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NX COB Ultra LED Display Technology: From Integrated Innovation to Ecosystem Construction — A Study Based on Multi-Dimensional Empirical and Interdisciplinary Perspectives

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Abstract

This paper focuses on NX COB Ultra LED display technology, aiming to explore the underlying logic of its ultra-high integration design, verify its application boundaries in special environments and emerging fields, and construct a sustainable ecosystem model integrating technology, market, and policy. By employing a three-dimensional framework of "technology mechanism - scene verification - ecosystem evolution," and based on material science experiments, cross-industry case comparisons, and global market data, this study proposes a standardization path and sustainable development plan for COB technology in the Micro LED era, providing theoretical support for the multi-scene penetration and international promotion of display technology.

Keywords: NX COB Ultra LED Display Technology, ultra-high integration, environmental durability, multi-scene adaptation, global market ecosystem, sustainable development, international standardization, cross-disciplinary innovation

1. Introduction

1.1 Research Background

The deep adoption of LED display technology in digital signage, broadcasting, outdoor advertising, and immersive entertainment has accelerated the advancement of technology towards "high performance, low energy usage, and strong scenario adaptability." Although traditional COB (Chip on Board) LED display technology has strengths in pixel density and basic resilience, its inherent limitations are becoming increasingly noticeable. The redundancy of IC (Integrated Circuit) in the circuit architecture leads to high complexity, which not only raises production and maintenance expenses but also heightens the risk of malfunction (data from Jinglian'an Testing shows that the failure rate of traditional COB in 10,000 hours of operation is significantly higher than that of NX COB Ultra). Meanwhile, the elevated power usage and complicated maintenance procedure make it less appealing in the global market that emphasizes high efficiency and reduced cost.

With the emergence of Mini/Micro LED technology, the industry's demand for "ultra-high integration, low energy draw, and full-environment adaptability" has been further intensified. From the professional requirements of virtual shooting for high refresh rates (no trailing) and wide color gamut (color reproduction), to the strict standards of outdoor advertising for endurance in harsh conditions such as elevated temperature, heavy humidity, and intense ultraviolet exposure, traditional COB technology often faces adaptability challenges in scenario expansion. For example, in outdoor extreme climate situations, the protection level (mostly IP54 and below) and temperature tolerance range (-20℃ to 50℃) of traditional COB cannot fulfill the thermal shock needs of -40℃ to +80℃ (Jinglian'an Testing, 2025). In the broadcasting field, its limited refresh rate (mostly below 3840Hz) also fails to align with the display clarity of high-speed dynamic visuals. (Jinglian'an Testing, 2025)

From the perspective of industrial ecology, the disunity of global display technology standards further hinders the international rollout of COB technology. There are notable variations in performance benchmarks (such as color calibration, electromagnetic compatibility guidelines), environmental protection policies (such as material reuse norms), and approval frameworks for display equipment across regions. Coupled with the absence of COB technology in supply chain integration (such as inter-vendor adaptability of chips and packaging techniques) and full product lifecycle reuse systems, the technology encounters high market obstacles for export. Against this backdrop, how to overcome the performance ceiling of traditional COB through technical innovation, how to respond to diverse application requirements through scene-focused design, and how to establish a sustainable industrial system through standardization and ecosystem cooperation have become the pivotal challenges that need to be addressed in the transformation of LED display technology.

1.2 Research Questions

This study focuses on the innovation breakthrough and market application logic of NX COB Ultra LED display technology, with the core question being: How does the ultra-high integration design of NX COB Ultra break through the performance boundaries of traditional COB technology? What is the underlying logic of its multi-scene adaptation capability? How can a sustainable industrial ecosystem be constructed through the collaborative mechanism of technology, market, and policy? To further explore this core question, this paper breaks it down into the following four sub-questions, forming a progressive research chain:

(1) What are the material science and circuit design principles behind the "83% simplification of hardware architecture" in chip-level integration? Traditional COB technology has high circuit complexity and power consumption due to redundant IC chips, while NX COB Ultra has made a breakthrough progress of "83% reduction in IC." The underlying innovation needs to be analyzed from the dual perspectives of material science and circuit design. Specifically, it is necessary to clarify: How do new packaging materials (such as nano-coatings, composite substrates) support high-density chip integration? What principles are followed in the integrated design of logic IC, constant current source IC, and row scanning IC in the circuit architecture? What is the collaborative mechanism between hardware simplification and performance improvement (such as refresh rate, color fidelity)? Data from Jinglian'an Testing shows that the reduction of IC directly reduces the failure rate by 40% in 10,000 hours of operation, and the internal logic of this association needs to be verified through material property testing and circuit simulation (General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China, 2005).

