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Article

Design of Bicycle Lighting Systems: Material Mechanics Design of Mounting Brackets and Light Field Relationship Studies

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Abstract: In today's post-pandemic era, the number of cycling enthusiasts continues to grow significantly. Due to work commitments during daytime hours, cycling sessions with friends typically occur on weekends or during evening hours, making night riding an excellent stress-relief activity and a preferred cycling mode for those who wish to avoid sun exposure. While urban nighttime environments feature abundant street lighting and illuminated signage, bicycles traveling on roadways often remain difficult for approaching vehicles from behind and pedestrians ahead to detect in time. Given the critical safety considerations for nighttime cycling, bicycle lights have become essential equipment components, making the installation of dedicated front and rear bicycle lights absolutely crucial for rider safety. However, selecting the appropriate bicycle light system presents significant challenges for most cyclists. The majority of riders instinctively gravitate toward lights offering high brightness levels and extended illumination distances, yet this approach may not address all safety requirements effectively. This research approaches bicycle light selection from a comprehensive design and manufacturing perspective, focusing on analyzing optimal light field patterns and distributions while simultaneously investigating the material mechanics design of mounting bracket systems. The objective is to ensure that properly selected bicycle lighting systems provide adequate safety coverage for both nighttime riding and daytime visibility applications, creating a holistic approach to cyclist safety through engineered lighting solutions and robust mounting mechanisms.

Keywords: LED, Mounting bracket, Light field, Illumination, 3D lamp fixture diagram, Lampshade, Bicycle headlight, Lamp housing design

1. Introduction

"When I used bicycle lights during daytime training, other drivers paid more attention to me. When they had to overtake me, they gave me more space and maintained a safer distance from me. Now, I advocate to everyone I know that when cycling, bicycle lights must be installed and turned on at all times, regardless of the time of day". This public statement from Mads Pederson, the Road Cycling World Champion, demonstrates the critical importance of bicycle lighting systems during daytime riding [1].

Bicycle light functionality can be categorized into two primary purposes: warning systems and illumination systems. First, warning lights serve the primary purpose of visibility and detection, typically used in well-lit environments such as urban streets [2]. Second, illumination lights are divided into general use and off-road applications. Off-road usage often occurs in unfamiliar terrain such as overgrown areas rather than paved roads, necessitating emphasis on broader illumination coverage. The functional difference between daytime running lights and warning lights lies in their application during adverse weather conditions or rainy cycling situations, where daytime running lights enhance safety visibility. Warning lights primarily function to "maintain safety and visibility", and during nighttime rides when battery power gradually depletes, emergency lighting capabilities allow cyclists to switch to low-power warning modes to remain visible in darkness.

Beyond warning and illumination functions, bicycle light characteristics can be further categorized into four distinct rider types based on specific cycling needs:

Urban cyclists represent primarily commuter riders who typically cycle during daylight hours or well-lit nighttime conditions. However, they inevitably encounter roads with sparse street lighting, making "warning light mode" essential to avoid potential hazards. For illumination purposes, lights with cutoff line design are recommended. The cutoff line creates a distinct bright-dark boundary designed to prevent light interference with oncoming vehicle safety, ensuring the light height does not exceed opposing drivers' eye level.

Road cyclists require both illumination and warning capabilities to be critically important on roadways. In areas with limited street lighting, illumination plays a crucial role in protecting rider safety by clearly illuminating road conditions within a 1-20 meter range. These lights must feature low battery indicators and provide stable illumination output. During persistent rainy weather, bicycle lights with "daytime running light mode" are highly recommended. Cutoff line-designed illumination lights prevent glare hazards or interference with oncoming traffic, while warning lights enhance visibility to opposing traffic lanes, increasing rider presence detection even in poor weather conditions from considerable distances.

Off-road cyclists operating in vegetation-dense environments require essential illumination capabilities, with light pattern selection being particularly crucial. Off-road cycling benefits from "full-road vision light patterns" that provide clear, wide, and evenly distributed brightness across entire paths, enabling early detection of surface elevation changes and sudden hazards from either direction. These lighting systems must possess shock-resistant characteristics, wide beam angle coverage, and excellent battery endurance. Helmet-mounted lights are especially recommended as they illuminate terrain according to the rider's direct line of sight.

Long-distance cyclists encounter diverse situations throughout their journeys, making "multi-functional lights" that combine all three aforementioned characteristics most suitable. However, battery endurance represents the most critical consideration, with replaceable battery systems or power bank-compatible charging capabilities recommended to ensure safe and smooth travel completion.

From this analysis, it becomes evident that satisfying the diverse day and night cycling needs of bicycle riders requires designing lights based on fundamental principles of safety, brightness, and human-centered design. Manufacturing bicycle lighting systems must maintain the dual capability of providing turning assistance through wide-range close-distance illumination and clear forward visibility through continuous near-to-far illumination coverage. These functional requirements must be integrated with sophisticated design aesthetics to create professional and fashionable bicycle products and accessories that meet the evolving demands of modern cycling enthusiasts.

Bicycle light beam pattern selection and design considerations: Beam pattern refers to the specific shape and brightness distribution of light projected by a lighting fixture, with different patterns serving distinct applications based on their intended use. For instance, search and rescue operations require concentrated central illumination capable of projecting several hundred meters while maintaining peripheral lighting to expand search coverage area, making flashlights ideal for such applications. When applied to transportation vehicles, beam patterns must prioritize illuminating the travel surface and providing clear visibility from near to far distances while ensuring no interference with oncoming traffic through proper cutoff line design. When purchasing bicycle lights, evaluating whether the beam pattern enhances nighttime riding safety represents a crucial consideration factor.

