# New ENT Laser Micromanipulator Design

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**Abstract:** It describes the shortcomings of traditional ENT laser micromanipulator, in order to improve the quality and reliability of output spot, using a reflective structure on the laser micromanipulator. With He-Ne laser as the indication beam, $CO_2$ laser as the working beam. We have optimized from coincidence, size of the spots and working distance of this device. So that the laser system has been greatly improved in terms of a predetermined distance within the spots coincidence, beam uniformity, stability and reliability, to meet the requirements of long-term care.

## 1. Introduction

Development of laser medical equipment earlier in seventies in China wasn't forming a market and get little application. As the laser medical equipment, especially manufacturing technology of He-Ne laser acupuncture treatment instrument and $CO_2$ laser beauty treatment machine was relative simple and inexpensive in the earlier market. Low requirements on medical laser performance, at the time development of laser technology was more suitable for this energy power and performance requirements. Laser medical equipment has becoming increased in demand for health care reforming, laser technology progression, market demand expandition. Such as laser instantaneous burst, short duration, small spot, nondestroy hair follicles, nondamage normal skin, no scars. People understand its advantages at the same time, medical safety is also of great concern.

For improving the quality and reliability of laser micromanipulator continuously, we should design a new kind of medical laser system meeting medical clinic needs. This system is particularly suitable for the throat, ears and other parts of minimally invasive surgery. We got an ideal multi-purpose medical laser system after clinical results.

## 2. Design ideas

Most biological tissues contain water, the interaction of laser with biological tissue is depending on the interaction of the laser with water to a large extent. Effective intensity of laser on tissue is directly related to the size of energy density, output power density, wavelength, tissue absorption coefficient

and other characteristics of laser, also these characeristics decide depth of penetration. The wavelength of $CO_2$ laser is 10.6μm, so skin has a high absorption on it, and its simple structure, lower price, good performance, stability, easy maintenance, these decide its broadly applications in medical field. He-Ne laser has much advantage, such as good direction (divergence angle less than $10^{-3}$ rad), good monochrome line width less than 20 Hz, simple structure, long life, small size, light weight, low cost, and easy to use. Besides the output power and wavelength can be controlled very stable. It is widely used for precision measuring, testing, collimation, orientation and other aspects [1]. Based on these characteristics, this design uses $CO_2$ as the working laser beam, He-Ne laser as the indicator [2].

**3 Design and operating results**

*3.1 Design*

*3.1.1 Technical requirements*
    Working distance: 200mm～400mm;
    Relationship of working distance and spot size is:
    200mm～400mm correspondence 0.16mm～4.6mm;
    Working laser and indication laser complete coincidence.

*3.1.2 Key considerations in design.* At present, the successful development of micromanipulator laser optical system is refractive. Because light beam is different from indication beam at wavelength. Lead to two wavelength of laser light produce great chromatic aberration when crossing the optical system. To correct chromatic aberration make configuration of system becoming very complicated. But it does not make sure the light beam and indication beam complete coincidence, so it affects treatment accuracy.

*3.1.3 Selective configuration of reflective system.* The reflective optical system has much characteristic such as no colour, light weight, compact structure etc. After reflective surface coating, high reflectivity, from far-infrared to X-rays over a wide spectral range. Reflective system will affect energy efficiency by obscuration of the restrictions, and then affect the therapeutic effect. So this design should consider to reduce obscuration ratio.

    Total reflective optical system is more common, such as Newtonian type, Cassegrain type, Gregorian style, Schwarzschild system. Newtonian system is the easiest type of reflective system, only a concave mirror, others belonging to the two mirrors system. The differences between them are bending directions of the reflective surfaces, and secondary mirror is relative to the position of primary mirror's focus. This article hopes to use spherical design and get minimize obscuration. The following discussion is correction primary aberration for spherical system:

Aperture provided on the main mirror, take the normalization condition: $h_1 = 1, u_1 = 0, f' = 1, u_3 = 1$,

the height of principal ray incident on the main mirror $h_{1z}=0$, incident angle $u_z=-1$, Lage invariant J=1. Refer to two variables:

$$\alpha = \frac{h_2}{h_1} 、 \quad \beta = \frac{l_2'}{l_2} = \frac{u_2}{u_3} \tag{1}$$

α is aperture ratio of two mirrors, β is magnification of secondary mirror. According to Gaussian optics and geometric relationship between every parameters, we get relations between the parameter and α, β.

Index of refraction $n_1 = 1$、$n_2 = -1$. The incident angle of first paraxial ray on the secondary mirror

$u_2 = \beta$，incident height $h_2 = \alpha$, the incident height of principal ray on the secondary mirror:

$$h_{2z} = \frac{\alpha - 1}{\beta} \tag{2}$$

radius of curvature of two reflection mirror respectively:

$$r_1 = \frac{2}{\beta} \quad 、 \quad r_2 = \frac{2\alpha}{1 + \beta} \tag{3}$$

their interval:

$$d = \frac{1 - \alpha}{\beta} \tag{4}$$

Use PW method to get the primary aberration coefficients:

$$\begin{cases} \alpha = 4.236 \\ \beta = 1.618 \end{cases} \tag{5}$$

$$\begin{cases} \alpha = -0.236 \\ \beta = 0.618 \end{cases} \tag{6}$$

By (5) and (6) we obtained

$$\overline{s_1} = \overline{s_2} = \overline{s_3} = 0 \tag{7}$$

When

$$\begin{cases} \alpha = 3.56, -0.56 \\ \beta = 0.39, -0.64 \end{cases} \tag{8}$$

$$\overline{s_3} = \overline{s_4} = \overline{s_5} = 0 \tag{9}$$

In this situation, when correcting two aberration , the third one is just zero.

