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Chip-on-the-Tip Endoscope with Flexible Tip

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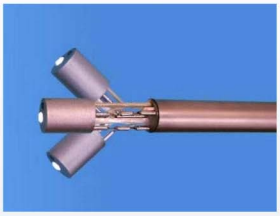
Concept

Current laparoscopic interventions are still not as safe as they could be: **rigid endoscopes are standard** since flexible fiber-optic scopes have a very limited image resolution. However, rigid scopes have **several disadvantages**. First, as the endoscope has to be moved around a pivot point and its own axis to change the frame of view, it is hard for the surgeon to keep a complete overview of the surgical site without losing orientation. Also, a **camera assistant** has to guide the endoscope to show the relevant portions of the surgical field. So, the surgeon has **no direct control over the picture**. The camera needs to be extremely well coordinated with the surgeon to ensure a safe intervention.

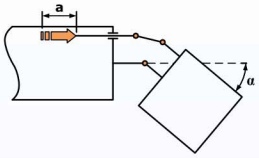
The **new type of endoscope** allows a change of field of view while keeping a constant horizon, thus improving orientation. It features a **deflectable tip** with two degrees of freedom and a maximum angle of view of 70 degrees. The **camera with focus shift is integrated into the endoscope**.
Tip deflection as well as focus shift is **controlled electronically**. Therefore, there is total freedom to integrate **any control interface** desired by the surgeon. A variant with a control pad integrated into the handle was built as well as a version that is controlled with a PC. Thus, this endoscope makes **interventions without a camera assistant** possible when fixed to a mounting device.



Bending mechanism

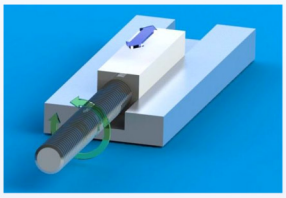
Bending of the encoscope tip is accomplished by moving rods. A linear movement (a) of the rods (blue) leads to a rotation of the tip (α) around a joint fixed to a static rod (green). Each moving rod bends the tip on one plane. Superposition of movements leads to a precise, three-dimensional movement with a constant horizon.

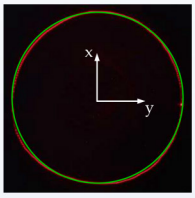
Each moving rod is fitted with two joints (2 DOF) to achieve a purely axial rod movement. Several types of joints were built and tested:



Kinematic Pairs	Flexure Bearings
+ precise movement	+ easy to fabricate
- complicated to fabricate	+ no abrasive wear
- abrasive wear (particles)	+ no maintenance needed
	- exact movement not predictable
example: kardan joint	**example:** silicone tube over rods

Flexure bearings made of **Nitinol** wire were chosen for the endoscope due to their **superelasticity** and **simple design**.

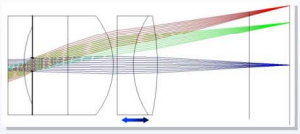


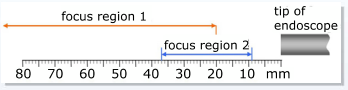


The rotation of a threaded spindle driven by an electric motor causes a threaded nut to move in a linear bearing. One such nut is fixed to each rod, moving them along. Motors are controlled electronically, so movement of the tip is very precise. Above, a red line shows the projected movement of the endoscope tip in comparison to a perfect circle (green).

Optical System

The optical system is **extremely short** in order to facilitate free movement in the abdominal cavity. This is achieved by integrating a movable achromat to shift focus. The resulting optical system has a **diameter of 3.0 mm** and a **total length of 8.3 mm, focal lengths** for the two discrete achromat positions are **14 mm and 55 mm**. A **sharp image** is possible for an object distance of **9 mm to infinity**.



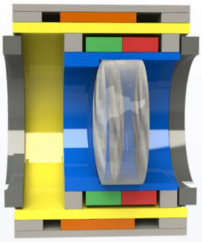


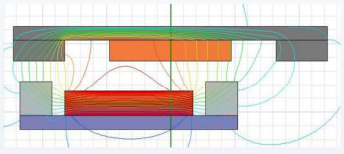
Integrated Electromagnetic Linear Drives

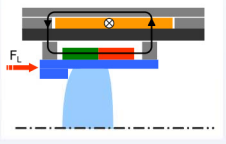
A linear drive moves the focus lens in the endocope's optical system. Linear drives for **discrete or continous positioning** have been successfully designed, built, and integrated into medical endoscopes by us. Here, discrete positioning with two stable positions is sufficient and leads to a smaller drive.

The linear drive's slide is held at one of two stable positions by **reluctance forces** due to the magnetic circuit caused by the **permanent magnet** (below, red).

As part of the magnetic flux passes the coil (orange), an electric current leads to a **Lorentz force** on the coil. Since the coil is fixed in the stator, a resulting force **moves the slide**.







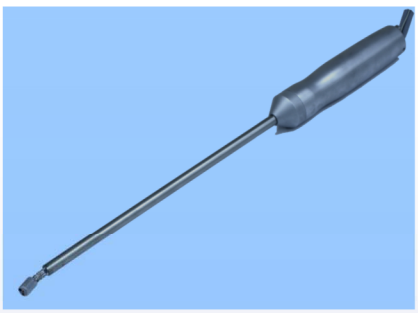
Conclusion

The **flexible tip** on this novel **rigid endoscope** offers a **panoramic overview** of the surgical site while maintaining a **constant horizon**.

No external camera is needed due to Chip-on-the-tip technology. The movement of optical lenses in the tip offers **zoom and focus functionality**. Hence, an optimal image is ensured at any time.

Electronic control of tip and lens movement enables **freehand control** of the endoscope using the **man-machine interface of the surgeon's choice**, including gaze tracking, head tracking, or voice control. When the endoscope shaft is mechanically fixed, previously defined areas can be found automatically and repeatedly with high accuracy. Also, software-based **autofocus** is easy to achieve. Therefore, **work without a camera assistant** becomes possible.

In sum, this new endoscope technology promises substantial benefits for intervention safety and the medical staff's working conditions.



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