Common beam pattern classifications: Bicycle lighting systems typically employ three primary beam pattern categories [3]. Elliptical patterns concentrate light for extended range projection, making them suitable for object searching and emergency response applications. However, their inability to illuminate near-field areas renders them inappropriate for bicycle lighting applications. Enhanced elliptical patterns moderately improve near-field illumination deficiencies but still fail to achieve uniform light distribution or adequate width coverage. This pattern tends to focus attention on the brightest forward point while potentially obscuring dangers hidden in darker peri optics design extended light sources optics design extended light sources pheral areas. Full-road vision patterns provide wide-angle coverage with uniform light distribution across entire roadways, ensuring clear visibility at both near and far distances. This pattern enables immediate detection of activity on either side of the bicycle, effectively preventing blind spot hazards and proving suitable for both mountain roads and urban pathways [4].

Optimal bicycle light design principles: Bicycle lighting systems should prioritize full-road vision patterns, emphasizing broad coverage and uniform light distribution while avoiding excessive brightness that creates road surface glare and obscures visibility [5]. Proper beam pattern selection prevents situations where single bright spots render other areas invisible, ensuring lighting systems meet both safety and performance requirements through appropriate optical design choices [6].

Functional design element one-Near-field illumination zone: Bicycle lights lacking dedicated near-field design project light in scattered patterns that fail to illuminate areas immediately adjacent to the bicycle frame. Angling lights downward to compensate reduces far-field coverage distance, creating potentially dangerous visibility gaps. Near-field zones require clear, bright illumination to enable riders to identify road conditions and avoid hazards such as debris or potholes, thereby enhancing overall riding safety.

Functional design element two-Cutoff line implementation: Conventional bicycle lights without proper beam shaping scatter light in all directions, potentially blinding oncoming traffic and creating hazardous situations where opposing riders cannot clearly assess their surroundings. Lights incorporating cutoff line design produce rectangular beam patterns with distinct bright-dark boundaries positioned approximately at shoulder height, providing adequate illumination distance without interfering with opposing cyclists' vision.

Functional design element three-Reflector cup engineering: Reflector cups featuring cutoff line design incorporate horizontal reflecting surfaces in their upper sections to suppress light scatter, while side concave angle designs direct illumination toward near-field zones, ensuring clear visibility of road conditions immediately adjacent to the bicycle. From a safety perspective, cyclists are strongly recommended to select lighting systems incorporating similar beam pattern characteristics to optimize both visibility and road safety during nighttime cycling activities.