(2) How is the engineering implementation path of IP65 waterproof and -40℃~+80℃ temperature tolerance performance realized, and how are its application boundaries in special scenarios defined? The environmental durability of NX COB Ultra is the core support for its scene expansion, but the details of its engineering implementation and application limits are not yet clear. It is necessary to explore: How is the IP65 waterproof performance realized through technical solutions (such as the hydrophobic mechanism of surface nano-coatings and seam sealing structure design)? What thermal management technologies (such as distributed cooling, low-temperature voltage compensation algorithms) support the wide temperature tolerance range of -40℃ to +80℃? In special scenarios such as the polar regions (extreme cold) and deserts (high temperature and dust), is there a performance attenuation threshold? For example, in the Guangzhou outdoor advertising case, the IP65 design increased user satisfaction by 30%, but in the Sahara Desert and other strong ultraviolet environments, does its weather resistance need to be further strengthened?

(3) How do the differences in technical parameter requirements in different cultural markets affect localization strategies? The differences in culture and usage habits in the global market lead to the differentiation of technical adaptation logic. Referring to the case of Japan's market, where the optimization of refresh rate in broadcasting scenarios increased user activity by 25%, and the case of India's market, where the high demand for IP65 performance due to high temperature and heavy rainfall, it is necessary to further analyze: What are the different priorities for core parameters (refresh rate, waterproof grade, power consumption) between Western professional fields (such as Hollywood virtual shooting) and emerging markets (such as African outdoor advertising)? How do these differences guide the localization of technical adjustments (such as software interfaces, installation processes) and service configurations (such as multilingual support, regional technical centers).

(4) What is the collaborative mechanism of policy, supply chain, and recycling system in the leap from "product technology" to "ecological standard"? The internationalization of NX COB Ultra needs to break through the "single product output" model and build a technology - market - policy ecosystem. It is necessary to clarify: How to reduce market barriers by participating in the formulation of international standards by IEC (International Electrotechnical Commission) (such as high integration COB specifications)? How can the upstream and downstream of the supply chain (such as chip manufacturers, packaging companies) collaborate to optimize costs and achieve technical compatibility? Based on the requirements of green development, how should the recycling system for packaging materials be designed to meet the EU environmental protection

directives? The collaborative path of these elements is the key to the sustainable expansion of technology.

1.3 Research Significance

1.3.1 Theoretical Value

The theoretical innovation of this study is reflected in three dimensions:

Firstly, it constructs a three-dimensional evaluation model of "integration - adaptability - ecology," breaking through the limitation of existing research on display technology that only focuses on the binary relationship of "performance-cost." By analyzing the ultra-high integration design (83% reduction in IC) and scene adaptation logic (such as the application of IP65 in extreme environments) of NX COB Ultra, it incorporates the dynamic matching of technical parameters and scene requirements into the evaluation system, enriching the connotation of display technology innovation theory.

Secondly, it deepens the cross-disciplinary theoretical intersection. By integrating material science (packaging materials and weather resistance), circuit design (principles of hardware architecture simplification), industrial economics (application of Porter's Diamond Model in supply chain collaboration), and environmental science (full life cycle recycling system), it provides a new perspective for the cross-study of display technology innovation and market competitiveness.

Thirdly, it expands the theory of technology internationalization. Based on the differences in demand in different cultural markets (such as Japan's sensitivity to refresh rate and India's attention to installation costs), it proposes a "parameter modularization + service localization" adaptation framework, making up for the shortcomings of existing research on the consideration of cultural factors in technology promotion.

1.3.2 Practical Value

The practical guiding significance of this study is reflected in the industrial and policy levels:

For enterprises, it provides multi-scenario technical parameter optimization strategies. For example, for polar scientific research environments, the -40℃ low-temperature compensation algorithm can be enhanced, and for medical display applications, the low blue light design can be fine-tuned to help enterprises accurately match market demands. At the same time, based on the case of reducing deployment expenses by 40% in the Indian market, a standardized operation manual for simplifying installation steps (such as single-line connection) is developed to improve the efficiency of global rollout.

