Focus and Zoom Function Drives for Video Endoscopes

Miniaturized Precision Drives Make It Possible

Conventional Chip-on-the-Tip video endoscopes typically use fixed focus optics, which are able to provide sharp imaging only for a certain depths of field in regard to the object distance. In case the object is at a different distance, the image loses focus. By integrating a miniature drive, it would become possible to achieve variable focusing, in a way that the object can always be displayed optimally in sharp focus.

Modern medical technology is aiming at causing patients as little discomfort as possible with their therapies. Endoscopes that allow minimally invasive surgery (MIS) provide an important contribution, for example in laparoscopy (Fig. 1).

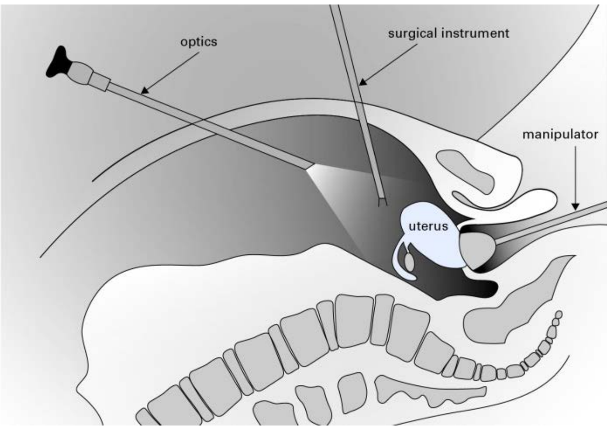

Fig. 1 Modern medical technology is aiming at causing patients as little discomfort as possible with their therapies. Endoscopes that allow minimally invasive surgery provide an important contribution, e.g., in laparoscopy (Figure: PI)

Nowadays these laparoscopic techniques require, instead of a long surgical cut as formerly required in open abdominal surgery, only two to three small incisions. Optics and special instruments (scissors, hooks, grasping forceps, ultrasound scissors, etc.) are then introduced into the abdominal cavity through so-called working trocars. Following surgery, the patient experiences less post-operative pain and can be discharged from hospital earlier, due to the quicker healing process.

The risk of wound infections or wound healing disorders is minimized. This also allows treatment of patients for whom, due to their poor general health condition, open surgery may be too great a risk.

Integration of the Image Sensor into the Endoscope Tip

Traditional endoscope technology using fiber bundles for image transmission has technical limitations in regard to achievable resolution and is rather susceptible for fiber cracks. Here the microelectronics has opened up new interesting perspectives: the integration of the image sensor into the endoscope tip in Chip-on-the-Tip endoscopes. The advantages of this method are the razor-sharp and clear image quality, the fact that susceptibility to mechanical stress is now a thing of the past and the direct electrical image transmission.

In customary endoscopes with fiber bundle technology, it was, however, possible to attach zoom and focus lenses between eyepiece and camera. This allowed the focus to be set to different object distances and the image to be optically enlarged. Both operations were done manually, but turned out to be very helpful, in particular in laparoscopy.

In contrast, the digital zoom function of the conventional Chip-on-the-Tip technology only allows a detail to be enlarged, which is always accompanied by a loss in image quality.

This is why, in the absence of these focus and zoom functions compromises must be found in regard to image quality and resolution and between depths of focus and image brightness. Compromises which should be overcome, soon.

Optical Focus and Zoom Functions for Chip-on-the-Tip Endoscopes

This type of compromise could soon be a thing of the past, because the actuators required for optical focus and zoom functions in Chip-on-the-Tip Endoscopes could in principle also be installed between the optics and the image processing chip (Fig. 2). However, with diameters of typically no more than 10 mm, the potential installation space is very small. It seems to be difficult, but not impossible, to find the right drives for the zoom and focus lens.

For example, small piezo motors and voice coil drives could open up a new area of application in this field. This is where PI (Physik Instrumente), comes into play. This company, which has been known as a specialist for small, mostly piezo-based precision drives for decades, also has miniaturized linear direct drives in its product range, today. These different drive technologies offer a solid base for use in modern video endoscopes.