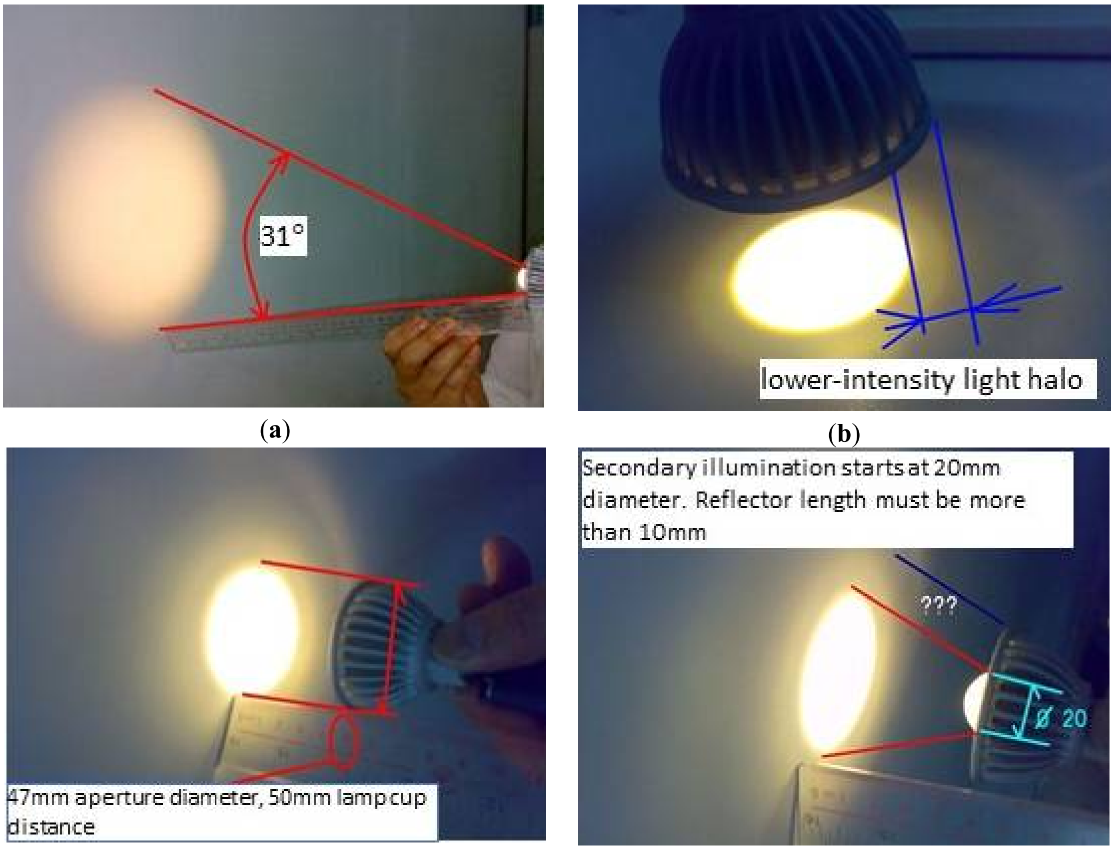
2. Materials and Methods

2.1 Beam Pattern Measurement and Lamp Housing Design

Fig. 1(a) demonstrates that the illumination light source (cup lamp) selected for this research exhibits a beam angle of 31 degrees. It is noteworthy that conventional household cup lamps typically offer selectable angles of 60 degrees and 45 degrees. However, roadway illumination applications necessitate concentrated light distribution rather than the wide-angle coverage and uniformity considerations prioritized in residential lighting applications. Fig. 1(b) illustrates that the cup lamp chosen for this study produces a perfectly circular beam pattern. Nevertheless, bicycle headlights must illuminate the roadway ahead of the bicycle's position rather than projecting directly downward from above the bicycle to the ground surface in a perpendicular orientation. Consequently, the bicycle light strikes the ground surface at a non-orthogonal angle. This angular requirement results in the bicycle illumination source creating an elliptical rather than circular light pattern when projected onto the ground surface. The elliptical beam pattern produced by this angled projection compensates for the illumination distance reduction effect caused by the bicycle's forward velocity. Determining the optimal projection angle requires subsequent experimental validation, which represents one of the primary objectives of this research investigation.

Additionally, Fig. 1(b) reveals a lower-intensity light halo surrounding the high-brightness core pattern, likely resulting from secondary illumination effects produced when light emitted from the cup lamp's internal LED chip structure passes through the external lens system. The cup lamp employed in this research incorporates lens design specifically intended to concentrate light output while suppressing the scattered light emission characteristics of LED chips. Since the low-intensity halo provides negligible illumination benefits, this research will subsequently utilize this halo region for visual design enhancement purposes. Finally, the peripheral dark zones indicated in Fig. 1(b) contain essentially no measurable brightness levels, representing areas completely outside the effective illumination range of the lighting system. Understanding these distinct illumination zones, the concentrated core, the secondary halo, and the peripheral dark areas, proves essential for optimizing bicycle headlight design to achieve both functional lighting performance and aesthetic visual appeal while maintaining appropriate light distribution patterns for safe nighttime cycling applications. The low-intensity light halo provides no effective illumination benefits while simultaneously creating glare effects that can be visually disturbing. Therefore, it becomes essential to eliminate the glare impact this halo creates for oncoming pedestrians and vehicles, which necessitates implementing a cutoff line design strategy.

Fig. 1(c) demonstrates the significant design challenges encountered when developing a cutoff line-equipped illumination headlight, particularly regarding reflector hood design considerations. The measurements presented in Fig. 1(c) reveal that to effectively block glare caused by the light halo, the reflector hood must extend 50mm beyond the cup lamp perimeter. This extension distance proves impractical for reflector hood design implementation, creating substantial engineering constraints that compromise both aesthetic appeal and functional mounting requirements [7]. Conversely, Fig. 1(d) illustrates that the secondary illumination generated by the cup lamp through its lens system initiates with a diameter of 20mm. This measurement indicates that reflector hood length must exceed 10mm to effectively intercept the light source and achieve the intended light contact design objectives. The disparity between the required 50mm extension for complete glare elimination and the minimum 10mm requirement for basic light interception presents a critical design optimization challenge. This dimensional conflict between glare prevention requirements and practical design constraints necessitates innovative engineering solutions that balance effective cutoff line implementation with reasonable reflector hood proportions. The research must therefore explore alternative approaches to achieve adequate glare suppression while maintaining compact, aesthetically pleasing, and mechanically viable reflector hood designs that can be successfully integrated into bicycle headlight systems without compromising overall lighting performance or mounting stability [8].



(**a**) (**b**) (**c**) (**d**)

Fig. 1. (**a**) Cup lamp beam angle measurement, (**b**) Cup lamp beam pattern measurement, (**c**) Cutoff line design measurement, and (**d**) Light guide measurement.

2.2 Lamp Shade Design and Optimization

Because the light source used in this study is not a spherical bulb or LED chip, but a packaged cup lamp. The lamp shade refers to the outer shell that covers the cup lamp. Based on the beam pattern constraints described in Fig. 1, comprehensive lighting fixture design requirements were systematically established through iterative practical testing and validation processes. Through extensive experimentation and refinement, the following optimized design configuration was achieved. Fig. 2 demonstrates that when the cup lamp axis is tilted 36 degrees relative to the horizontal reference line, subtracting half of the corresponding total illumination angle of 31 degrees results in the cup lamp's uppermost light ray exhibiting a 20.5-degree downward inclination from the horizontal plane. This angular configuration effectively serves as the cutoff line design for the lighting fixture. Conversely, when the cup lamp axis maintains its 36-degree tilt relative to the horizontal reference line and half of the corresponding total illumination angle of 31 degrees is added, the cup lamp's lowermost light ray demonstrates a 51.5-degree downward inclination from the horizontal plane. The primary reasons for choosing a 36-degree tilt for the lamp shade design are: 1. To prevent rainwater from entering the heat dissipation holes above the cup lamp during rainy days; 2. To compensate for the divergence angle of the lamp's light source, achieving a cutoff point and preventing glare for people in oncoming lanes; 3. The finished lamp shade is expected to be horizontal to maintain a streamlined aesthetic. While the tilt angle that meets these three design requirements does have a range, a fixed setting is used for mold convenience. Since the rider can freely adjust the angle during installation, it is not fixed to the design setting, so there is a permissible range for actual road lighting conditions. For computational convenience, assuming the bicycle light positioning at 1 meter above ground level, trigonometric tangent functions can be employed to calculate that the headlight illumination projects onto the ground surface creating a beam pattern spanning approximately from $\tan^{-1}(51.5°) = 0.795$ meters to $\tan^{-1}(20.5°) = 2.674$ meters ahead of the light fixture, forming the primary illumination zone.

