IEEE Biorob 2012
Workshop on Robot-Assisted Laryngeal Microsurgery

Medical Robotics: Background, Today, and the Future!

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Background - General

- 1985 First non-laparoscopic robot surgery using PUMA 560 (Kwoh et al.)

- 1987 First laparoscopic surgery (Cholecystectomy)

- 1988 PROBOT – Transurethral Surgery PUMA 560 (Davis et al.)

- Robodoc – Intuitive Surgical Supplies (FDA Approved)

Background - NASA and US Army

- ## NASA (Early-1990′s):
  - NASA AMES RC and SRI
  - Virtual Reality
  - Robots
  - Medicine
  - Teleprescence Surgery (Hand Surgery)

- ## US Army (Early-1990′s):
  - MASH Units
  - Objective, decrease wartime mortality
  - Surgeon uses robotics surgical equipment (could be teleoperated)

Endoscopic Surgery

- Procedure viewed by small camera inserted with surgical implements
- Instrument manipulation via cables and electronics
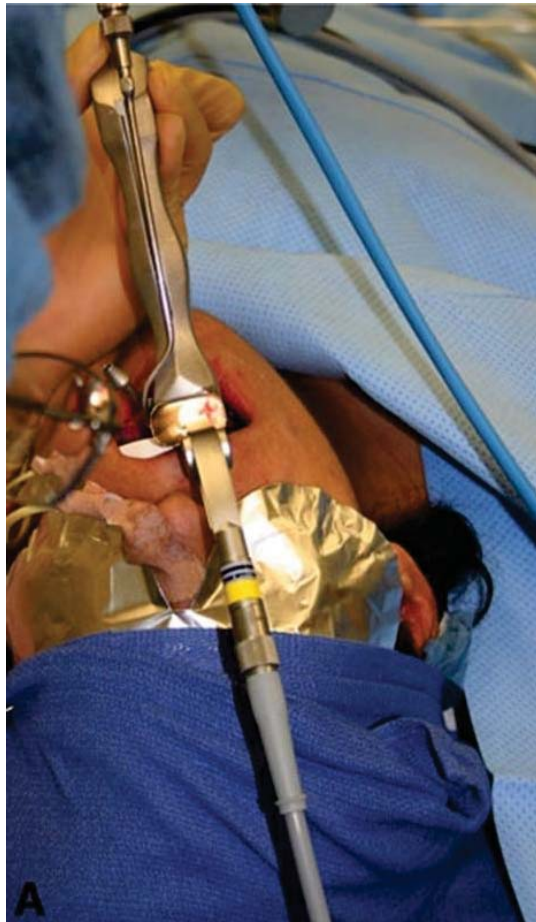
Images taken from Rubinstein and Strong, Transoral laser microsurgery for laryngeal cancer: A primer and review of laser dosimetry; Lasers Med Sci (2011) 26:113–124

CAS Clinical Applications

- Neurosurgery
- Orthopaedics
- Maxillofacial, craneofacial, and dental surgery
- Laparoscopic and endoscopic surgeries
- Radiotherapy
- Specific procedures in ophtalmology, othorhinolaringology, etc.

Background –Industries and Products

- **Computer Motion Inc.**
  - **AESOP ® (1993)**
    - Voice activated robotic system
    - First robot approved by FDA
  - **HERMES ® (1993)**
    - Control center
    - Introduced voice command and recognition system to MR
  - **ZEUS ® (1998)**
    - Surgeon control center and three table mounted robotic arms
    - Used for endoscopic surgery
    - Used for first beating-heart coronary bypass procedure

Background –Industries and Products

- **2000 Intuitive Surgical Systems Inc. (Intuitive Surgery Inc.)**
  - **da Vinci Surgical System** ®
    - Uses true 3-D visualization
    - Uses EndoWrist
    - FDA approved
    - Widely used for prostatectomy

- **2003 Computer Motion Inc. and Intuitive Surgical Systems Inc. Merge!**

- **Robotics in medicine is still a new, exciting, and advancing field!!**

MR – State-of-the-Art
(Intuitive Surgical Systems Inc. - da Vinci® Robot System)

