/10.1016/0030-4018(95)00071-F

[17] L. Hazra and C. A. Delisle, (1997), "Higher order kinoform lenses: diffraction efficiency and aberrational properties," Optical Engineering 36(5), https://doi.org/10.1117/1.601375

[18] L. N. Hazra, Y. Han, C. Delisle, (1992), “Curved kinoform lenses for stigmatic imaging of an axial object at infinity”, Optics Communications, Volume 90, Issues 4–6, Pages 201-206, https://doi.org/10.1016/0030-4018(92)90260-X

[19] J. W. Goodman, (1996), Introduction to Fourier Optics, Second Edition, McGraw-Hill Series

[20] R. E. Blahut, (2004), Theory of Remote Image Formation, Cambridge University Press

[21] J. D. Schmidt, (2010), “Numerical Simulation of Optical Wave Propagation With examples in MATLAB”, SPIE Press

[22] T. W. N. Dickinson, (2016), "Simulation, Design, and Test of Square, Apodized Photon Sieves for High-Contrast, Exoplanet Imaging". Theses and Dissertations. https://scholar.afit.edu/etd/336

[23] Y. Peng, (2018), “Computational Imaging with Diffractive Optics”, A Thesis Submitted In Partial Fulfillment Of The Requirements For the Degree Of Doctor Of Philosophy, The University of British Columbia April DOI : 10.14288/1.0365608

[24] Y. Peng, Q. Fu, F. Heide, W. Heidrich, (2016), “The Diffractive Achromat: Full Spectrum Computational Imaging with Diffractive Optics” ACM Trans. Graph. 35, 4, Article 31 (July 2016), https://doi.org/10.1145/2897824.2925941

[25] X. Zhang, Z. Yang, T. Sun, H. Yang, K. Han, B. Hu, (2017), "Optical system design with common aperture for mid-infrared and laser composite guidance," Proc. SPIE 10256, Second International Conference on Photonics and Optical Engineering, 102560S doi: 10.1117/12.2256433

[26] Barış, M., Metin, F. C., Karabulut, N. K., Özyücel, F. Ö. (2018). 8-125 MM KOLEMANİT CEVHERİNİN NIR/CCD OPTİK AYIRICI İLE ZENGİNLEŞTİRİLMESİ. Gazi University Journal of Science Part C: Design and Technology, 6(2), 414-425. https://doi.org/10.29109/http-gujsc-gazi-edu-tr.344767