However, due to visual distance compression effects caused by cycling velocity, this calculated beam pattern area clearly does not encompass the optimal range required for bicycle travel applications. It is crucial to note that these parameters assume the lamp shade maintains a horizontal orientation during design calculations. If the complete lighting assembly lacks proper horizontal calibration when installed on the bicycle frame, the actual beam pattern will exhibit significant variations from theoretical projections. Consequently, riders who do not require intensive near-field illumination or those needing extended illumination distances can adjust the horizontal lighting angle to accommodate specific illumination requirements and riding conditions. Therefore, riders who require strong near-field illumination or extended lighting distance need a lamp housing design that can freely adjust the horizontal lighting angle without precise angle measurement to suit specific lighting requirements and riding conditions. Furthermore, based on rider habits and the human reaction time of 0.3 seconds, a safe sight distance of 10 meters is generally considered safe. At a speed of 36 kilometers per hour in urban areas, this equates to 10 meters per second. This means the rider has one second to react and brake in real cycling conditions. Therefore, the rider can adjust the angle of the lamp shade to the horizon according to road conditions to achieve a safe sight distance of 10 meters.

The lamp shade design illustrated in Fig. 2 reveals that the lower edge of the vertical cross-section at the light output direction will obstruct illumination rays due to the cup lamp's 36-degree downward tilt. Simultaneously, the upper edge of the vertical cross-section at the light output direction loses its protective function for the cup lamp assembly as a result of the same 36-degree downward inclination. Therefore, the lamp shade design necessitates final geometric adjustments to address these functional and protective challenges while maintaining optimal light distribution characteristics and structural integrity for practical bicycle headlight applications.

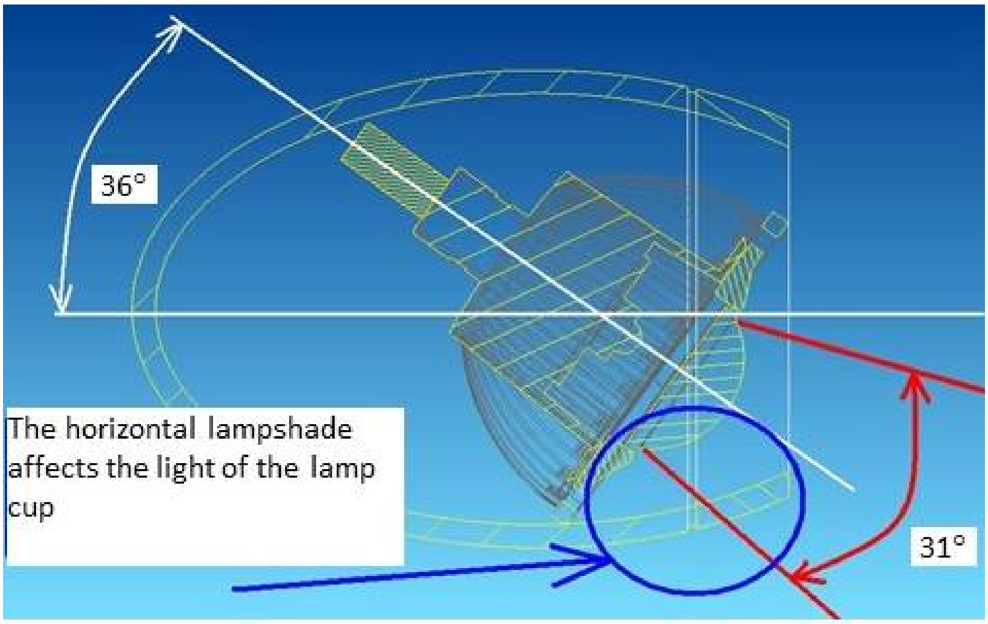


Fig. 2. Lamp shade design.

3. Results and Discussion

3.1 Mounting Bracket Design and Engineering

Bicycle lights require secure attachment to bicycle frames through dedicated light mounting systems or fastening straps to prevent light displacement, angular deviation due to road vibrations, and potential equipment loss during cycling operations. Mounting bracket design must satisfy the following essential criteria: first, the system must provide stable attachment to bicycle frames while enabling convenient adjustment capabilities; second, it must securely hold the lighting fixture in position; and third, it must facilitate easy installation and removal of the bicycle light. This research developed two distinct mounting bracket designs, both utilizing clip-on mechanisms for optimal functionality. The first design features a rear-activated compression system, while the second design incorporates a front-activated compression mechanism. Fig. 3 and 4 present comprehensive details of the first design iteration, specifically the rear-activated compression clip mounting bracket system that fulfills all three specified design requirements.

Fig. 3 provides detailed explanation of the operational principles and compression button dimensional specifications for the rear-activated clip mounting bracket system. Based on ergonomic design principles, a 7.5mm compression distance was established to optimize user interaction and comfort during operation. The compression button length was engineered to complement the material characteristics of the clip mounting bracket, ensuring durability and reliable performance under various operating conditions [9]. The detailed inset illustration presents an enlarged view of the clip geometry design, showcasing the precise engineering considerations that enable secure light fixture retention while maintaining ease of use. This mounting bracket configuration allows cyclists to quickly attach and detach lighting equipment without requiring additional tools, while the ergonomic compression distance ensures comfortable operation even when wearing cycling gloves. The rear-activated design provides intuitive operation where users can easily access the release mechanism while maintaining visual contact with the lighting fixture during installation and removal procedures.

