True 4K Optical Transmission for Next-Generation Surgical Lighting Systems
Addressing Latency, EMI, and Mechanical Constraints in Modern Operating Rooms

1. Executive Summary

The operating room is undergoing a rapid transformation from a standalone clinical environment into a fully connected digital platform. As surgical lighting systems increasingly integrate high-performance cameras, they are becoming strategic imaging hubs that support surgical recording, medical education, remote consultation, robotic-assisted procedures, AI-based image analysis, and real-time collaboration.

This shift is raising performance requirements for video transmission. Hospitals and medical equipment manufacturers are moving beyond Full HD toward true 4K imaging, where large volumes of uncompressed video data must be transmitted with no visible latency, no frame loss, and no compromise in image quality.

However, conventional transmission methods are reaching their practical limits. Electrical cables are exposed to electromagnetic interference (EMI), mechanical fatigue from continuous arm movement, bulky cable routing, and distance constraints. Wireless transmission can simplify installation, but it often depends on compression and shared RF environments, which can introduce latency, image degradation, and reliability concerns.

Optical fiber transmission directly addresses these challenges. By enabling uncompressed 4K video transmission with exceptional signal integrity, EMI-resistant optical links , long-distance reach, lightweight cabling, and electrical isolation, optical fiber provides a robust foundation for next-generation surgical lighting systems.

This white paper explains how OptoHub's 4K Camera Optical Interface Board helps OEMs accelerate the development of advanced surgical lighting products by combining true 4K optical transmission, low-latency performance, compact system integration, and future-ready scalability for AI, robotic surgery, and 8K imaging applications.

2. The Evolution of Surgical Imaging

Hospitals worldwide are investing heavily in digital operating rooms where medical devices are interconnected through high-speed networks.

Key drivers include:

- Surgical recording
- Medical education
- Remote consultation
- AI-assisted diagnosis
- Workflow optimization

Fig. 1 summarizes the evolution of digital operating rooms. The benefits of surgical lighting systems with integrated cameras include:

- Clinical Documentation: Accurate recording of procedures.
- Medical Education: Live streaming to classrooms.
- Telemedicine: Remote participation by specialists.
- AI: Future automatic recognition of surgical scenes.

High-quality, low-latency video transmission is the foundation of digital operating rooms.

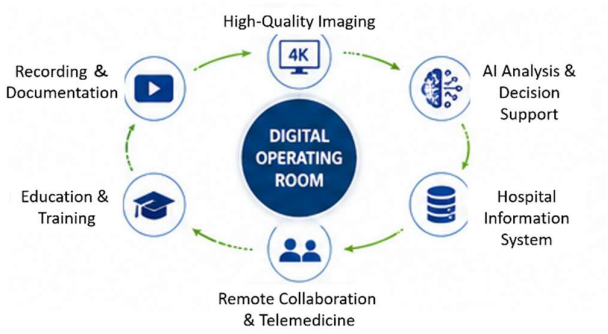

Fig. 1. Summary of the evolution of digital operating rooms.

3. Surgical Lighting Market Size

The global surgical lighting market size is projected to reach USD 1.85 billion by 2025 and grow from USD 1.95 billion in 2026 to USD 2.94 billion by 2034, with a compound annual growth rate (CAGR) of 5.26% during the forecast period from 2026 to 2034[1)], driven by increasing surgical procedures, aging populations, and the transition to LED-based lighting systems. Camera-equipped surgical lights represent one of the fastest-growing product categories within this market.

