

Technical Renovation of 4K Laser Projection and Surround Sound Systems: A Case Study of the Film Screening Room at Guangxi Radio and Television Station (Postprint)

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Abstract

[Objective] With the acceleration of film industrialization, film screening rooms, as the core component for quality control of motion pictures, have long experienced technological upgrades that lag behind innovative breakthroughs in production-end technologies.

[Methods] This study takes the film screening room of Guangxi Radio and Television Station as its research subject. A technical renovation was conducted to address issues identified in the original system's review workflow, including optical performance degradation of the projection system, performance defects in the surround sound system, and insufficient system compatibility.

[Results] Using the Digital Cinema System Specification version 1.0 (DCI specification) as the core framework, engineers successfully established a high-fidelity technical review platform aligned with film industrialization production standards, through the collaborative upgrade of a 4K laser projection system and immersive surround sound system, along with systematic reconstruction of compatibility.

[Conclusion] The renovation validates the applicability of DCI standards in regional film screening room upgrade projects, provides a reusable technical pathway for similar screening rooms in construction and renovation, and offers significant reference value for promoting collaborative upgrades across the entire film industry chain workflow.

Full Text

Preamble

Technical Renovation of 4K Laser Projection and Surround Sound Systems: A Case Study of the Film Screening Room at Guangxi Radio and Television Station (Guangxi Radio and Television Station, Nanning, Guangxi Zhuang Autonomous Region, 530022)

Abstract

[Objective] As film industrialization accelerates, film screening rooms—critical nodes for quality control—have long lagged behind technological innovations in production. **[Methods]** This paper examines the technical renovation of the film screening room at Guangxi Radio and Television Station. Addressing issues such as optical performance degradation in the projection system, performance defects in the surround sound system, and insufficient system compatibility, a comprehensive technical upgrade was implemented. **[Results]** Using the Digital Cinema System Specification Version 1.0 (DCI Specification) as the core framework, engineers successfully built a high-fidelity technical verification platform matching film industrialization production standards through the collaborative upgrade of 4K laser projection and immersive surround sound systems, along with system compatibility reconstruction. **[Conclusion]** This project validates the applicability of DCI standards in regional film screening room renovations, provides a reusable technical pathway for similar facilities, and offers valuable reference for promoting full-chain collaborative upgrades across the film industry.

Keywords: Film screening; DCI standard; 4K laser projection; Immersive audio; System compatibility

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Introduction

The film screening room at Guangxi Radio and Television Station, a key facility for film review in Guangxi Zhuang Autonomous Region, has been in operation for over a decade. In recent years, technical bottlenecks have directly impacted the objectivity and accuracy of film reviews: the xenon lamp projection system suffered from insufficient resolution, optical performance degradation, and color reproduction loss; the surround sound system exhibited significant hardware

performance defects due to missing vertical sound fields and mismatched channel configurations; and system compatibility issues, including hardware interface conflicts and outdated protocol standards, required technical downgrading of review copies to accommodate the screening system, resulting in data loss and inability to faithfully reproduce the production quality of submitted film masters. The lack of automatic switching between primary and backup links necessitated manual interface switching during failures, disrupting the continuity and safety of the review process.

China's film industry has achieved generational technological leaps in recent years, developing a globally competitive industrial system. The 2025 animated film *Ne Zha: The Demon Child's Havoc in the Sea*, a milestone in China's animation industrialization, continues to break world box office records, marking a historic transition from technology import to paradigm export. Guo Fan's team pioneered a new paradigm for domestic sci-fi film production in the *Wandering Earth* series, while the integration of real racing footage and CG technology in *Pegasus* brought thrilling rally action to the screen. As China's film industrialization workflow matures and projection technology and viewing experiences advance, the demand for full-chain technical coordination across "production-review-exhibition" has become increasingly urgent. In 2024, the National Development and Reform Commission, Ministry of Housing and Urban-Rural Development, Ministry of Culture and Tourism, National Film Administration, National Radio and Television Administration, and National Cultural Heritage Administration jointly issued the *Implementation Plan for Promoting Equipment Renewal in Culture and Tourism* [1], explicitly proposing strategic goals to "promote quality upgrades in film production, improve overall film production standards, and advance independent innovation in film projection technology." This underscores the importance of full-chain technical coordination in the film industry. However, the review stage—as the core node for content review and technical quality control—has lagged behind production-side technological breakthroughs, becoming a pain point in the industrial chain.