Fig. 4 provides detailed specifications for the lamp shade installation positioning within the compression clip mounting system and the dimensional design of the parallel slot configuration. The illustration utilizes dimensional markers D1, D2, and D3 to indicate precise engineering specifications for optimal fit and functionality. The diagram demonstrates that at position D1, the front end incorporates a 2mm plastic positioning ridge that securely locks and fixes the lamp shade in place, preventing forward displacement during operation. At position D2, the rear section features a 1.5mm clip limitation mechanism that restricts the lamp shade from arbitrary forward and backward movement, ensuring stable positioning throughout various riding conditions and vibrations. At position D3, both left and right sides incorporate groove channels with a minimum depth of 2.5mm each. These grooves work in conjunction with the lamp shade's integrated groove design to prevent any lateral movement of the lamp shade assembly. This three-dimensional constraint system, combining front ridge retention, rear clip limitation, and bilateral groove engagement, creates a comprehensive securing mechanism that maintains precise lamp shade positioning while allowing for controlled installation and removal procedures. The precision engineering of these dimensional specifications ensures that the lamp shade remains securely fixed within the mounting bracket across all three spatial axes, eliminating unwanted movement that could compromise illumination angle accuracy or create safety hazards during bicycle operation. This multi-point engagement system provides both mechanical security and operational reliability essential for demanding cycling applications [10].

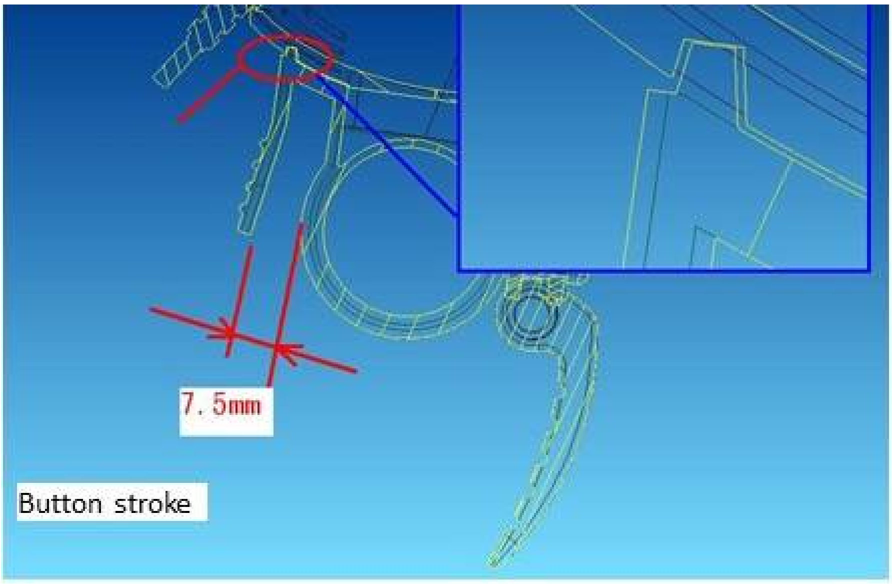


Fig. 3. Operating principle and compression button dimensional design of rear-activated clip mounting bracket.

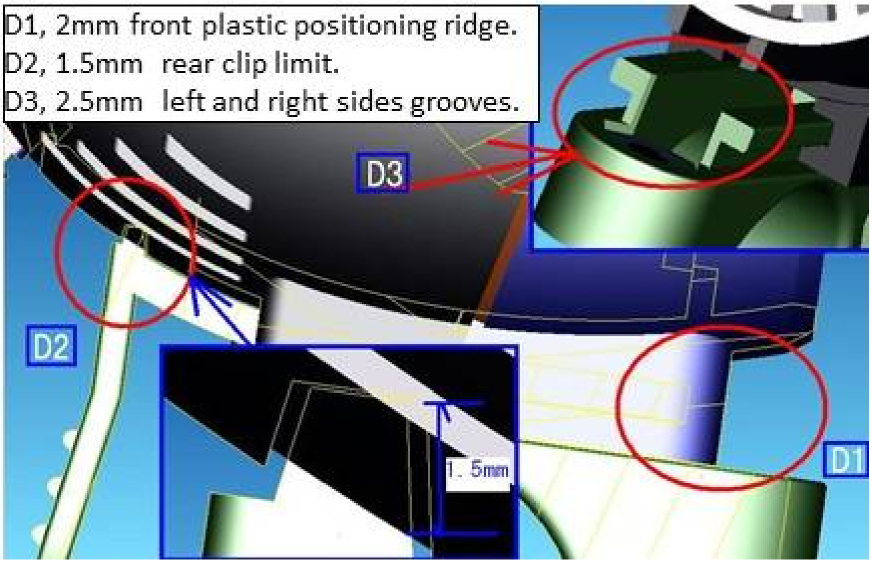
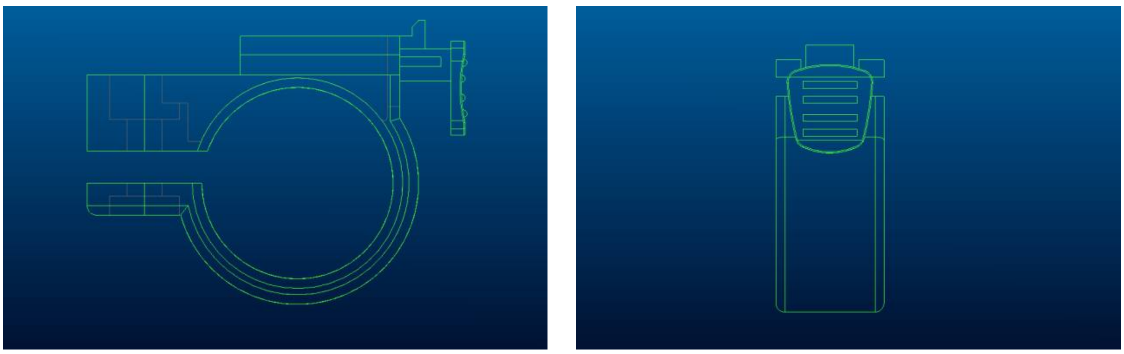