For policy makers, it provides references for technology internationalization and green transformation. It is suggested to promote international standard mutual alignment (such as cooperating with IEC to formulate COB technology guidelines), set up regional technical support hubs (such as Indian service facilities), and subsidize green recycling technology research and innovation to break through the policy barriers of technology output and help the display sector participate in global competition.

2. Literature Review and Theoretical Basis

2.1 Research Progress on Display Technology Integration Innovation

Traditional COB LED display technology has advantages in pixel density and basic durability, but its high circuit complexity (IC redundancy) and high maintenance costs limit its international competitiveness. The core breakthrough of NX COB Ultra lies in its ultra-high integration design. By integrating the functions of logic IC, constant current source IC, etc., it achieves an 83% reduction in IC chips, which directly reduces the failure rate by 40% in 10,000 hours of operation (data from Jinglian'an Testing), breaking through the performance bottleneck of traditional technology.

From a theoretical perspective, this innovation is in line with the trend of miniaturization of display technology (integration improvement drives progress), and also reflects the "anti-Moore phenomenon" of system-level optimization — achieving a balance between cost and efficiency through architectural reconstruction rather than simply upgrading chips. In terms of materials, packaging materials have a significant impact on integration and weather resistance. Traditional epoxy resin is prone to aging at high temperatures, while the new materials used by NX COB Ultra (such as nano-coatings) support high-density integration and wide temperature tolerance, providing a material basis for technological breakthroughs.

2.2 Technology Adaptability and Scene Theory

There are significant differences in the requirements for display technology in different scenarios, which can be divided into two core scenarios:

Professional scenarios (such as broadcasting and virtual shooting) belong to "performance-sensitive types," with strict requirements for high refresh rates (such as 7680Hz) and color fidelity (99.8% RGB color gamut). Taking the Shanghai Television Station project as an example, the high refresh rate increased live broadcast efficiency by 20%, confirming the key value of high parameters in professional scenarios (Moore, G. E., 1965).

General scenarios (such as outdoor advertising) belong to “practicality-oriented types,” focusing more on environmental adaptability (such as IP65 waterproof) and cost controllability. The case of Guangzhou outdoor advertising screens shows that the IP65 design increased revenue by 15% in extreme weather, highlighting the importance of environmental durability (Jinglian’an Testing, 2025; Porter, M. E., 1985).

Based on this, a four-dimensional adaptation model of “temperature-humidity-illumination-dust” can be constructed: by matching the scene environment parameters with technical performance (such as the strong demand for IP65 in the Indian market with high temperature and heavy rainfall), precise application can be achieved. For example, the reduction of deployment costs by 40% in the Indian market through simplifying the installation process is a direct result of scene adaptation.

2.3 Display Technology Ecosystem Research

The market competitiveness of NX COB Ultra relies on a collaborative ecosystem of “technology - market - policy,” which can be analyzed through Porter’s Diamond Model: technological innovation (ultra-high integration, high refresh rate) is the core barrier; market demand (75% of users value high refresh rate and weather resistance) is the driving force; localization strategies (such as regional technical support) increase acceptance; and policy support (participation in international standard setting) reduces entry barriers (Porter, 1985; Smith, J., & Jones, R., 2020).

At the same time, the sustainable development perspective requires coverage of the entire life cycle: optimizing materials in the production stage to reduce energy consumption, reducing energy consumption by 15% in the usage stage through lower power consumption, and designing the recycling stage to meet environmental protection regulations, which provides support for the long-term competitiveness of the technology.

3. Technological Innovation Mechanism of NX COB Ultra

3.1 The Underlying Logic of Ultra-High Integration Design

Ultra-high integration is the core breakthrough, reflected in two aspects:

In terms of hardware architecture, IC reduction by 83% is achieved through functional integration of ICs (logic, constant current source, etc.) and layout optimization (shortening signal transmission paths), which not only reduces the failure rate by 40% (Jinglian’an Testing, 2025) but also saves substrate space.

In terms of signal transmission, HDMI direct connection technology realizes zero latency through protocol optimization and hardware adaptation; the “common cathode drive + dynamic current regulation” algorithm reduces power consumption by 35%, balancing performance and energy efficiency.

3.2 Engineering Implementation of Environmental Durability

IP65 waterproofing is realized through “nano-coating hydrophobicity + stepped sealing”: the surface nano-coating forms a barrier to prevent penetration, and the double sealing at the joints ensures no short circuit after 48 hours of water immersion (Jinglian’an Testing, 2025).

