Research on the Application of 4K Technology in Television: Postprint

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Abstract

4K ultra-high-definition television represents the principal direction for future development in television technology: compared to high-definition television, it not only substantially enhances television resolution (3840$×$2160), but also features exceptionally high resolution (lens resolution measured coefficient exceeding 1000 lines), a broader viewing angle (exceeding 60 degrees), higher image frame rates (standards include high frame rates such as 100 fps and 120 fps), greater image dynamic range (pre-production shooting can exceed 14 stops of aperture), and a wider color gamut range (color gamuts such as ITU-R BT.2020), thereby delivering a high-quality and highly immersive visual feast for viewers. This article takes research on the application of 4K technology in television as its entry point, upon which it conducts in-depth exploration; the related content is described below.

Full Text

Abstract

4K Ultra High Definition (UHD) television represents the primary direction for future television technology development. Compared with high-definition television, 4K not only substantially increases resolution to 3840$×$2160 pixels but also delivers exceptionally high resolving power (with measured lens resolution exceeding 1000 lines), wider viewing angles (exceeding 60 degrees), higher frame rates (including 100 fps and 120 fps standards), greater dynamic range (exceeding 14 stops in production), and an expanded color gamut (such as ITU-R BT.2020), collectively providing audiences with a high-quality, immersive visual experience. This paper examines the application of 4K technology in television as a foundation for deeper investigation.

Keywords: 4K technology; television; application; research

1. Overview of 4K Television Technology

Current 4K television technology achieves a resolution of 3840$\times$2160, $with 4K displays containing approximatel$ $definition televisions. As a relatively cutting-edge technology in the video field, 4K television adheres to ITU stan$ $high-definition display science domain. Based on resolution analysis, the 4K standard represents an eight foldin$ $definition display benchmark, with maximum resolution reaching 3840\times$2160P [Figure 1: see original paper] [Figure 2: see original paper]. In practical applications, 4K technology offers an exceptionally broad visual angle range with more refined image display. The sensory effect of 4K television more closely approximates reality without suffering from reproduction loss or low screen clarity issues.

2. Research on 4K Technology Application in Television

China's 4K television production is currently in a developmental stage. The film *The Return* marked the beginning of 4K film production in China. At present, 4K television production resources remain relatively scarce, with few established achievements. However, 4K technology has gradually gained attention from major Chinese television stations, which have initiated research and platform development initiatives. This study analyzes a specific broadcast television station as a case study.

The station's 4K equipment system currently utilizes Sony and Blackmagic Production Camera configurations. Lens selections include Zeiss Master Prime T1.3, ARRI/FUJINON 18-80mm, and Angenieux OPTIMO 24mm. Since most subjects involve location shooting, equipment portability represents a key consideration, leading the station to adopt combinations of zoom and wide-angle lenses. Analysis of captured footage reveals that imagery from the F65 camera demonstrates not only superior picture quality exceeding conventional HD due to higher resolution but also distinct color reproduction characteristics. While HD production typically involves focusing on distant subjects before capturing panoramas—with other lenses rendering actual scenes once focus is established—F65 shooting, even when paired with Zeiss Master Prime T1.3 wide-angle lenses, produces panoramic images with strong depth perspective. This sense of depth, often unachievable in HD due to defocus and other objective limitations, becomes remarkably pronounced in 4K technology.

This evidence demonstrates that 4K cameras exhibit particular sensitivity in focus, making focus pulling a critical operational consideration during shooting. Since depth cannot be completely eliminated, the primary approach involves focusing on subjects during wide-angle shooting while increasing ISO and minimizing aperture. Based on practical experience, ISO 200 with wide aperture produces noticeable depth, whereas ISO 800 better suits panoramic shooting with deep focus requirements. Even with substantial outdoor lighting variations, the F65's latitude provides effective handling capabilities. Therefore, factors affecting depth extend beyond light intensity, with picture resolution exerting a more significant influence.

Regarding color, the BT.2020 standard introduces adjustments compared to Rec.709, maintaining the D65 white point concept while increasing color depth from Rec.709's 8-bit to 10-bit and 12-bit. This enhancement profoundly improves overall image color depth and gradation, fundamentally altering optimal dynamic range indicators. Beyond increased color depth, the BT.2020 standard's color triangle area exceeds Rec.709's by more than twofold, demonstrating a substantially broader color gamut in high-definition systems.