Laryngeal Laser Surgery

- Less risk of infection
- Laser can be configured to cauterize and cut
- Lasers surgery reduces blood loss during surgery
- Lasers can be controlled endoscopically for surgeries in small spaces (Larynx)
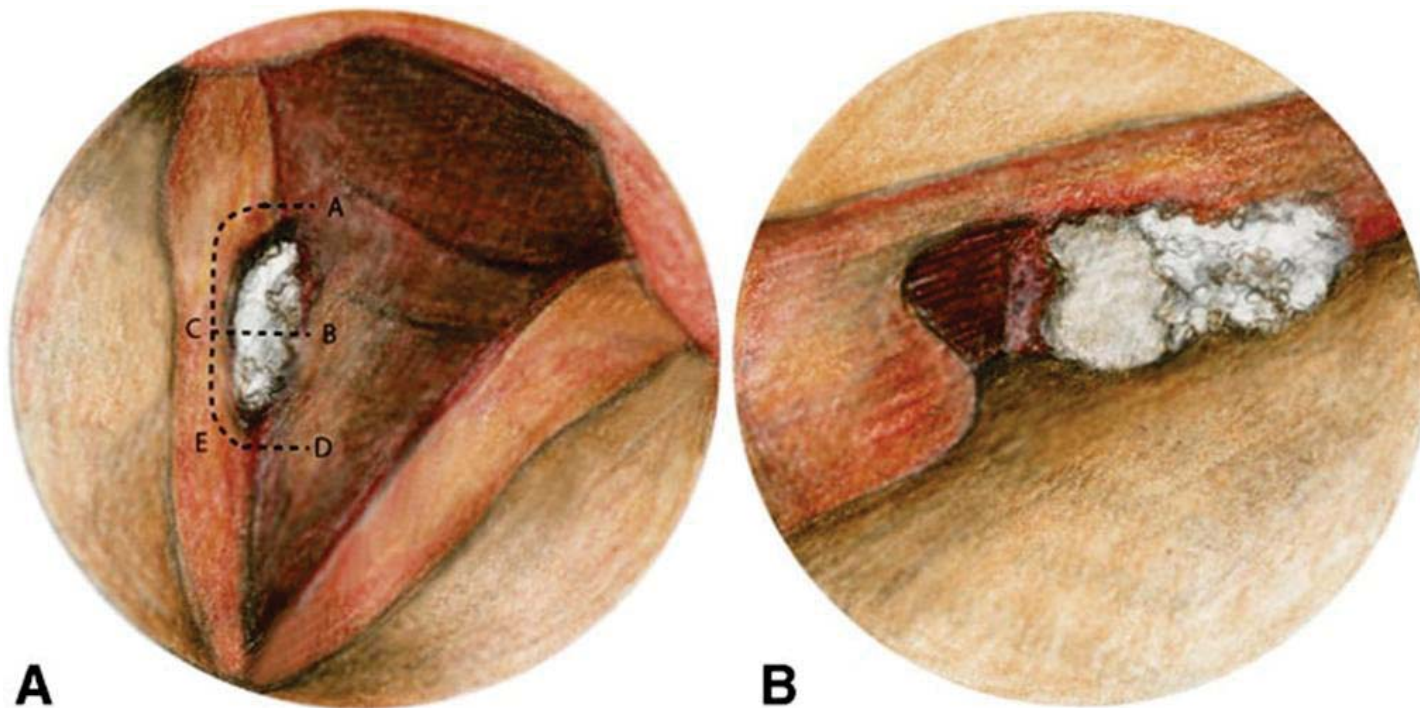

