Individual Component Analysis: Fiber Optics Applications in Surgical Procedures

Hans Chen

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Project Description

Current instruments for orbital surgery have significant limitations. Due to the tendency of orbital fat to obstruct vision, surgeons grapple with challenges to access vital structures, such as the optic nerve. Even more, with the orbital region having a high concentration of blood vessels, the risk for hemorrhage and subsequent vision loss is always high [3]. The development of an orbital surgical tool that will efficiently displace fat to improve visibility would reduce procedure duration as well as the overall risk associated with orbital surgical procedures.

Functional Requirements

Fiber optic systems are increasingly becoming more common in the operating room, due to easier access to viewing the target as well as diminishing the need for invasive surgeries. The goal of the implementation of fiber optics to the designed tool will be

- Illuminate target area
- Provide sufficient resolution for visualization onto monitor in surgical room [1]

The component has to have the ability to vary power output to decrease accidental thermal burns that may arise. The risks come from

- Light source tip reaching 250°C
- Endoscope tip reaching 100°C [2]

With this in mind, a thermal sensor will be included so the surgeons are aware of a thermal limit being reached. Lastly, the fiber optics must be flexible so there is no loss of ability when different angles are taken.

Descriptions of Component Options

There are 3 main types of subclasses of step-index fibers that are most commonly used. All 3 subclasses range in terms of their accessibility, flexibility, and optical resolution that can be analyzed for the optimal case to meet the functional requirements.

1) **Single-Mode Fibers (SMF)**: SMFs are widely available and are well-suited for illumination because they only guide a single spatial mode of light, as seen in Figure 1. Light is confined to a single, well-defined path. Images are also relatively high resolution.

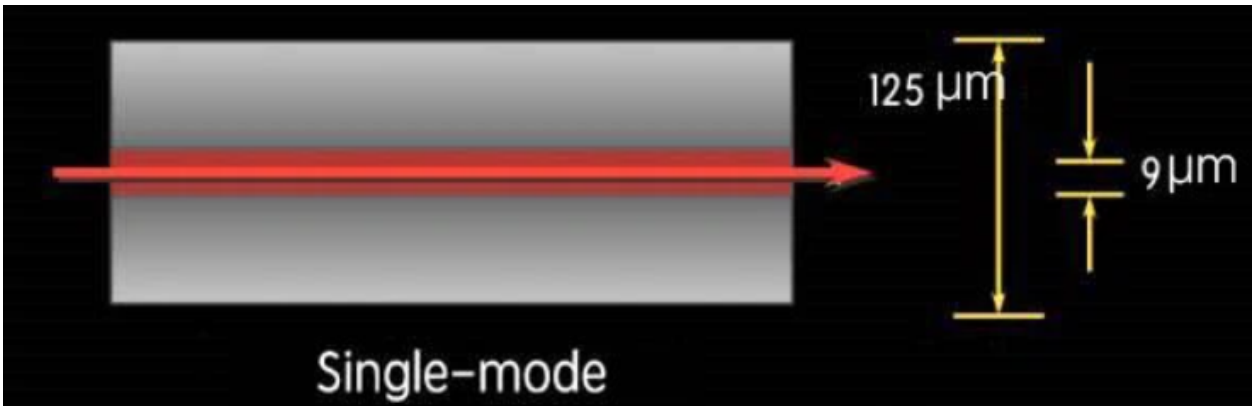

Figure 1: This shows the single path that occurs when SMFs are implemented.

2) **Multimode Fibers (MMF)**: MMFs are also relatively widely available. Similar to SMFs, they are used commonly in medical devices such as endoscopes. Shown in Figure 2, they have a high numerical aperture, which means there is a higher range of angles in which light can be captured. They are also one of the most flexible types of optical fibers, which is important for surgical applications.