The station's 4K post-production color grading employs IQ52 version and Autodesk Flame, both capable of digital image processing at 16-bit depth. However, larger color gamut triangles demand higher display device performance. Under current BT.2020 standards, conventional television projection equipment fundamentally cannot meet 4K technology color reproduction requirements, impacting 4K master playback. To accommodate high-definition channel broadcasting, 4K masters must be converted to HD resolution while addressing color space limitations by transforming video from BT.2020 to HD Rec.709 color space.

Analysis of BT.2020 standards and practical 4K production reveals that 4K production processes are considerably more complex than HD production, requiring substantial technical support. Accumulating extensive practical and theoretical experience represents the sole pathway for 4K television technology development. From a shooting effectiveness perspective, 4K ultra-high-definition systems not only enhance picture quality through resolution but also improve refresh rates and color gamut, with the expanded color triangle particularly enabling higher color fidelity that substantially differs from high-definition systems.

3. Research on Industrialized 4K Television Production

4K television production involves multifaceted processes with specific requirements for storage and post-production systems. Due to 4K shooting's large memory footprint, the broadcast station has assigned technical personnel to perform dual data backups and organization to ensure production schedules.

For post-production, the station conducts offline editing directly in AVID or Premiere using Sony RAW format without transcoding. Without centralized storage, signals are recorded onto small hard drives, with EDL and AAF files transferred to compositing equipment after editing. While testing confirms this approach effectively completes 4K offline editing when disk array speeds meet standards, material loads depend on maximum disk array capacity, creating storage system pressure.

To accommodate high-definition channel broadcasting, comprehensive adjustments to resolution and color gamut are necessary for 4K masters since existing television projection equipment cannot meet BT.2020 4K image standards. The station's 4K production quality already matches cinema levels, substantially exceeding BT.2020 television 4K standards. Given these complex processes and

production pressures, adopting high-compression-ratio shooting directly matching television 4K broadcast standards is recommended. This approach simplifies workflows, eliminates format conversion, reduces color grading complexity, and alleviates material storage and post-production system overload.

Comprehensive 4K television coverage represents the inevitable future, making research on 4K technology application in television a long-term endeavor. During the current high-definition 普及 period, these methods constitute the most effective measures for 4K adaptation to high-definition system platforms and have become a new milestone in 4K television production development. However, to meet current television technology development demands, we must build professional 4K television production teams while ensuring personnel fully master relevant technical workflows to pave the way for future 4K televisionization.

4. Prospects for 4K Television

Driven by continuous development in LCD panel and processor performance, 4K television technology has emerged. At the 2012 CES exhibition, numerous manufacturers prominently featured "4K" terminology in their advanced display equipment presentations. By 2013, many manufacturers had begun 4K technology research, with some adopting the UHD (Ultra High Definition) term—an ITU-standardized designation.

In recent years, China has released several 4K films whose stunning picture quality demonstrates perfect fusion between technological innovation and cinematic art. In developed countries, 4K technology has achieved certain successes. Moving forward, we must conduct targeted adjustments to 4K product resolution and color gamut while terminal manufacturers research audience demands and broadcast source limitations. From a developmental perspective, the 4K television industry chain is gradually entering a substantial growth period. Although 4K technology is maturing, a gap remains from achieving true 4K effects, requiring improvements not only in 4K terminal products but also in viewing environments.

Furthermore, perfecting 4K content service providers and transmission pathways represents an urgent issue. This constitutes the primary constraint preventing comprehensive 4K television technology 普及, as 4K film production standards remain ambiguous. Although current 4K television content remains relatively scarce, most successful video service providers have begun 4K content production. In China, new media platforms such as Sohu and LeTV have started 4K television content production. With comprehensive bandwidth improvements, 4K television will inevitably 普及 in the near future, with 4K television technology and processes becoming more refined.

4K television technology development remains a long-term task. Only through comprehensive development across 4K technology, production, transmission, and terminal equipment—coupled with gradual, sequential improvement of 4K

television foundations—can the 4K television industry chain gradually normalize and mature.

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