To address these issues, this paper proposes a technical renovation of the 4K laser projection and surround sound systems using the DCI standard (Digital Cinema Initiatives, DCI) [2] as the core framework. Established in 2002 by Hollywood's seven major studios—Disney, Fox, MGM, Paramount, Sony Pictures, Universal, and Warner Bros.—the DCI standard provides a high-performance, high-reliability technical architecture that unifies technical standards and quality control across the entire digital film workflow from production and distribution to exhibition [3]. The DCI standard provides engineers with crucial guidelines [4] for building a high-fidelity technical verification platform that matches film industrialization production standards.

1. System Design and Technical Implementation

1.1 4K Laser Projection System Upgrade

1.1.1 Problem Analysis and Technical Requirements (1) Insufficient Native Resolution and High Motion Blur Index

The original xenon lamp projection system only supported 2K (2048 \times 1080) native resolution and required interlaced resolution, resulting in a high Motion Blur Index (MBI) and insufficient image clarity. The DCI standard requires digital projection systems to natively support DCI 4K resolution and be compatible with 24/48 fps high-frame-rate formats.

(2) Light Source and Brightness Gain Mismatch

The original xenon lamp projector suffered severe light source brightness attenuation, resulting in insufficient screen brightness, particularly noticeable at screen edges when viewing 3D films. The mismatch between the projection system's optical architecture and screen gain led to poor brightness uniformity, low contrast, and missing dark-field details. The DCI standard requires that projection system light sources maintain brightness attenuation within reasonable thresholds during their rated lifespan, not exceeding 30% of initial values, and that light output efficiency matches screen gain to ensure brightness differences between screen center and edges remain $\leq 15\%$, avoiding localized over-bright or over-dark areas.

(3) Insufficient Color Gamut Coverage

Due to mismatched light source spectral characteristics and metal screen reflection properties, the original xenon lamp system exhibited color reproduction deviation and lost HDR highlight details. The DCI standard mandates that projection systems natively support DCI P3 color space with chromaticity coordinate error $\Delta u'v' \leq 0.015$ to prevent color shift-induced image distortion.

1.1.2 Upgrade Solution and Technical Implementation To simultaneously meet DCI standard requirements for “resolution-optical-color” performance, engineers implemented a collaborative design using the Barco SP4K-35B laser projector [5] and Harkness Clarus XC170 screen [6], constructing a new optical imaging system as shown in Table 1. The Barco SP4K-35B laser projector is illustrated in [Figure 1: see original paper].

Table 1 Main Technical Parameters of Projection System Equipment

Barco SP4K-35B Laser Projector
Harkness Clarus XC170 Screen

6. Color Gamut Coverage: DCI P3 (covering 98.5% of Rec.2020 color space when measured in xy coordinates)

1. Arc-shaped metal screen design increases reflectance, improves light distribution, enhances clarity, boosts color saturation, and provides better depth performance

6. Micro-perforated acoustic design (screen aperture ≈ 0.6 mm)

3D Effects

2. Native 4K resolution per eye (4096×2160)

High gain compensates for polarized 3D light-splitting loss

1.1.3 Synergistic Effects and Performance Improvements (1) Resolution Enhancement

The Barco SP4K-35B laser projector's 4K DMD chip supports native 4K (4096×2160) resolution and native DCI standard frame rates (24/48/60/120 fps). This eliminates edge artifacts and motion blur issues caused by interpolation-based 4K output from the original projector, ensuring image clarity meets DCI standards. The Clarus XC170 screen's micro-perforated acoustic design and Nanolast™ optical coating better accommodate the Barco SP4K-35B's native 4K projection, effectively reducing inter-pixel interference and enhancing image sharpness to present richer details.

(2) Optical Performance Optimization

The Barco SP4K-35B laser projector's RGB laser light source stably outputs 35,000 lumens with a dynamic contrast ratio of 2000:1. This ultra-high brightness and high dynamic contrast are key to optimizing projection system optical performance. The high-performance light source combined with the Clarus XC170 screen's 1.7 gain not only reflects more light but also enhances dark detail representation. The screen's arc-shaped structure design further optimizes light path reflection efficiency, reducing brightness differences between screen center and edges and improving brightness uniformity. Additionally, the new optical imaging system employs polarized 3D technology, with collaborative design among the projector, high-gain screen, and polarized 3D glasses compensating for light-splitting loss, enhancing brightness and depth performance in 3D mode, and improving immersive stereoscopic imagery, systematically resolving the original projection system's optical performance deficiencies.