4. Engineering Challenges

Fig. 2 shows a conventional electrical cable-based architecture for camera-equipped surgical lights. When high-resolution image transmission is required, the following challenges can become system-level design constraints

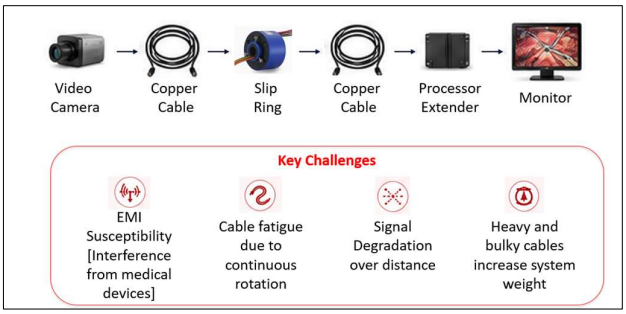

Fig. 2. Conventional electrical cable-based architecture for camera-equipped surgical lights.

a. EMI
Operating rooms may include MRI systems, X-ray systems, electrosurgical generators, and high-frequency equipment. These systems generate significant electromagnetic noise, making copper-based transmission increasingly difficult.

b. Continuous Rotation
Surgical lights rotate continuously. Electrical cables experience twisting, bending, and fatigue, reducing long-term reliability.

c. Longer Distance
Video is now distributed to operating room displays, recording servers, conference rooms, and remote hospitals. Transmission distances continue to increase.

d. Heavy Weight
Heavy and bulky cables increase overall system weight.

e. Image Quality
Modern surgeons expect zero frame loss, no artifacts, no compression and zero latency.

Cable-based electrical systems can struggle to meet the demands of modern 4K surgical imaging.

5. Optical Fiber Solution

Optical fiber can address may of the engineering challenges discussed in the previous section.

a. EMI Immunity
Optical fiber is inherently immune to electromagnetic interference.

b. Long Distance
Optical fiber supports transmission over hundreds of meters to kilometers, depending on the optical module configuration.

c. Electrical Isolation
Optical fiber provides electrical isolation and helps improve patient safety.

d. Lightweight
Optical fiber significantly reduces cable weight.

Table 1 compares wireless transmission technology and optical fiber transmission technology.

Feature	Wireless	Optical Fiber
Image Compression	🔴 Usually required	🟢 Not required [Uncompressed]
Latency	🔴 10 – 100 ms [Variable]	🟢 < 1 ms [Near-zero]
Image Quality	🔴 Variable [Artifact possible]	🟢 Original quality [Lossless]
EMI Immunity	🔴 Susceptible to RF interference	🟢 Completely immune
Security	🟡 Network dependent	🟢 Physical medium [Highly secure]
Reliability	🟡 Environment dependent	🟢 Highly stable
Cost of Ownership	🟡 High [network Infrastructure]	🟢 Low [24/7 operation]

In addition to optical fiber transmission, wireless transmission is also considered a technology for transmitting high-resolution image signals. Table 1 compares wireless transmission technology and optical fiber transmission technology. Wireless transmission offers installation flexibility but often relies on video compression, introducing latency and potential degradation of image quality.

6. OptoHub Solution

6-1. Optical Architecture Proposed by OptoHub

To achieve reliable, high-quality imaging for next-generation surgical lighting systems, OptoHub proposes uncompressed 4K video transmission using optical fiber and fiber optic rotary joints (FORJs). Fig. 3 illustrates the optical architecture for camera-equipped surgical lights proposed by OptoHub.

One of the major advantages of this architecture is that the FORJ can be incorporated into the rotating arm without introducing signal degradation, enabling continuous 360-degree rotation while maintaining stable transmission.

The key benefits of this architecture are:

a. EMI immunity: Immune to electromagnetic interference from medical devices and equipment
b. Ultra-low latency: Near-zero latency ensures real-time visualization and response
c. Uncompressed 4K video: Delivers original image quality with no compression artifacts
d. Long-distance transmission: Supports long-distance transmission over multimode fiber (MMF) or single-mode fiber (SMF).

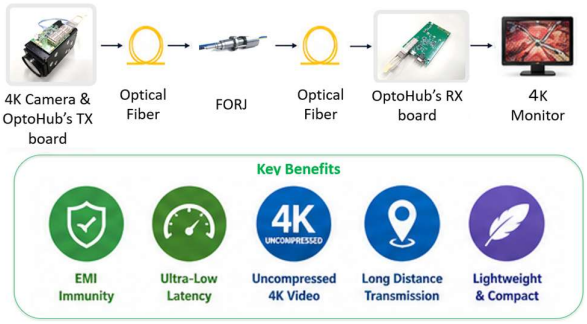

Fig.3. Optical architecture of camera-equipped surgical lights proposed by OptoHub.