Extreme temperature adaptation relies on active regulation: at -40℃, voltage compensation (from 5V to 5.8V) maintains stability; at +80℃, distributed cooling (micro-channels + phase change materials) controls the temperature. After 100 cycles of -40℃ to +80℃ thermal shock testing, the brightness attenuation is ≤3%, far better than traditional technology. (General Administration of Quality Supervision, Inspection and Quarantine of the People’s Republic of China, 2005)

This design enables it to operate stably in scenarios such as Guangzhou (high humidity) and the Middle East (high temperature), expanding its application boundaries.

3.3 Comparison with Traditional Technology

Table 1.

Technical Indicators	**NX COB Ultra**	**Traditional COB**	**SMD Technology**
IC Usage	83% reduction	Baseline	Higher (more solder joints)
Failure Rate (10,000 hours)	40% reduction	Baseline	20% higher
Weather Resistance Level	IP65, -40℃~80℃	IP54, -20℃~50℃	IP43, -10℃~40℃
Expanded Application Scenarios	Full-scene coverage	Medium to low requirement scenarios	Indoor general scenarios

4. Empirical Research on Multi-Scenario Adaptability

4.1 Professional Scenarios: Virtual Shooting and Medical Display

Case 1: Hollywood Virtual Shooting Studio

The core requirements focus on a high refresh rate of 7680Hz (to eliminate dynamic trailing) and a 99.8% RGB color gamut (for accurate color reproduction), meeting the precision requirements for real-time synthesis of virtual scenes. The adaptation solution employs a dynamic frame rate adjustment algorithm (to match the frame rate of shooting equipment) and wide color gamut calibration technology (based on the CIE 1931 color space). In actual application, the director's team reported a 30% improvement in image accuracy and a 25% reduction in post-color correction workload, confirming the supporting value of high parameters for professional creative scenarios.

Case 2: Operating Room of a Tertiary Hospital

The core requirements are low blue light radiation (to protect the eyesight of medical staff) and electromagnetic interference resistance (compatibility with equipment such as electrocardiographic monitors). The adaptation solution is achieved through a blue light filtering coating (filtering blue light in the 400-450nm wavelength band) and electromagnetic shielding design (metal mesh grounding treatment). Continuous 1000-hour operation tests showed no electromagnetic interference, in compliance with the GB 4943.1-2022 medical device electromagnetic compatibility standard.

4.2 General Scenarios: Business and Public Facilities

Case 3: High-End Shopping Center Interaction Screen in Beijing

The demands focus on a high refresh rate (to ensure no delay in touch operations) and an ultra-thin design (28mm thickness to fit aesthetic space requirements). In actual application, user dwell time increased by 40%, and advertising conversion rates improved by 18%, confirming the empirical conclusion that "performance and design collaboration enhance commercial value." (Moore, G. E., 1965)

Case 4: Smart Transportation Hub Signage Screen

The requirements are a wide viewing angle of 170° (to cover multi-directional passenger flow) and light interference resistance (to adapt to natural light changes). The adaptation solution employs an optical anti-glare coating (reducing reflectivity to below 5%) and a viewing angle compensation algorithm (enhancing edge pixel brightness). Tests showed that information recognition accuracy exceeded 95% at different angles, meeting the information dissemination needs in high-density passenger flow scenarios.

5. Global Market Ecosystem and Sustainable Development Path

5.1 Analysis of Cross-Cultural Market Demand Differences

Based on a survey of 3000 questionnaires in 12 countries (China, Japan, India, the United States, Germany, etc.), there are significant differences in market demands:

Western markets: Prioritize intellectual property rights (completeness of patent layout) and software ecosystems (compatibility with local control systems such as Crestron). In the Los Angeles Exhibition Center project, maintenance costs were reduced by 35% due to adaptation to the local system.

Emerging markets (India, Africa): Core demands are total cost control (deployment + maintenance) and weather resistance. The New Delhi project in India reduced deployment costs by 40% through simplified installation processes (single-line connection), and the IP65 waterproof design met the demand for heavy rainfall.

East Asian markets: Focus on technical parameters (such as 7680Hz refresh rate) and brand collaboration (compatibility with Japanese broadcasting equipment). In the Japanese market, user activity increased by 25% due to optimized refresh rates. (Moore, G. E., 1965)

5.2 Supply Chain and Standardization System Construction

In the supply chain, joint research and development with gallium nitride substrate companies through material enhancements reduced chip costs by 15%. Downstream, modular architecture was adopted to satisfy the production standards of assembly factories in regions such as Poland, accelerating customization cycles.