(3) Color Performance Upgrade

RGB three-color laser technology represents the current industry-leading light source technology. The Barco SP4K-35B laser projector's RGB laser source achieves $\Delta E < 2$, surpassing even the stringent DCI standard requirements in spectral purity and color accuracy. Its color gamut coverage reaches DCI P3, encompassing 98.5% of the ultra-high-definition Rec.2020 color space, providing an extremely rich color performance range. With 12-bit HDR color depth capable of presenting 6.87 billion colors, it improves smoothness in color gradient scenes (e.g., light-shadow transitions, sky rendering), solving HDR color banding issues. After the color performance upgrade, the system can fully adapt to current film industrialization production color technology and accurately reproduce the color of submitted film masters.

2. Surround Sound System Renovation and Immersive Sound Field Construction

2.1 Technical Bottlenecks in Immersive Sound Field Construction

(1) Missing Vertical Sound Field

The screening room at Guangxi Radio and Television Station measures 20 meters long, 14 meters wide, and 10 meters high. Due to insufficient ceiling load-bearing capacity, overhead speakers could not be deployed, resulting in lost vertical sound field information. The DCI standard requires uniform sound field distribution in theaters, with vertical sound pressure level differences controlled within ± 3 dB to ensure seamless energy distribution between overhead and horizontal channels, avoiding ambiguous height sound image localization.

(2) Surround Sound System Performance Defects

The original system's outdated codec model created a clear protocol generation gap, supporting only Dolby Digital (5.1/7.1) channel decoding and unable to parse current mainstream immersive audio formats such as Dolby Atmos or DTS:X. Submitted film masters required technical downgrading to accommodate the screening system, causing data loss. The DCI standard mandates support for IAB (Immersive Audio Bitstream) format to ensure comprehensive compatibility with immersive audio technologies.

Due to imprecise matching of audio processors, amplifiers, and speakers, the surround sound system not only failed to achieve optimal performance 叠加 (stacking) but also exhibited power and impedance mismatches, dynamic range compression, and frequency response phase inaccuracies when reviewing high-quality film masters. This prevented faithful reproduction of submitted film masters' production quality, directly affecting review objectivity and accuracy.

2.2 System Architecture and Technical Implementation

Engineers designed the surround sound system renovation technical solution around the QSC Q-SYS platform [7].

(1) Q-SYS Platform 3D Sound Field Reconstruction

Reconstructing the three-dimensional sound field was a critical objective of this screening room renovation. The innovative application of QSC Q-SYS platform's virtual height sound field mapping technology [8] achieved this goal. The principle of virtual height sound field mapping involves parsing vertical sound field parameters from immersive audio metadata through QSC's Spatial Acoustic Mapping algorithm [9], then mapping signals to the horizontal surround speaker array based on sound source elevation angles and energy distribution. Adapting to the screening room's physical constraints and the impossibility of installing ceiling speakers, engineers used virtual height sound field mapping technology to reconstruct a three-dimensional sound field with height layers.

Q-SYS platform's time-domain equalization technology eliminates sound wave delays caused by speaker position differences or room reflections by adjusting

audio signal timing characteristics, preventing sound “smearing” or phase shifts. Gain compensation technology dynamically adjusts volume ratios across channels based on coverage range and energy attenuation characteristics of different speakers. For example, gain compensation can dynamically enhance output energy of specific horizontal speakers based on different sound source heights, compensating for high-frequency loss due to insufficient vertical dispersion while suppressing sound distortion in high-volume scenes to ensure clarity in dynamic effects like explosions without compromising overall audio quality.

In implementation, engineers deployed 12 surround speakers (4 each on left/right/rear walls) forming a horizontal surround array [10] based on acoustic modeling for three-dimensional sound image localization in the screening room. Using Q-SYS Core 110F processors with virtual height sound field mapping technology, combined with room acoustic modeling and film master audio metadata parsing, high-precision 3D sound field reconstruction was achieved. Coordinated use of time-domain equalization and gain compensation technologies [11] systematically resolved phase distortion, uneven energy distribution, and dynamic range compression issues in 3D sound field reconstruction [12-13].

