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Bringing Image-Guided Laser Surgery to Endoscopy

In an effort to advance the benefits that lasers can offer to surgeons, Memorial Sloan-Kettering Cancer Center partnered with a motor and motion control specialist to fabricate an endoscopic laser scalpel that incorporates a remote-controlled beam steering device right in the endoscope head. This article highlights the efforts of that collaboration.

By David Henderson, CTO and CEO, New Scale Technologies

Surgical lasers are precise, minimize bleeding, reduce risk of lymphatic metastases from tumors, and reduce damage to adjoining tissue. While their use is growing rapidly, today, these benefits are largely limited to procedures in which there is direct access to the tissue being operated on, such as eye or skin surgery. They are underutilized in minimally invasive surgical techniques, including endoscopy and laparoscopy. Today's beam steering techniques make lasers awkward and difficult to control in small, confined body cavities with limited access.

The infrared beam of a surgical laser travels in straight lines, steered with mirrors and lenses. It can be used in rigid endoscopy, where the beam is delivered through rigid tubes and controlled using manual manipulators outside the body. It is extremely challenging for a surgeon to accurately control the working end of the laser this way; imagine holding a 15-inch long pencil by the eraser, and moving the tip around to draw tiny, accurate patterns on a 3D surface.

To bring endoscopic laser surgery to more patients who would benefit from it, surgeons and researchers at the Memorial Sloan-Kettering Cancer Center partnered with New Scale Technologies (www.newscaletech.com) to create an endoscopic laser scalpel that incorporates a remote-controlled beam steering device right in the endoscope head.

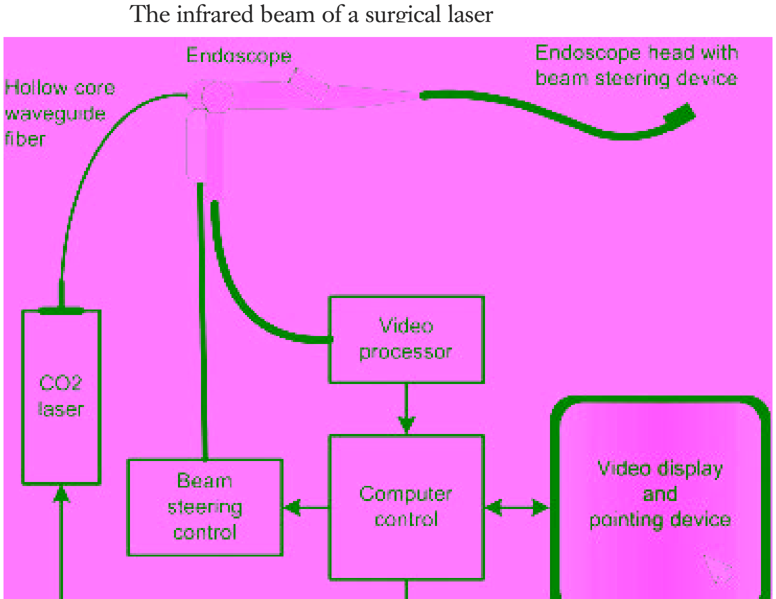

Figure 1: The endoscope head is mounted on a conventional endoscope. The focused laser beam inside the body is controlled remotely using a pointing device on the video display.

By putting the steering mechanism inside the body cavity and providing remote control of the beam with visual feedback, the new endoscopic laser scalpel greatly simplifies the procedure for both patient and surgeon. It allows the use of flexible endoscopes, reduces the laser spot size, and increases fine control and stability of the laser spot. When the entire system is complete, it will enable remote-controlled, image-guided surgery in minimally invasive settings, and will be readily integrated into robotic and tele-surgery platforms.

A video microscope in the endoscopic laser scalpel sends real-time video of the target tissue to an external display or touch screen, which can be next to the patient or halfway around the world. The surgeon moves a pointer over the image, and the opto-mechanical beam steering mechanism inside the endoscope head guides the focused laser spot to match the surgeon's commands (Figure 1).

The Memorial Sloan-Kettering design team chose to use a Risley prism pair rather than mirrors for beam steering. Risley prism systems are smaller, use less power, and weigh less than gimbal mirror systems. They provide a straight clear aperture for the optical axis, maximum transmission, fast response, and greater optical and mechanical simplicity. By separately rotating the two wedge prisms, an incident beam can be steered over a continuous range of directions (Figure 2).

To rotate the prisms, New Scale developed a closed-loop piezoelectric motion system using its UTAF motor technology. The miniaturized, fully-integrated motion module rotates the two prisms independently, maintaining a large clear aperture for the beam without significantly increasing the outside diameter of the endoscope. The prototype device, with 9.65-mm diameter optics, has a 17 mm outer diameter and can be made smaller (Figure 3).

