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Synopsis of paper

Paper title

# Front view and panoramic side view videoscope lens system design

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## 1. Introduction

A typical endoscope, either for industrial or medical purpose, is conventionally the front viewing type, which have a limited view angle. There are several designs that can achieve wide field of view, such as fish-eye lens, panoramic reflector, panoramic annular lens (PAL), multi cameras or other designs. For an endoscope, especially medical endoscopes, the acceptable distortion is one limitation. The requirement of image performance is always high, which means the endoscope system must collect as much information as possible and achieve high image quality at the same time.

To increase the field of view, the side viewing endoscope was first proposed by Matsuno in 1998, which a prism is fixed before the lens to obtain a side view image. And the swing prism type was proposed in 2003 by Ramsbottom, where a configuration of lenses and prisms was used to simultaneously provide illumination to, and collect information from, the observed field. The prisms could be adjusted to direct the lighting and the location observed.

However, the viewing area of the swing prism types is only extended to one side of the endoscope. Another problem is that is the viewing angle is increased to directly extend the observable area to the side, the resolution of the image will drop due to the resultant distortion. Therefor in this paper, the author present a novel structure of a rigid panoramic endoscope which contains a rotary prism about the longitudinal axis of the endoscope and an auxiliary navigator lens, shown in Fig. 1. The inspected target field is imaged on the sensor by an optical lens with a dynamic mechanical module.

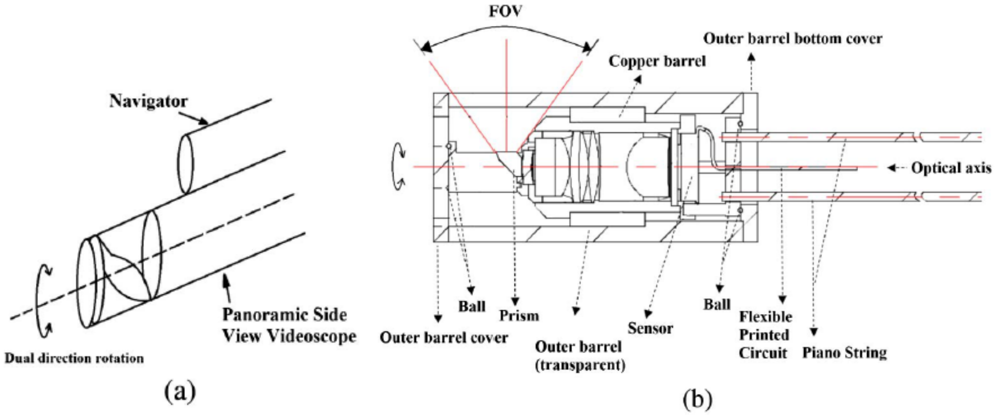



Fig. 1. (a)Conceptual schematic of the panoramic side view endoscope.

(b)Conceptual schematic of the panoramic side view endoscope as a cross-sectional view.

## 2. Panoramic Side View Endoscope Design

In this design, the total diameter of the tube is 10 mm, which means the lens diameter must be smaller than this value. So the lens curvature is limited by the manufacturing process, which will limit the viewing angle of the lens. For a normal panoramic reflector, the object NA is always small since the limitation of the sagittal ray aberration. That’s because the normal panoramic reflector must be symmetry of the optical axis. Although the aspherical surface can be used to correct the tangential ray aberration, the sagittal ray aberration is always difficult to correct. It provides a method to achieve larger object NA. That’s the reason why I choose this paper as my synopsis.

The panoramic side view videoscope(PSVV) is presented, as shown in Fig. 1. The first optical element is the cylindrical window which is limited to a tube diameter of 5 mm. The surface is biconic, which can be described by

$$z = \frac{c_x x^2 + c_y y^2}{1 + \sqrt{1 - (1 + k_x) c_x x^2 - (1 + k_y) c_y y^2}}$$

Where z is the surface sag value which is difference between the surface center and each point in the directions of optical axes. This element will induce an optical path difference in the two orthogonal directions due to the curvature difference thus can correct aberrations for both tangential ray and sagittal ray. Although a freeform surface would be better for the optical performance, the biconic surface is enough considering the manufacturing difficulty.

Followed the surface is the objective lens and the sensor. The signal is transferred by the circuit on the flat printed circuit board. Four balls located in the trench of the outer barrel cover and the outer barrel bottom cover of the barrel are used for rotating the lens and sensor. The rotation mechanism is used by the piano strings driven by a pair of gears and a control knob. The mechanical design is shown in Fig. 2.

