

LED Fiber-Optic Lighting Devices Developed for Medical Assistance for the Local Treatment Retractor

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국부치료를 위한 Retractor용 LED 광섬유 의료보조조명 장치 개발

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Abstract This paper introduces a device providing close local lighting to the affected part, where the operation-purpose astral lamp alone cannot shed light directly, in an operation room of hospitals or clinics, which helps clinical doctors perform safe treatment of the affected part deep inside a human body. This medical assisting lighting is a device necessary to prevent fatal operation failures, which can occur with minute operation processes, such as tumor removal or angiorrhaphy. The components, such as the light source and power supply were designed to be low power consuming and small in size, have a narrow angle lens was used to increase the light spreading effect and focused illumination. The end-caps of the light transmission device using an optical cable and the lighting device were designed in the waterproof type to enable disinfection of these devices after use for the next patients. According to the measurement of the light source properties made after development of the retractor lighting device, the illumination intensity was 490 lux, the brightness was 11,550cd/m², general color rendering index was 78, color temperature was 11,000K, and the intensity distribution was even, which were confirmed to be adequate for medical assisting local lighting.

요약 본 논문에서 소개하는 기기는 병원의 수술실에서 수술전용조명인 무영등만으로는 직접 조명할 수 없는 수술부위의 환부에 근접 국부조명을 제공하는 장치로서, 임상의들이 인체 깊숙한 환부의 질환 치료를 안전하게 시술하도록 한다. 이 의료 보조조명 장치는 중앙계거나 혈관봉합과 같은 미세한 수술과정에서 발생할 수 있는 치명적인 수술 실패를 방지하기 위해서 필요한 장치이다. 광원 및 전원부 등의 구성요소는 저전력, 소형화로 설계되었으며, 협각렌즈를 사용하여 광확산 효과의 증가와 집중 조명에 용이하도록 하였다. 광케이블을 사용한 조명전송과 조명장치의 Endcap은 사용 후 다음 환자를 위하여 소독이 가능하도록 방수형으로 설계되었다. 리트랙터 조명장치 개발 후 이루어진 광원특성 측정 결과, 조도 490lux, 휘도 11,550cd/m², 연색성 78, 색온도 11,000K 및 고른 조도분포도를 보여 국부 의료보조조명으로서 적합하였음이 확인되었다.

Keywords : LED, Lens, Medical Lighting, Optical Fiber, Retractor.

1. Introduction

The retractor is an apparatus used in every hospital or clinic to open the affected part for the purpose of securing space around the treatment spot for clear view

and smooth operation, when the affected part is located deep in a human body. Medical Retractors are traction apparatus for medical purposes and have diverse types depending on operations and cases[1].

Retractor types are largely divided to manual

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Retractors and Self-Retractors. A manual retractor is used by a person other than the operating person to maintain the affected part as opened while a self-retractor opens and fixes the affected part and its usage may change depending on the scale of each hospital or clinic, or operation scale. The manual retractor is used less and less because of the issues of operation radius and complexity of operations, while use of the self-retractor is increasing because once it fixes the affected part, it keeps fixing. But, in case direction of light needs to be changed, position of the retractor should also be changed, which is inconvenient. To solve this problem, some doctors use head lamp but its use is substantially low because of its inconvenience, and heating and weight of the lamp.

Therefore, sometimes, fatal operation failures are caused by instant misjudgment of doctors even in a simple operation, and consequently patients' lives may be endangered[2]. Hence, rather than for mere merchantability, marketability, or competitiveness, retractors with a lighting device need to be developed in order to ensure lives of patients' while operation.

In this research, a lamp was installed to the Self-Retractor which is the most widely used by general surgery, thoracic surgery and orthopedic surgery, to develop an anti-fouling and water-resistant LED lamp type[3] Self-Retractor by which light source is directly illuminated to the affected part without shade, so that clinical surgeons may directly shed bright light to the blind spot created even by the astral lamp to easily secure clear view during operation.