6-2. OptoHub's 4K Camera Optical Interface Board

OptoHub's 4K Camera Optical Interface Board converts TMDS video output from compatible 4K camera blocks into optical signals for long-distance transmission over optical fiber.

Fig. 4 summarizes the key specifications of OptoHub's 4K Camera Optical Interface Board. Key functional features include:

- Designed to be compatible with Sony FCB-4K series camera blocks
  FCB-ER8530 and FCB-ER9500
- Camera control via VISCA compliant with RS-232C
- Transmission up to 150 m using a single 12-core MPO optical fiber cable

- Power supply:
  Transmitter (Tx) board: DC +12 V
  Receiver (Rx) board: DC +5 to +24 V
- Low power consumption: Tx Board 2.0 W max.; Rx Board 4.5 W max.
- Compact size, Tx board: 50 x 65 mm, Rx board: Size to comply with Compact PCI

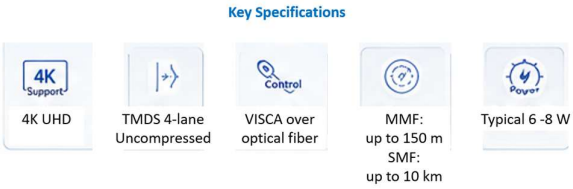

Fig. 4. Key specifications of OptoHub's 4K Camera Optical Interface Board.

The transmitter (TX) and receiver (RX) board architectures are optimized for OEM integration into surgical lighting systems while maintaining reliable high-resolution video transmission. Detailed product specifications are provided in the product brief or datasheet[2)].

6-3. Connection Example

A connection example of the 4K Camera Optical Interface Boards is shown in Fig. 5. A key advantage for customers is that the product is a turnkey solution.

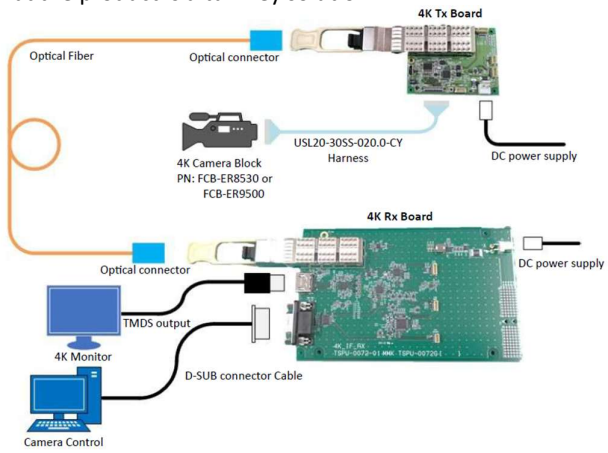

Fig. 5. Connection example of the 4K Camera Optical Interface Boards.

Future Trends

Because uncompressed signal transmission preserves high image quality, optical fiber architectures can support future requirements such as AI-assisted surgery, which requires original image quality; robotic surgery, which demands low latency; and 8K imaging.

7. Conclusion

Optical transmission is no longer simply an alternative to copper cables. It is becoming an enabling technology for the next generation of digital surgical lighting systems. By combining ultra-low latency, EMI-resistant fiber links, long-distance transmission, compact OEM integration, and future scalability, OptoHub's 4K Camera Optical Interface Board provides medical equipment manufacturers with a practical platform for developing next-generation surgical lighting products.

8. References

1) https://straitsresearch.com/jp/report/surgical-lights-market
2) https://us.optohub.com/products

About OptoHub

OptoHub is a brand of Mimaki Electronic Components Co., Ltd. and OptoHub Co., Ltd.

OptoHub develops OEM optical transmission technologies for medical imaging, industrial vision, defense, and broadcast applications. Core technologies include:

- 4K Camera Optical Interface Boards
- Fiber Optic Rotary Joints
- Optical Video Transmission Systems
- Customized OEM Optical Solutions

Learn more

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