(2) Acoustic Performance Optimization

Employing a modular design concept, the system achieved DCI standard’s stringent requirements for dynamic range and frequency response through coordinated configuration of main channels, low-frequency compensation, and power drive units. Main channels deployed three groups (left/center/right) of QSC SC-424 speakers [14]. The QSC SC-424’s three-way acoustic design, with dual woofer units and waveguide-mounted mid-high frequency components, achieves optimized multi-band phase consistency. The matching design of horizontal coverage angles and sensitivity parameters maintains dialogue clarity and background sound separation in complex sound fields, ensuring clear and pleasant off-screen narration.

For low-frequency design, engineers used four DCS-SB-7218 subwoofer speakers [15] with dual 18-inch units in symmetric layout, optimizing spatial balance of low-frequency energy through cabinet structure design. Special inverted-phase port and internal damping layer designs ensure impactful energy for explosions and collisions while avoiding low-frequency standing wave interference with mid-high frequencies. Two QSC DCS-SB-2180 subwoofer speakers [16] serve as mid-low frequency transition units, employing short-stroke linear drive technology to strengthen frequency transition between main speakers and subwoofers, ensuring layered restoration of mid-low frequency details.

Using QSC SC-424 speakers combined with DCS-SB-7218 subwoofers and Low-Frequency Phase Correction (LFC) algorithms, engineers corrected multi-band phase offsets through dynamically optimized phase synchronization and energy ratios. This enhanced temporal consistency in complex sound effects like explosions and collisions, suppressed non-linear distortion in high-dynamic scenes to preserve mid-high frequency dialogue and background sound purity, and bal-

anced low-frequency energy distribution to strengthen separation between ultra-low and sub-low frequencies, achieving high-fidelity restoration of submitted film masters' sound fields and improving review objectivity and accuracy.

QSC Surround Speaker Array is shown in [Figure 2: see original paper].

3. System Compatibility Upgrade and Optimization

After completing the 4K laser projection and surround sound system technical renovation, the Guangxi Radio and Television Station film screening room has undertaken technical review of Guangxi-produced films including *A Beautiful Life*, *What a Beautiful Jasmine Flower*, and *The Nightingale*. *What a Beautiful Jasmine Flower*, adapted from the true story of He Yue, a primary school student from Yangshuo, Guilin, who donated organs to save three people and was honored as a “Touching China” figure by China Central Television in 2012, holds significant meaning for promoting national organ donation policies and socialist core values. *A Beautiful Life*, based on the story of Huang Wenxiu—a national role model in poverty alleviation—accurately restored ethnic elements, natural lighting, and humanistic textures of northwestern Guangxi villages through strict technical quality control under the coordination of the Guangxi Zhuang Autonomous Region Party Committee Propaganda Department. The film has won 12 honors including the China Golden Rooster Award for “Best Small-Medium Cost Story Film,” becoming a regional benchmark case for main melody film creation.

In system compatibility optimization, engineers constructed a hierarchical compatibility architecture based on DCI standard requirements for signal transmission redundancy, protocol unification, and system scalability.

The Barco SP4K-35B laser projection system features DCI-certified 12G-SDI and HDMI 2.1 dual-link transmission architecture, achieving seamless signal source switching through redundant Barco ICP-D projection server design. Engineers built a QSC Q-SYS platform dual-machine hot backup system, enabling redundant audio link transmission and automatic hot backup switching through the Q-SYS Core 110F processor's intelligent redundancy control module. Unified AES67 transmission protocol avoids audio stream timestamp conflicts and metadata parsing errors, meeting DCI standard requirements for audio redundancy, protocol consistency, and audio-visual synchronization, significantly enhancing the system's ability to parse and restore complex soundtracks from submitted film masters.

The entire system employs modular design, supporting dynamic hardware resource expansion and software function iteration upgrades. It flexibly adapts to different format signal processing requirements, providing underlying architecture support for future 8K ultra-high-definition, high-frame-rate, and panoramic sound technology upgrades while ensuring continuity and stability in the review workflow.

Through technical performance upgrades and system compatibility reconstruction, the Guangxi Radio and Television Station film screening room has systematically resolved technical generation gaps between film review and production stages, validating the engineering applicability of DCI standards in regional screening room renovations. This provides a reusable technical pathway for full-chain coordination in the film industry and offers valuable reference for similar screening room construction and technical upgrades.

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Note: Figure translations are in progress. See original paper for figures.

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