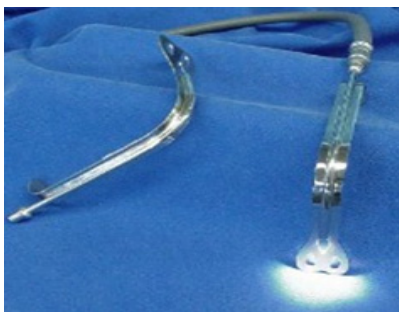


Fig. 1. Example of Lighted Manual Retractor (Miltex Instrument company)

2. Composition of the overall system

[Fig. 2] introduces the optical fiber medical lighting device, for retractor, assisting the operation room's astral lamp for a local treatment in hospitals or clinics, showing the overall system composed of a LED light source and its power supply, optical lens, and GOF(Glass Optical Fiber).

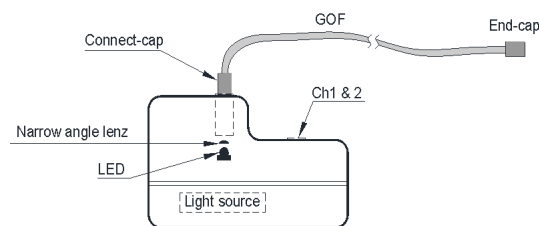


Fig. 2. Overall block diagram

2.1 Light source and power supply

The optical properties of LED which is suitable for the usage environment and satisfies sufficient conditions as a retractor light source are as follows:

- Type : Round $\Phi 5\text{mm}$, High Flex(particularly, circular shape with the height below 6mm)
- Operation voltage : 2.7V-3V
- Power consumption : 65mA(considering hours of battery use)
- Table 1 shows the Optical properties

Table 1. Optical Properties

I_f	T_j	V_r	T_{opr}	T_{stg}	CCT	V_f	l_m
650mA	120°C	5V	-40 to 80°C	-60 to 100°C	11,000K	3.7	30

The lamp's power supply can be used for more than 10 hours by charging once and adopts the constant current supply method, and the PCB containing the power supply battery and light source LED is located at the lower part not to contact the external case directly and underwent insulation treatment. Line alignment was made so that the center of light source

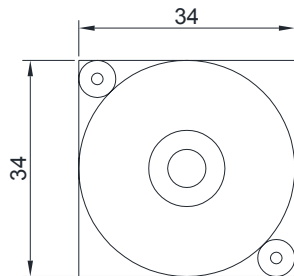
is coincident to the correct center of optical fiber, and the properties of DC power supply are as follows:

- Nominal Capacity : 1,300mAh(650mAh×2parallel connection)
- Nominal Voltage : 3V
- Dimension : D 18.25mm×H 65mm
- Charge Method : Constant Current, Constant Voltage(3V)
- Discharge Temperature : -20°C ~ +60°C
- Charging Time : Standard 3 hrs, Rapid 2.5 hrs.

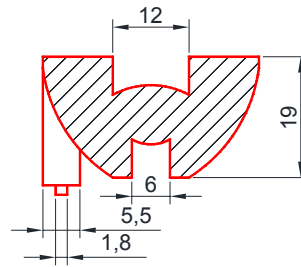
2.2 Optical lens

The lens was attached to the terminal of the optical fiber to improve the opening angle property of the light beam emitted through the optical fiber. This is because light spread effect is necessary depending on the treatment spot and LED is made to shed light on an extremely small part in a narrow space due to its strong straightforwardness. Also, coating process is required to prevent lighting from being weakened because of contamination by surgery waste. The specifications of the lens used for the experiment are as follows:

- Pattern type : Clear
- Collimator material : PMMA(poly methylmethacrylate)
- FWHM : 11°
- Lens size : D34×19mm



(a) Plan



(b) Section

Fig. 3. Dimensions of the lens

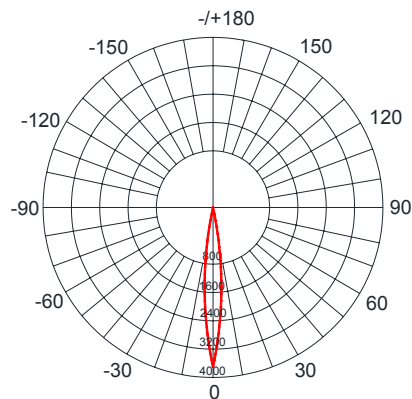


Fig. 4. Relative Intensity with different Beam angle

A narrow lens was used to make the equipment applicable for local lighting. [Table 2] lists the specifications of the lens used for the experiment.