When -1<α<0, β<0, we get a virtual image, the system is divergent, not suitable for laser micromanipulator optical system. In addition, when α=1, the interval of two mirrors is 0, So it should be removed from these solutions. It can clearly be seen the remaining solutions consist Schwarzschild system. Thus can be derived, Cassegrain and Gregorian system can adjust one kind of spherical aberration, the Schwarzschild system can correct up to three aberrations. When α>1, 0<β<1, the primary mirror and the secondary mirror is required openings in Schwarzschild system. Effect of stray light and obscuration are more serious, so we adopt the structure of α>1,β>1 in design.

It is known the incident light needs pass through secondary mirror to reach the primary mirror. So the secondary mirror requires opening. After reflected from the primary mirror toward the secondary mirror, only a part on the secondary mirror, and the rest through the hole on the secondary mirror does not participate in the imaging[3]. This is the first obscuration. Additionally, the secondary mirror

reflected light, there may be blocking by the primary mirror to form a second obscuration. Therefore, in order to improve energy efficiency, should be reduced caliber of primary mirror. It is discovery the obscuration is least over optimization when the stop on the main mirror.

*3.1.4 200mm～400mm working distance.* Working distance of this design need to achieve 200 ~ 400mm adjustable. Regardless of internal or external focus system will bring difficulty on aberration correction in design. The multiple design features in ZEMAX namely Multi- Configuration is a very practical function. It is based on a variety of patterns or structures used for debugging and analysis. For multi-structure analysis, its application involves many aspects, such as the zoom lens, magnification lens, eliminate temperature designing and the scanning lens. It allows the position of optical assembly to make a change with focus or magnification as function. It is also very easy to achieve, therefore, this design consider using multi-functional structure to realize working distance adjustable.

*3.2 Operating results*

The initial structure of the objective lens shown in Table 1. For debugging, aberration correction, analysis and evaluation the structural parameters of the initial objective with optical design software ZEMAX [4].

**Table 1.** Initial objective structural parameters

| Surf : Type | | Comment | Radius | Thickness | | Glass | | Semi-Diameter |
|---|---|---|---|---|---|---|---|---|
| OBJ | Standard | | Infinity | Infinity | | | | 0.0000 |
| 1 | Standard | | Infinity | 25.0000 | | | | 1.5000 |
| STO | Standard | | 25.8927 | -24.0000 | V | MIRROR | | 1.5000 |
| 3 | Standard | | 50.0000 | 78.0860 | V | MIRROR | | 4.2739 |
| IMA | Standard | | Infinity | - | | | | 8.32E-005 |

Setting a single system is very similar to the multiple structure. Multiple Structure Editor is used to indicate those design parameters between different configuration parameters [5]. For this design, we will need three configurations: The first configuration is used to define the working distance 200mm. The second and the third, respectively, will be used to define the working distance of 300mm and 400mm. Table 2 is the multi-system configuration parameters. Using above parameters we got the structure of objective lens. Figure 1 is the structure when working distance is 200 ~ 400mm. It meets the design requirements.

**Table 2**. multiple structure parameters

| Active : 1/3 | | Config 1* | | Config 2 | | Config 3 | |
|---|---|---|---|---|---|---|---|
| 1: THIC | 2 | -9.174100 | V | -6.872908 | V | -5.774110 | V |
| 2: THIC | 3 | 209.174124 | V | 306.872911 | V | 405.774096 | V |
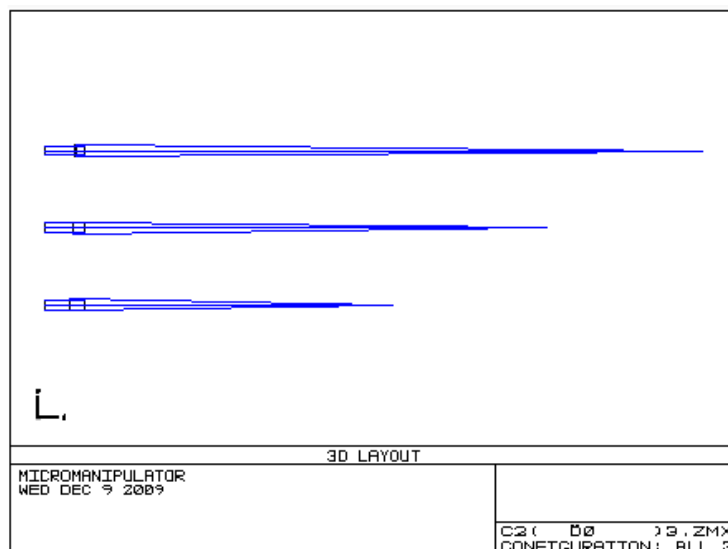
**Figure 1.** structure of objective lens

After debugging, we got an optical system the working distance can be adjusted. And the spot size is smaller than the required value in their working distance. As shown in Table 3 is spot diagram of 200mm～400mm work distance.

**Table 3.**Spot diagram of 200mm～400mm work distance

| work distance（mm） | 200 | 250 | 300 | 350 | 400 |
|---|---|---|---|---|---|
| required value（mm） | <2.8 | <3.2 | <3.7 | <4.1 | <4.6 |
| geometric radius（μm） | 0.595 | 9.495 | 17.166 | 24.131 | 30.659 |

## 4. Conclusion

In this paper, we use the characteristics of Schwarzschild reflective system, combined with the characteristics of the laser micromanipulator. Designed a new ENT laser micromanipulator which direction beam and working beam are complete coincidence and has small spot size. Meet the design requirements, to improve the accuracy of treatment. It is foreseeable that laser microscopy techniques will become increasingly widespread in the medical area. Laser micromanipulator quality and reliability will gradually increase.

## 5. References

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