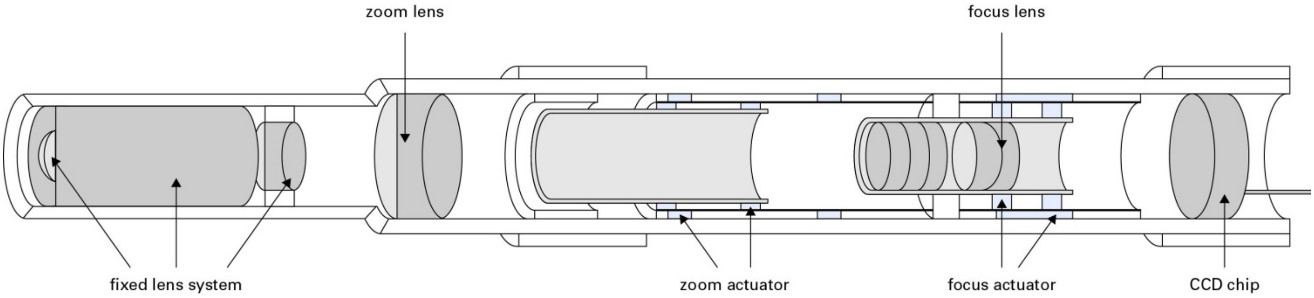

Fig. 2 The actuators required for optical focus and zoom functions in Chip-on-the-Tip Endoscopes can in principle also be installed between the optics and the image processing chip (Image: PI)

Small Piezo Motors or Voice Coil Drives

Interesting approaches are provided, for example, by piezo ultra-sound drives. Direct drives, which are available in different designs (Fig. 3), work without the mechanical components of traditional motor-spindle drive systems - such as clutch or gearhead - in favor of costs and reliability. Independently of the design, the functional principle is always the same: Oscillations of a piezo-ceramic actuator at ultrasonic frequencies are converted along a moving rod into linear motion, thereby driving the moving part of a mechanical structure, on which the lens is mounted (Fig. 3).

Fig. 3 An annular piezo motor moves an autofocus lens. The mechanics is integrated into the drive PCB (Image: PI)

Overall, this gives a uniform motion of theoretically unlimited travel range. The result are lightweight drives that are suitable for travel speeds of up to about 100 mm/s and work in open-loop mode at a position resolution of typical 100 nm.

Secondly, thanks to their small dimensions and their favorable cost/performance ratio, piezo-based inertia drives (Fig. 4) are likewise ideally suitable for use with endoscopes. They use the stick-slip effect for achieving unlimited travel ranges and have a resolution of few nanometers.

Fig. 4 Thanks to their small dimensions and their favorable cost/performance ratio, piezo-based inertia drives are likewise ideally suitable for use with endoscopes (Image: PI)

Due to the stick-slip effect, the piezoelectric actuator expands slowly taking along the moving rod. Then the actuator contracts so rapidly that the moving rod cannot follow due its inertia, and thus remains in the same position. The electric control is easy and similar to a saw-tooth voltage.

Thirdly, in order to implement an optical focus and zoom function, magnetic drive solutions are also possible, here as voice coil drives (Fig. 5).

Fig. 5 Voice coil drives are also suitable for the travel ranges of between a few millimeters and centimeters required in endoscopes, especially since they can be manufactured in extremely small sizes (Image: PI)

These linear drives work by the same principle as loudspeakers. Since they can be manufactured in extremely small sizes, they are also highly suitable for travel ranges of a few millimeters to a few centimeters required in endoscopes and they can work highly dynamic. Fig. 6 shows a very compact PCB controller board for this voice coil drives.

Given these drive technology options, it is important to select the right one for each specific task and boundary conditions to produce better image quality and depth of focus in the next generation of Chip-on-the-Tip endoscopes.

Fig. 6 Control for a voice coil drive with integrated magnetic sensor. Miniaturized drive systems require compact electronics, e.g., on a flexible PCB (Image: PI)

About PI

PI (Physik Instrumente), headquartered in Karlsruhe, is the market and technology leader for high-precision positioning technology and piezo applications in the semiconductor industry, life sciences, photonics, and in industrial automation. In close cooperation with customers from all over the world and for 50 years now, PI's specialists (approx. 1,300) have been pushing, again and again, the boundaries of what is technically possible and developing customized solutions from scratch. More than 350 granted and pending patents underline the company's claim to innovation. PI has six production sites and 15 sales and service offices in Europe, North America, and Asia.

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