Table 2. Lens Properties

Property	Test method	Unit	Result	Operation Temp. Range
Light Transmittance	ASTM 1003	%	92	-35 to 75°C
Thermal Deformation Temperature	ASTM D648	°C (kgf/cm ²)	18.6	
Izod Impact Strength	ASTM D256	J/m (kgf/cm ²)	1.5	

Using a focusing lens (34 mm) neglecting spatial constraint conditions, at the time of designing lens size, is improper. Because it is related to the battery size and

so placement of power supply would be difficult and eventually a small power supply would be used, which would substantially reduce duration of use of the light source.

2.3 Optical fiber and connection part

Optical Fiber refers to a Cylindrical Wave Guide composed of the core with a high index of refraction and the cladding with low index of refraction. For transmission, use is made of the phenomenon that light incident on the boundary surface of two materials with different index of refraction each at an angle larger than the critical angle is totally reflected at the boundary surface, to keep reflecting totally the light incident to the core part within the core. This way, light is transmitted to a long distance. In this research, the optical fiber of 3 mm radius GOF and fluoro-carbon resin was used.

Circuits are placed in such a way that the light source and peripheral circuits are loaded on the same PCB and the light source center and the optical fiber center coincide, and to reduce light loss from the connection part of the light source and optical fiber, a middle adaptor was used.

In the design of the connection part between the light source and the optical fiber, a preliminary experiment verified that if the light from the light source is focused by using a lens and if this is put into the anti-reflection coated optical fiber, the total light intensity generated from the light source can be delivered relatively efficiently. But, in this case, an adaptor was employed because it was impossible to install an attach & detachable structure with the LED and focusing lens integrated, at a limited space.

Also, a lens was attached to the optical fiber terminal to improve the opening angle property of the light emitted through optical fiber. This is to give light spread effect to prevent that the lighting effect of LED may be reduced significantly because LED has strong straightforwardness and so illuminates only an extremely small part in a narrow space. This is also

required for the coating process to prevent lighting from being insufficient due to contamination by operation waste during operation.

2.4 Design of detachable function

There may be several reasons for making a retractor attach & detachable, but it should be made such because of the sterilizing and disinfection process after use, above all other reasons. After use, metal equipment is usually washed by flowing water and disinfected by a high pressure sterilizer or a sterilizer. The sterilizer does not use high temperature and so cause no substantial problem, but if the high pressure sterilizer is used, the built-in battery may cause problems.

Therefore, in this experiment, the retractor equipment was designed in such a detachable way that the equipment can be disinfected as a whole system in the disinfection process of using a sterilization gas but can be disinfected in separation if the high pressure sterilizer is used. Particularly, a special connector was made so that the Vaginal Specula upper part where optical fiber is attached and the pendulum part where power supply is built-in are separated from each other, and as the materials used are not easily rusted or deformed under high pressure and temperature, these do not cause any problems to washing and disinfection.

Also, waterproof functions, such as water resistance, easy maintenance and easy sterilization and disinfection, were supplemented so that washing and disinfection would not be inconvenient during clinical use, and disassembly & assembly of the corresponding parts was made easy for maintenance. This equipment was made to be a simple equipment without any separate care besides charging when it is not used.

3. Experimental results and discussion

In this experiment, 0.2W LED (2ch.), portable power supply and optical fiber were used to emulate

the retractor's lighting device, and then the equipment was made for verification.

As measurement values of the light source obtained after making, illumination intensity LED (Mod. 9000) was 490lux at the 10cm distance and brightness (MINOLTA LS-100) was 11,550cd/m². [Fig. 5] show Prototype performance test.

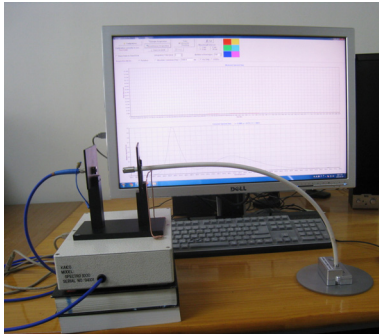


Fig. 5. Prototype performance test

In [Fig. 6], with X co-ordinate 0.2825 and Y co-ordinate 0.2660, color coordinates show high color temperature, and color rendering group is 2, color appearance group is 3(cold), and general color rendering index is 78.