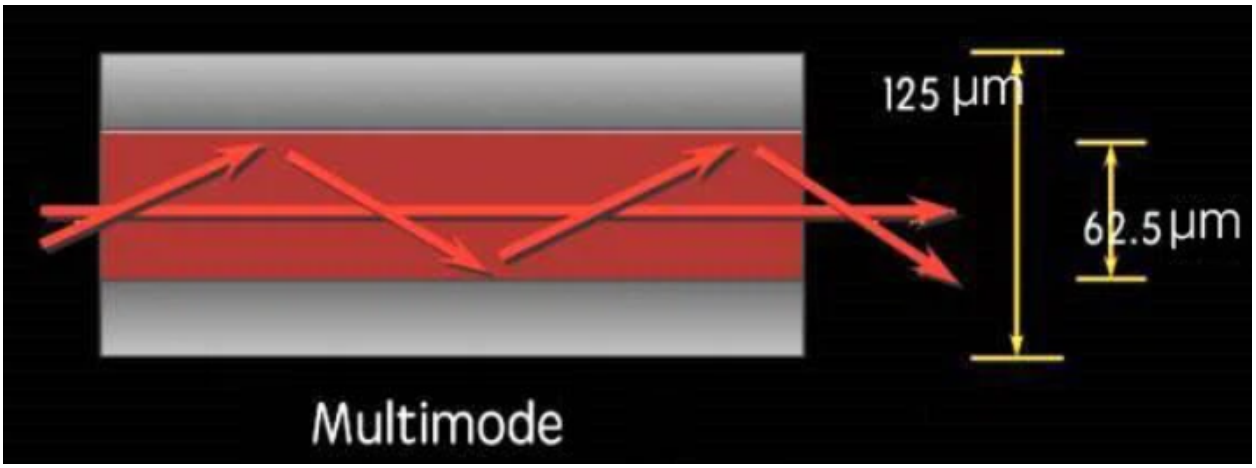

Figure 2: MMFs are able to capture light from a greater range of angles.

3) **Gradient Refraction Index (GRIN) Fiber**: In most of the other imaging applications, in order to adjust the focal plane, the optical object must be physically moved. However, with GRIN Fiber, the refractive index naturally provides a mechanism that is able to adjust the focal plane, as displayed in Figure 3. This subclass is quite flexible as well but has limited optical resolution compared to the other methods [1].

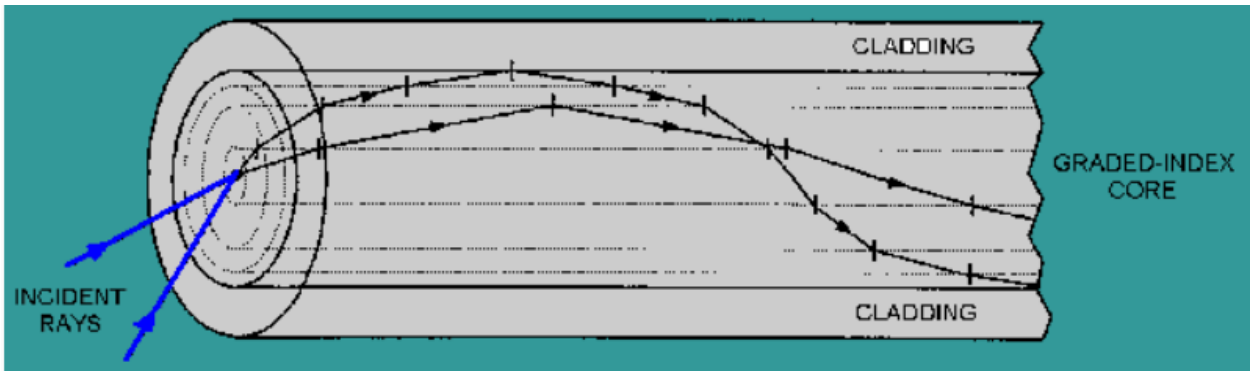

Figure 3: GRIN Fiber naturally adjusting the focal plane is displayed.

A combination of SMFs and MMFs in a fiber optic bundle is also a possible option that can be considered, on top of exclusively using either of the subclasses mentioned above.

In addition, there will be a thermal sensor that will detect the temperature of the head of the tool. There are several factors to be taken into consideration when selecting the sensor:

1) **Dimensions:** The dimensions and size of the sensor set-up will dictate how it will be implemented with the rest of the tool.
2) **Display Method:** A display could be included in the sensor set-up, or it could be displayed on the surgical monitor.
3) **Temperature Range Accuracy:** The higher the accuracy of the temperature reading, the less possibility that errors and injuries occur during the operation.

Summary Table

Fiber Optic Options	Pros	Cons
Single-Mode Fibers (SMF) $27.49	- Widely commercially available - Excellent image resolution - Reduced modal dispersion (focused and stable signal)	- Less flexible - Require more sophisticated, expensive light source - Less cost-effective for short-distance applications
Multimode Fibers (MMF) $18.74	- Cost-effective - Greater flexibility - Use a broader range of light sources	- Limited data transmission capacity - Modal dispersion occurs - Lower image resolution
Gradient Refraction Index (GRIN) Fibers $28.87	- Improved light propagation, leading to reduced modal dispersion - Flexible	- Complex design leads to high costs - Limited transmission distance

Sensor Set-Up Choices	Pros	Cons
Fiber Optic Monitor $6254.54	- Accuracy of ± 0.5°C across full temperature range - Display method provided, easy to set up	- Setup takes up a lot of space in operation
Temperature Surface Sensor $125.84	- Accuracy of ± 0.15°C across full temperature range - Sensor is 2 mm by 2 mm by 0.8 mm, can be placed near tip of tool	- No built-in display
Temperature Transmitter $337.77	- Sensor diameter is 18 mm, can possibly be placed inside of tool	- Accuracy of ± 1.0°C across full temperature range - No built-in display

References

Databases:

- Elsevier's ScienceDirect Database

Keywords:

- Fiber Optics for Biomedical Applications
- Review of Development of Fiber Optics
- Fiber Optics for Surgical Applications
- Dangers of Fiber Optics for Surgical Applications

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