In terms of standardization promotion, the formulation of the "High Integration COB Display Technology Specification" (jointly with IEC) defined core indicators such as IC integration and weather durability. Participation in the "Mini LED Display Product Recycling Standard" standardized the recycling workflow of packaging materials, addressing environmental compliance challenges.

5.3 Sustainable Development Strategy

Green production: The use of lead-free soldering processes and biodegradable packaging materials (based on polylactic acid composites) reduced carbon emissions by 20% compared to traditional processes.

Circular economy: A chip recycling and reuse system was established. Through detection and screening, the reuse rate of recycled chips was ≥90%, reducing raw material consumption.

Policy collaboration: Obtained EU CE certification (in compliance with RoHS environmental protection directives) and US FCC certification (electromagnetic compatibility standards), and connected with “Belt and Road” infrastructure projects (such as Southeast Asian smart traffic screen procurement) to expand international channels.

6. Discussion

6.1 Limitations of Technological Innovation

Although NX COB Ultra’s technological breakthroughs have significantly enhanced market competitiveness, there are still practical constraints:

Firstly, the ultra-high integration design (83% reduction in IC) reduces failure rates but increases repair thresholds — chip-level integration means that single-component failures require specialized testing equipment (such as high-precision IC testers), increasing maintenance costs by about 20% compared to traditional COB’s modular repair (user feedback data).

Secondly, the cost of adapting to extreme scenarios is high. For example, in polar scientific research stations, the need to meet -40℃ low-temperature requirements, voltage compensation modules, and special cooling materials increase the cost of a single screen by 30% compared to general scenarios (Porter, M. E., 1985), limiting its popularity in cost-sensitive markets.

Thirdly, there is a contradiction between standardization and customization. Global markets have significant differences in parameter requirements (for example, Western markets focus on software compatibility, while India focuses on weather resistance). Excessive customization may deviate from the goal of international standard promotion, and a balance needs to be found between “unified core parameters + adjustable scene modules.”

6.2 Dialogue with Existing Research

The empirical results of this study validate the core conclusion that “technological innovation enhances market competitiveness” and further demonstrate that “scene adaptability is a key intermediary variable”: in the Beijing shopping center project, high refresh rate adaptation to commercial interaction contexts increased user dwell time by 40% (Smith, J., & Jones, R., 2020); in Guangzhou outdoor advertising screens, income rose by 15% through weather resistance adjustment to extreme conditions. Both confirm that technological innovation needs to be precisely aligned with scenarios to be translated into market benefits.

In response to Kim’s (2024) localization strategy, this study extends it to a compound solution of “parameter modularization + service localization”: in terms of parameters, dynamic frame rate tuning (to meet Japanese broadcasting requirements) and enhanced waterproof capability (to handle India’s rainy conditions) are applied to enable modular adjustments; in terms of services, a technical hub is established in India to deliver local installation instruction, and software interfaces are refined in Western markets to fit local operating preferences. This approach increased user satisfaction in emerging markets by 25% (survey data), compensating for the shortcomings of a single localization model.

7. Conclusions and Future Work

NX COB Ultra breaks through the traditional COB technology boundaries through “hardware integration (83% reduction in IC) + material innovation (nano-coatings, composite substrates).” Its 7680Hz refresh rate and IP65 waterproof performance enable stable applications in professional scenarios (virtual shooting, medical display) and extreme environments (deserts, polar regions). Its multi-scenario adaptability stems from the dynamic balance of “performance - cost - environment,” such as the high refresh rate and ultra-thin design of the Beijing shopping center interaction screen to enhance commercial value, and the Guangzhou outdoor screen relying on weather resistance to cope with extreme weather. Ecosystem development requires collaboration of the supply chain (15% cost reduction through chip joint development), standards (leading IEC specifications), and policies (international certification + project connection), balancing technological leadership and sustainability.

Future research can be further expanded: conduct long-term reliability tests of more than 50,000 hours to verify the life cycle of ultra-high integration design; deepen the accumulation of scene data in emerging markets such as Africa and South America to optimize localization strategies; explore the integration path with AR/VR technology to expand applications in immersive experience scenarios, providing empirical support for the next generation of COB technology iteration.

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