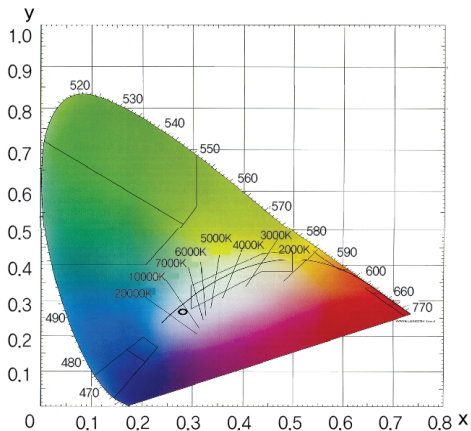


Fig. 6. Chromaticity

In [Fig. 7], the Dominant wavelength is 444nm, the Excitation purity is 2.0, and Colorimetric purity was verified to be 11%.

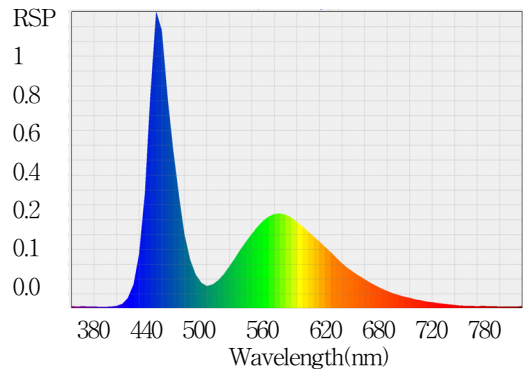


Fig. 7. Relative spectral power wavelength

[Fig. 8] and [Fig. 9] show illumination distribution when the completed lighting device sheds light at the 1m height onto the area of 1m length and 1m width. It is possible to know that this value can be used for similar lighting devices.

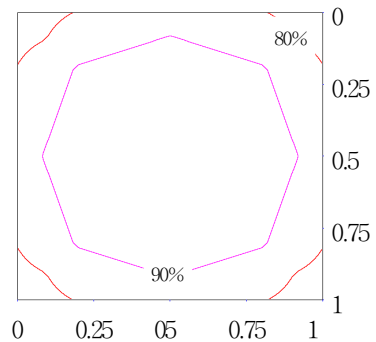


Fig. 8. Isometric lux

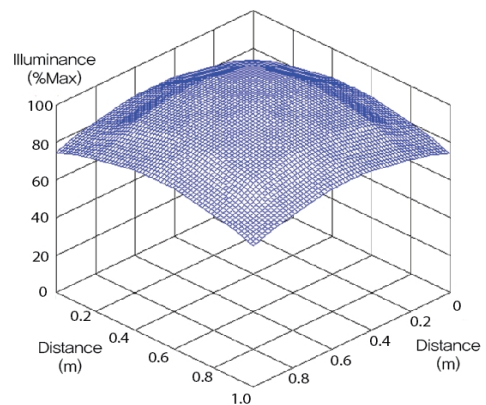


Fig. 9. 3D Lux web

4. Conclusion

This R&D verified that the above is a technology of providing a close lighting means to the affected part located where external lighting cannot shed light directly in a real operation site which help clinical doctors do safe treatment of the affected part deep inside a human body. And that this equipment is a medical assisting equipment definitely necessary to prevent fatal operation failures which may happen to minute operation processes such as tumor removal or angiorrhaphy. Results of the experiment may be summarized as follows:

1. As a device transmitting light to a limited distance using optical cable, its illumination intensity of 490lux (at the 10cm distance) and brightness of 11,550cd/m² were verified[4] to give properly bright assisting lighting for operation.
2. Color temperature was bright with 11,000K, and the General color rendering index of 78[4] was judged as adequate for identification of accurate operation spot.
3. Also, this development has significant meaning as a medical assisting lighting considering that this equipment can easily be applicable to other medical equipment and the scope of usage is very wide.

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<Research Interests>

Electrical Facilities, Lighting and design, Heat-sink