Pre-op image of a laryngeal tumour
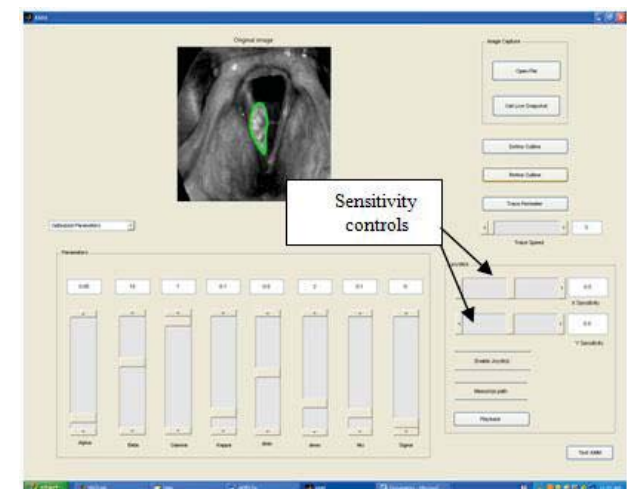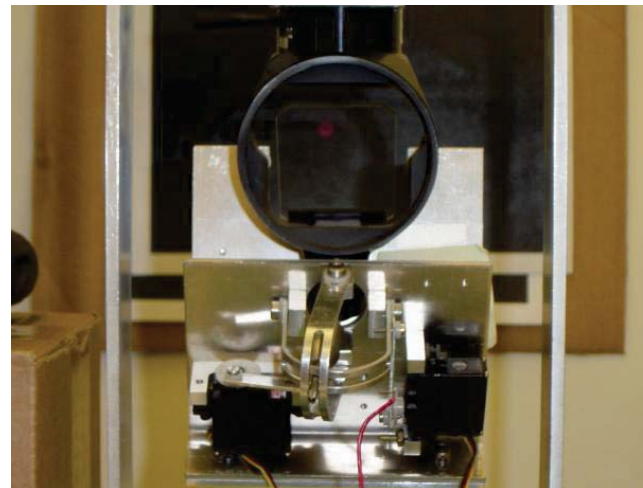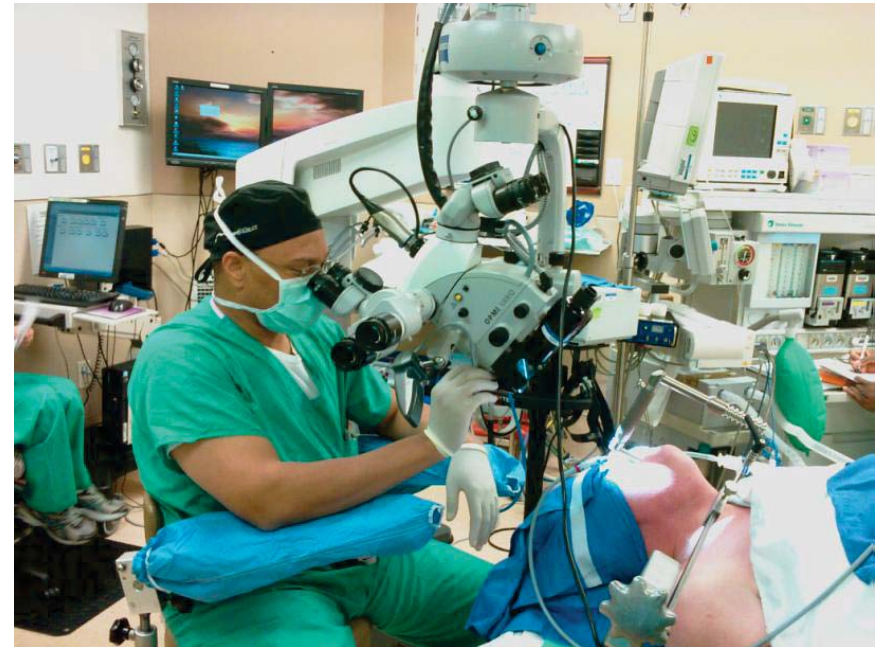
Larynx immediately after laser ablation surgery

Six weeks after laser ablation surgery

Piecewise Removal of Laryngeal Tumour

CRIM MR - Laser Surgery

- Laser phonomicrosurgery
- Mirror & laser control
- Camera calibration
- Fast steering mirror
- Stewart platform-based
- Collaboration with IIT

# CRIM MR – Fast Steering Mirror

- Thorlabs fast steering mirror
- +/- 12 degree tilt in 2D
- Fast response time (< 15ms)
- Controlled via serial commands from LabVIEW control code

CRIM MR – Fast Steering Mirror Calibration and Control

- A medical robotic laser surgery platform is being developed that gives:
  - **Precise control**
  - **Small in size**
  - **Gives a clear view of the target area**
  - **Economic**