In the motion system, micro ball bearing guides support the prisms with very low friction and low wobble. A UTAF piezoelectric ultrasonic motor is frictionally coupled to the outside diameter of each prism, producing continuous bi-directional rotation with ±0.35-degree resolution, ±2.0-degree accuracy, and no backlash.

Absolute position sensors determine

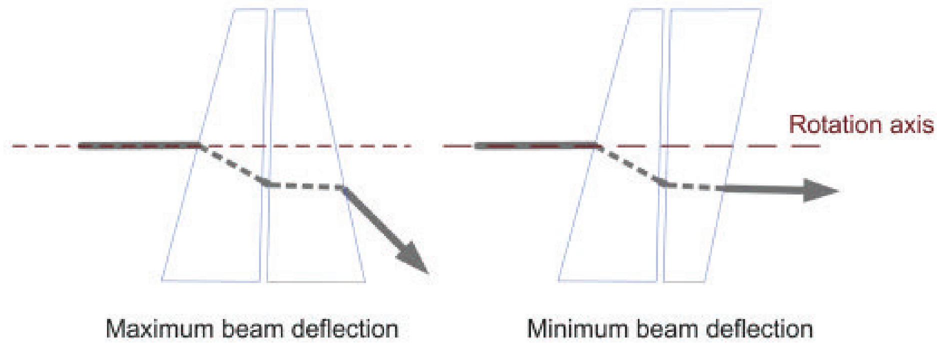

Figure 2: A Risley prism pair—Rotating two wedge prisms independently around a common rotation axis allows steering of an incident beam over a continuous range of directions.

the position of each prism without interfering with the clear aperture. These sensors use a magnet and Hall sensor configuration. Closed-loop positions for each prism are achieved via on-board motor drive and control electronics with a dedicated microprocessor and embedded firmware.

Each piezoelectric motor requires only 3.3 volts to operate using a full-bridge switch at the motor resonant frequency of 110 kHz. No power is needed to hold position.

As the surgeon moves a pointer on the image from the video microscope, the piezoelectric motion system responds to the pointer input, rotating the optics to steer the beam to the desired position. First, the path drawn by the surgeon will be transformed into motion profiles for the beam (both time and position). These beam motion profiles will be transformed into separate motion profiles for each prism, which are then used by the closed-loop motion system to produce the required rotations.

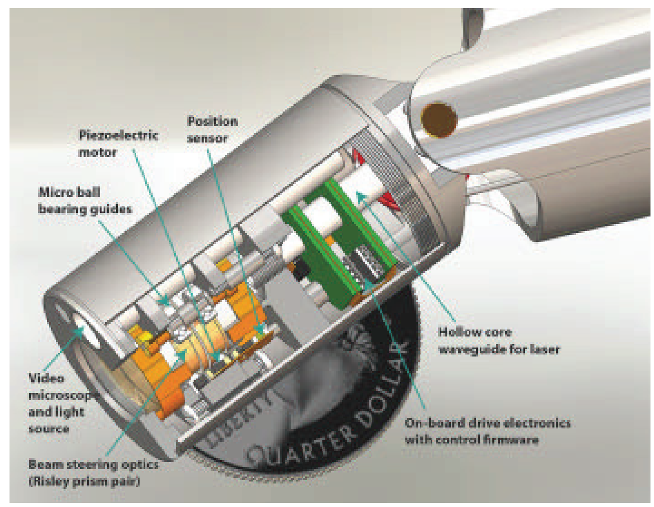

Figure 3: An integrated piezoelectric motion system from New Scale Technologies rotates the beam steering prisms in the endoscope head with high resolution and small size.

A critical challenge for commercializing the laser scalpel will be to execute these transformations in near real time, so that surgeons can actively monitor and make adjustments during treatment. The piezoelectric motion system has demonstrated the required mechanical response, producing continuous rotation of the prisms with angular velocity of 900 degrees per second and acceleration of 225,000 degrees per second.

The Memorial Sloan-Kettering team has formed a startup company, ColdSteel Laser (www.coldsteellaser.com), to commercialize the endoscopic laser scalpel for remote image-guided endoscopic surgery. With the prototype, the team has met its initial goals for size, mechanical speed, accuracy, resolution, competitive costs and manufacturability. Ongoing development will focus on real-time control, optimizing the user interface to meet surgeon's requirements, and obtaining FDA certification.

For more information

- "The Endoscopic Laser Scalpel: Out of the Lab and into the World," Memorial Sloan-Kettering Center News Magazine, Dec. 2011 http://bit.ly/mdt1310a
- "A New Look at Risley Prisms," Photonics Spectra, June 2006 http://bit.ly/mdt1310b
- "UTAF micro motor technology," New Scale Technologies, http://bit.ly/mdt1310c