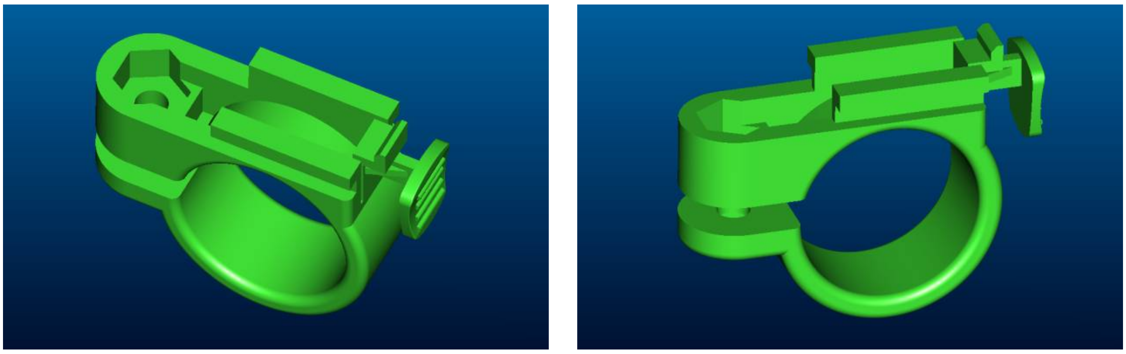
Fig. 4. Dimensional design of mounting base and parallel slot configuration for rear-activated clip bracket.

Fig. 5 through 7 present the comprehensive design specifications for the second mounting bracket iteration, which fully satisfies the three essential mounting bracket design criteria previously established. This second design features a front-activated compression clip mounting system that represents an alternative approach to secure bicycle light attachment. Fig. 5(a) and 5(b) respectively illustrate the side view and front view technical drawings of the clip mounting bracket assembly. This mounting bracket system is specifically engineered for attachment to the bicycle's horizontal handlebar position, utilizing a screw-based fastening mechanism to ensure secure and stable connection to the bicycle frame. The screw attachment method provides reliable mounting stability while accommodating various handlebar diameters and configurations commonly found on different bicycle types.Fig. 5(c) and 5(d) present the front-side view and rear-side view perspectives of the clip mounting bracket, revealing the three-dimensional geometry and structural details essential for proper functionality.

The mounting bracket employs a parallel slot design configuration for lamp shade retention, combined with a front-activated compression clip mechanism that facilitates convenient installation and removal procedures. This front-activated design offers distinct operational advantages, allowing users to engage and disengage the lighting fixture from the front-facing direction, which provides improved accessibility and visual confirmation during attachment procedures. The parallel slot system ensures precise lamp shade positioning while the front-activated compression mechanism enables single-handed operation, making it particularly suitable for cyclists who frequently remove their lights for security purposes or battery charging requirements. The integration of these design elements creates a mounting system that balances secure retention with operational convenience, addressing the practical needs of regular bicycle light users.



(a) (b)

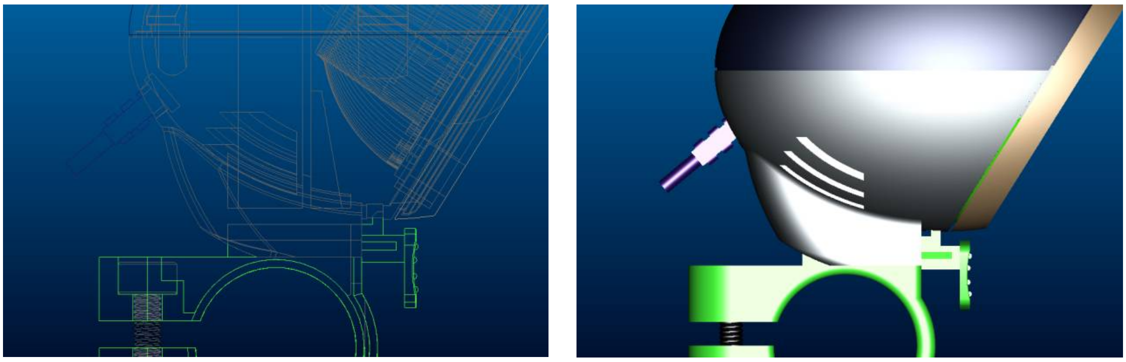


(c) (d)

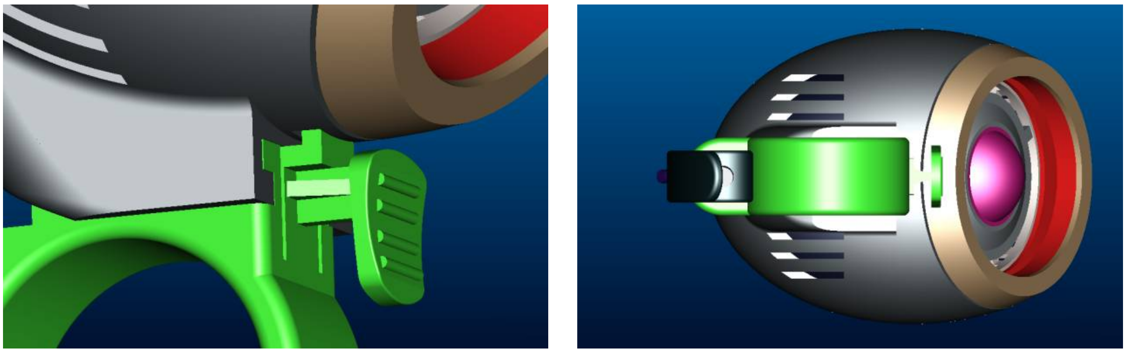
Fig. 5. Front-activated clip mounting bracket showing (**a**) side view design drawing, (**b**) front view design drawing, (**c**) front-side 3D view, and (**d**) rear-side 3D view.