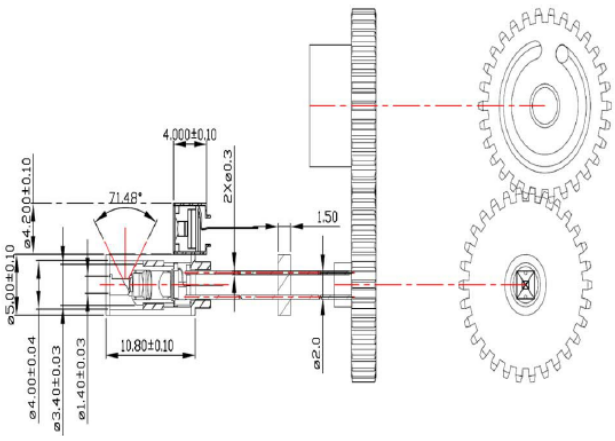



Fig. 2. Cross section of the PSVV system

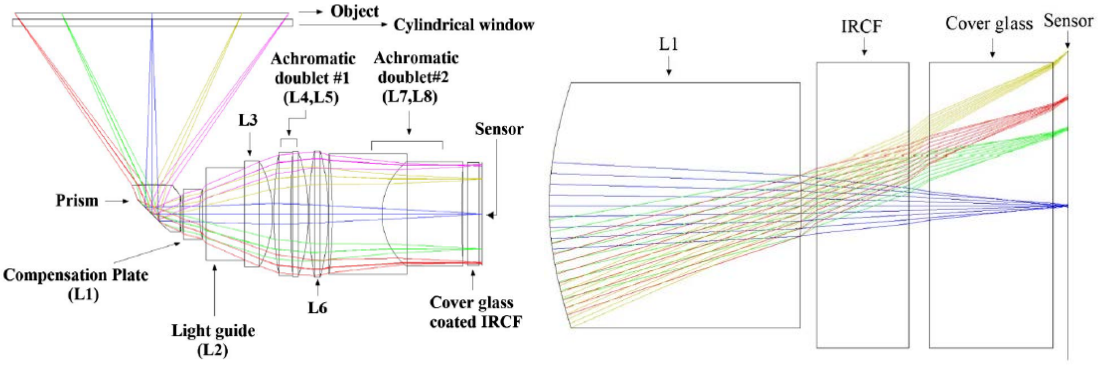
The sensor of the endoscope is 1/10.6 in with 400 by 400 pixel resolution. The distortion is kept below 20% with relative illumination (RI) above 50%. The specification of the panoramic side view vidoscope is shown in table 1.

## 3. Front View Navigator Design

The front view lens images the field on front of the endoscope and assists the operator in determining the endoscope position in the inspected space. In this design, the navigator lens is designed to achieve a longer DOF base on Ref. [1]. This method provides a reference process in designing and optimizing a lens with extended DOF. Overall, the front view design is not special with other endoscopes. The sensor is 1/18 in and the acceptable object distance covers the 15-50 mm range to the forward view. The specifications of the Navigator is shown in table 2. The author doesn’t talk about the design method in detail. Therefore, if anyone is interested in this method, please read the reference directly.

## 4. Design results

The PSVV layout is shown in Fig. 2(a). Light is incident on the cylindrical window, reflected by bioconic surface and then proceeds through the light guide to reduce the light beam diameter. Followed the prism is imaging lenses consist of L3, achromatic doublet #1, L6, and achromatic doublet #2 with a sensor at the back. And the navigator layout is shown in Fig. 2(b).




(a) (b)

Fig. 2. (a)PSVV layout. (b)Navigator layout.

Table 1. Specifications of the Panoramic Side View Videoscope

| Item | Specification | | |
|---|---|---|---|
| Effective focal length | 1.365 mm | | |
| Field of view | 71° | | |
| Resolution | Image Height (mm) | Spatial Frequency (cycles/mm) | MTF Value |
| | 0 (on axis) sagittal | 41.5 | 0.6 |
| | | 83 | 0.3 |
| | 0 (on axis) tangential | 41.5 | 0.6 |
| | | 83 | 0.3 |
| | 0.433 (half-field) sagittal | 41.5 | 0.6 |
| | | 83 | 0.3 |
| | 0.433 (half-field) tangential | 41.5 | 0.6 |
| | | 83 | 0.3 |
| | 0.612 (on axis) sagittal | 41.5 | 0.5 |
| | | 83 | 0.2 |
| | 0.612 (on axis) tangential | 41.5 | 0.5 |
| | | 83 | 0.2 |
| Distortion | ≦ ± 20% | | |
| Relative illumination | ≧50% | | |

Table 2. Specifications of the Navigator

| Item | Specification | | |
|---|---|---|---|
| Effective focal length | 0.866 mm | | |
| Field of view | 60° | | |
| Resolution | Image Height (mm) | Spatial Frequency (cycles/mm) | MTF Value |
| | 0 (on axis) sagittal | 50 | 0.6 |
| | | 100 | 0.3 |
| | 0 (on axis) tangential | 50 | 0.6 |
| | | 100 | 0.3 |
| | 0.25 (half field) sagittal | 50 | 0.6 |
| | | 100 | 0.3 |
| | 0.25 (half field) tangential | 50 | 0.6 |
| | | 100 | 0.3 |
| | 0.50 (on axis) sagittal | 50 | 0.3 |
| | | 100 | 0.2 |
| | 0.50 (on axis) tangential | 50 | 0.3 |
| | | 100 | 0.2 |
| Distortion | ≦ ± 20% | | |
| Relative illumination | ≧50% | | |

## 5. Discussion

Compare to other endoscope designs which covers both the front and side field of view [2][3][4], this design uses a rotary biconic surface to provide the side view. Using this method, better image performance and larger object NA are possible to achieve. The disadvantage is that the mechanical design is much more difficulty.

## 6. Reference


[1] Lin, Chen-Hung, et al. "Study of lens design method for narrowing primary aberration variation during conjugate change for a finite conjugate system."*Optical Engineering* 53.8 (2014): 085104-085104.

[2] Stürzl, Wolfgang, et al. "Rugged, obstruction-free, mirror-lens combination for panoramic imaging." *Applied optics* 47.32 (2008): 6070-6078.

[3] Katkam, Rajender, et al. "Compact dual-view endoscope without field obscuration." *Journal of biomedical optics* 20.7 (2015): 076007-076007.

[4] Yu, Zong-Ru, et al. "Design and development of bi-directional viewer." *SPIE Optical Engineering+ Applications*. International Society for Optics and Photonics, 2012.