1 Introduction

Endoscopes have traditionally been considered either "rigid" or "flexible," depending on the geometry required by the physician in accessing different areas of the body. Rigid endoscopes were the high-quality devices with stacks of lenses arranged to relay images from the tip of the scopes to eyepieces or large video cameras outside the body. These rigid endoscopes are surgical devices and are inserted through temporary access ports created by the physician. Flexible endoscopes were lower-quality devices, typically fiber-optic or with a miniature video camera at the tip directly coupled with an equally small camera lens.

Due largely to cell phone camera improvements, the state-of-the-art for miniature video cameras has undertaken a renaissance in image quality. The endoscope industry has been a fortunate beneficiary of this progress. Improvements in miniature video cameras initially advanced flexible endoscopes, allowing them to be made with a smaller diameter and higher resolution. This was obviously a boon to patients, providing access to additional areas in the body with less trauma and with faster recovery times.

Rigid endoscopes are also benefitting from image sensor improvements. With Olympus Corporation as the forerunner, we are now seeing "chip-on-tip" endoscopes with quality that rivals their relay lens predecessors.[1] We are even seeing the newest three-dimensional (3-D) endoscopes, previously using relay lenses, now using pairs of miniature cameras positioned side-by-side.[2]

This eBook discusses the optics of digital endoscopes, whether used for flexible or rigid applications. As the optical engineering community is challenged to provide ever-decreasing diameters and ever-increasing pixel counts, the optical engineer has to be aware of the clinical trade-offs that are inevitable in their new innovative designs. At every step in the development of digital endoscopes, the designer must consider the bottom line, which is what is of importance to the physician and, therefore, what is of importance to the patient.

2 History

In 1806, Philip Bozzini, a physician in Mainz, Germany, used a metal tube with mirrors to illuminate and view nearby the distal end of the device.[3] (Note that the terms "distal" and "proximal" are used in the medical community to indicate position "further from the physician" and "nearer to the physician," respectively. Thus the distal end is the tip of the endoscope.) Dr. Bozzini set the stage for more than 200 years of innovation in endoscope technology. As shown in Fig. 1, the Bozzini endoscope suffers from an extremely narrow field of view.

The first endoscope using a miniature lens system was a cystoscope designed by Nitze in 1879 with the help of an optician from Berlin and an instrument designer from Vienna.[4] A gastroscope of similar design was built the following year. These first endoscopes incorporated a reflecting prism at the distal tip to incline the direction of view. In 1931, the first practical arthroscope was