Fig. 6 presents detailed views of the lamp shade securely mounted on the front-activated compression clip bracket, including side view (a) design drawing and (b) 3D rendering, along with (c) front view 3D close-up and (d) bottom view 3D close-up perspectives. Particularly noteworthy is Fig. 6(b), which reveals that the side view 3D rendering of the dual-color lamp shade demonstrates a non-perpendicular relationship between the horizontal reference line and the front cross-sectional angle of the lamp shade. This geometric configuration indicates that the lamp shade's external form has been specifically redesigned based on the beam pattern measurement results presented in Fig. 1, incorporating the optimized 36-degree downward tilt design to achieve improved cross-sectional angle performance.

This angular modification represents a critical design evolution that directly addresses the optical requirements identified through empirical testing and measurement. The non-perpendicular front cross-section ensures that the lamp shade geometry complements the predetermined 36-degree cup lamp inclination, creating a cohesive optical system that maximizes illumination effectiveness while maintaining the desired cutoff line characteristics. The dual-color lamp shade design visible in these detailed views not only provides aesthetic appeal but also serves functional purposes by potentially offering visual differentiation between different operational modes or illumination zones. The precise angular adjustments demonstrated in these technical drawings reflect the iterative design process that transforms initial beam pattern analysis into practical, optimized lighting hardware. A comprehensive overview of the complete lighting fixture appearance and final integrated design will be presented in Fig. 8, showcasing how these individual design elements combine to create a fully functional and aesthetically refined bicycle lighting system.



(a) (b)

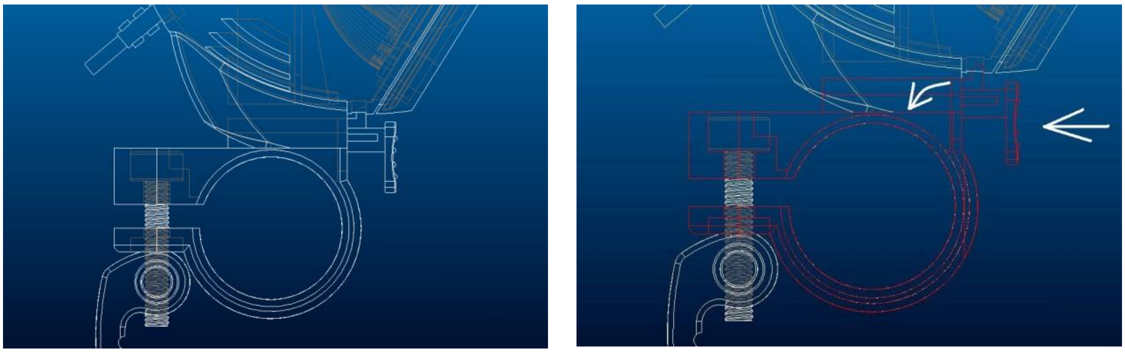


(c) (d)

Fig. 6. Lamp shade fixed in position showing (a) side view design drawing, (b) side view 3D diagram, (c) front view 3D diagram, and (d) bottom view 3D diagram.

Fig. 7 illustrates the improved mounting system featuring a quick-release screw mechanism for bicycle frame attachment, shown in (a) side view design drawing and (b) side view schematic diagram depicting the compression direction and slot positioning for the front-activated clip mounting bracket. The implementation of quick-release screws provides significant operational advantages for cyclists, enabling tool-free adjustment of illumination distance and beam pattern configuration in response to changing road conditions or lighting requirements throughout their journey. This enhanced functionality allows riders to optimize their lighting setup dynamically without carrying additional tools or stopping for extended periods to make adjustments using conventional fastening systems.

The compression clip mounting bracket design facilitates rapid lamp shade removal, transforming the bicycle-specific lighting fixture into a portable illumination device suitable for various alternative lighting applications beyond cycling. This dual-functionality design consideration recognizes that cyclists often require versatile lighting solutions that can serve multiple purposes, such as camp lighting, emergency illumination, or general portable lighting needs when away from their bicycles. The combination of quick-release mounting capability and rapid lamp shade detachment creates a comprehensive lighting system that balances secure bicycle integration with operational flexibility. This design approach acknowledges the practical reality that modern cyclists value equipment that can adapt to diverse situations while maintaining reliable performance in its primary bicycle lighting role. The tool-free adjustment and removal features significantly enhance user experience by eliminating the friction often associated with lighting system modifications during rides or when transitioning between different lighting applications.



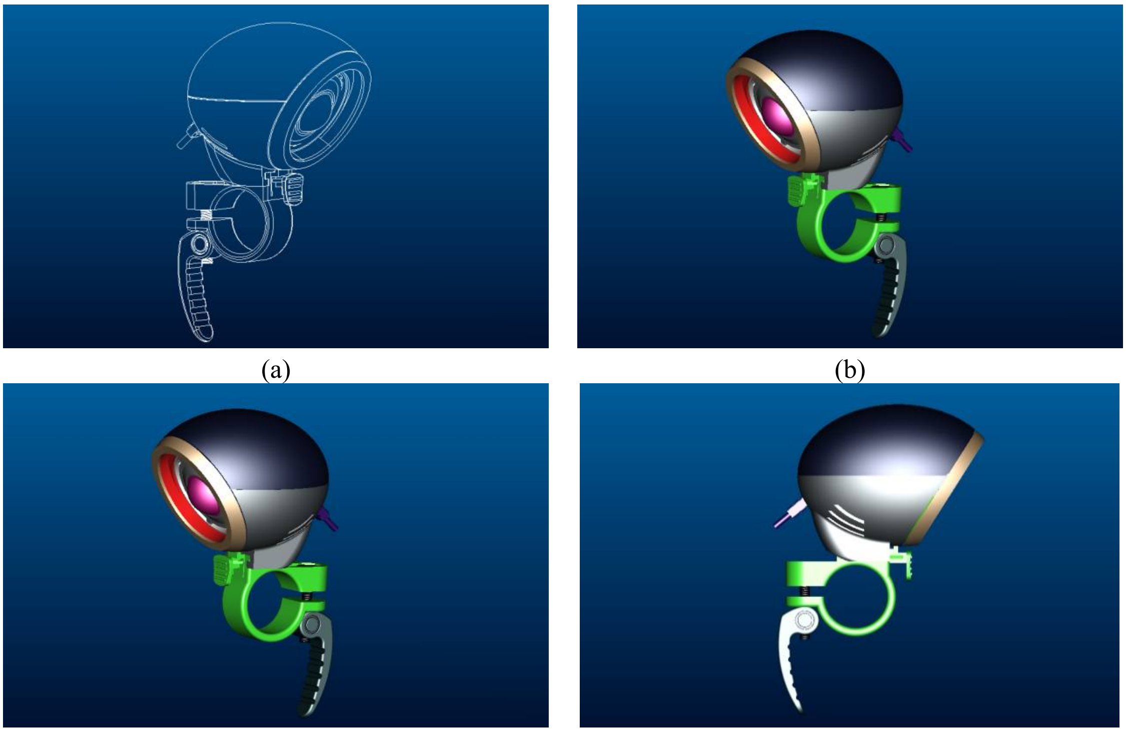
(a) (b)

Fig. 7. (a) Improved side view design drawing of quick-release screw for clip mounting bracket and (b) Side view schematic diagram of operating direction and slot position for front-activated clip mounting bracket.

Fig. 8 presents the complete bicycle light assembly with the lamp shade securely mounted on the front-activated compression clip bracket, shown in (a) design drawing and (b) 3D rendering. This mounting bracket configuration achieves the most compact overall dimensions, enhancing portability and facilitating convenient removal procedures for various operational requirements. The direct handlebar mounting position provides several distinct advantages over alternative bicycle frame locations. Primarily, the handlebar represents the highest available mounting point on the bicycle frame, which significantly benefits illumination angle selection and delivers superior lighting performance compared to lower mounting positions. This elevated positioning enables optimal light projection geometry while maximizing the effective illumination range and improving overall visibility conditions for nighttime cycling operations.

Most critically, the compact short-distance mounting bracket design substantially reduces the impact of road-induced vibrations and jolting motions that occur during bicycle travel, resulting in significantly more stable light beam projection. This vibration reduction directly translates to improved illumination consistency and enhanced rider safety through maintained lighting performance across various terrain conditions. From a mechanical engineering perspective, the shortened bracket design reduces the moment arm length, which correspondingly decreases stress concentrations and mechanical loading throughout the mounting system. This reduced force magnitude significantly enhances the overall mechanical strength characteristics of the mounting assembly while extending the operational lifespan of the lighting fixture through decreased fatigue loading and improved structural durability. Fig. 8(c) and 8(d) respectively provide front view and side view 3D renderings of the complete integrated bicycle light assembly, demonstrating the final aesthetic and functional integration of all design elements into a cohesive, professional-grade bicycle lighting system that balances performance, durability, and user convenience.

Notably, this design, which doesn't include the power supply, achieves a final weight of less than 200 grams. This is because adding a battery not only increases the weight of the lamp but also often causes vibration torque that damages the lamp's lifespan. This is also a major goal of this work. The next step will be to reveal the relationship between power supply capacity and lighting duration. This will prevent riders from losing their lighting mid-race or carrying unnecessary power supplies.



(a) (b) (c) (d)

Fig. 8. Complete bicycle light with lamp shade fixed to front-activated clip mounting bracket showing (**a**) design drawing, (**b**) 3D diagram, (**c**) front view 3D diagram, and (**d**) side view 3D diagram.

4. Conclusions

This research has successfully completed the mechanical engineering study for mounting bracket design, achieving reliable lamp shade attachment to bicycle frames. The investigation resulted in two distinct clip-on mounting bracket designs, differentiated by their activation mechanisms: rear-activated compression and front-activated compression systems. Both design iterations fully satisfy the three fundamental mounting bracket requirements established at the project's inception. These mounting systems demonstrate the ability to securely attach to bicycle frames while providing convenient angle adjustment capabilities, and both facilitate easy installation and removal of the lighting fixture for various operational needs. Additionally, both designs incorporate short moment arm characteristics that significantly enhance mechanical strength performance under loading conditions, contributing to improved durability and extended service life. The research team has previously published comprehensive findings regarding lamp shade material selection, establishing the foundation for optimal optical and structural performance in bicycle lighting applications. The next phase of this ongoing research initiative will focus on designing the complete electrical power system integration for the bicycle illumination fixture, including detailed analysis of lighting endurance capabilities and comprehensive testing protocols under various weather conditions and diverse road surface scenarios. This systematic approach ensures that the final bicycle lighting system will deliver optimal performance across the full spectrum of real-world cycling conditions, from urban commuting to challenging off-road environments. The integration of mechanical, optical, and electrical engineering principles throughout this research program represents a comprehensive methodology for developing advanced bicycle safety equipment that meets the evolving needs of modern cycling enthusiasts while maintaining the highest standards of reliability and performance.

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