CRIM MR – Fast Steering Mirror Calibration and Control
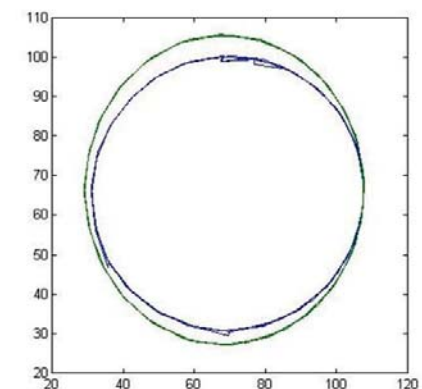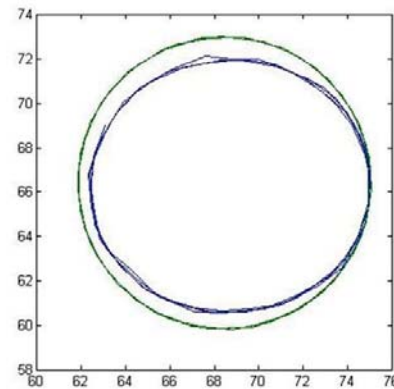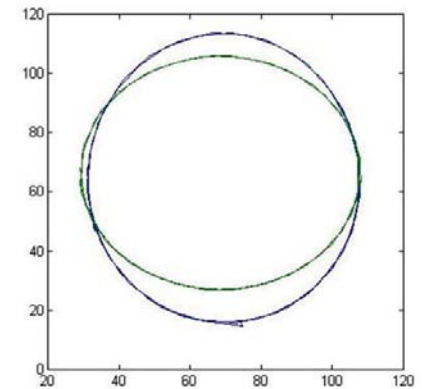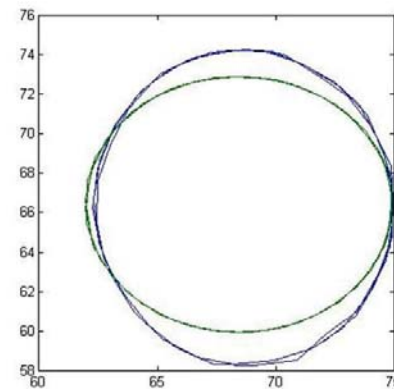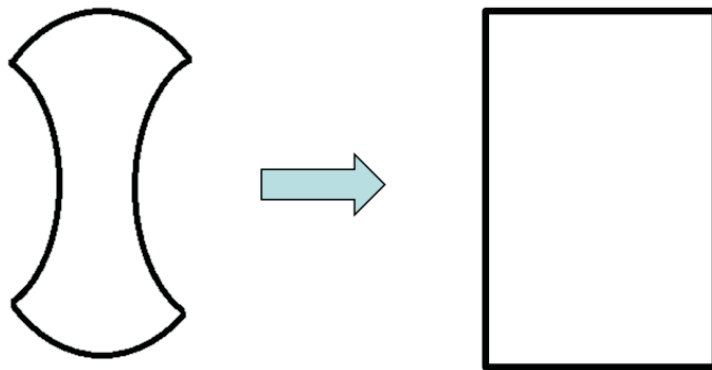
CRIM MR - Cell In Vitro Fertilization

- Cell in vitro fertilization
- Interactive user interface
- Faster throughput
- Increased injection success rate
- Reduced training period
- Full automation demonstrated
- Collaboration with UNC-CH and IIT
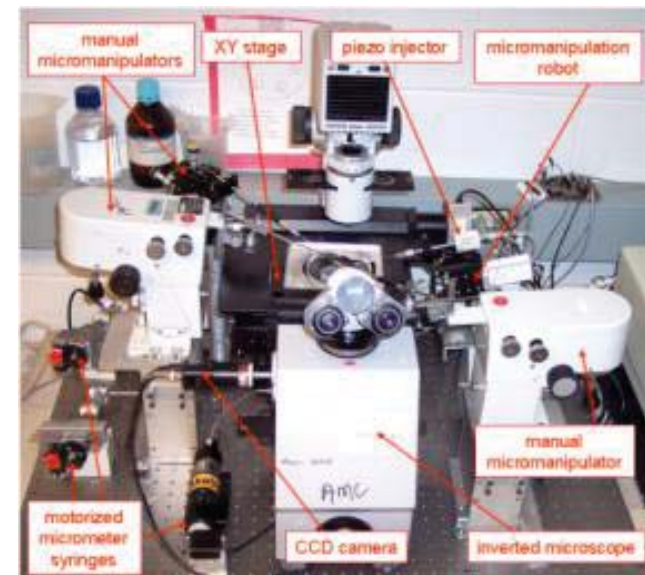
MR – Products and Systems
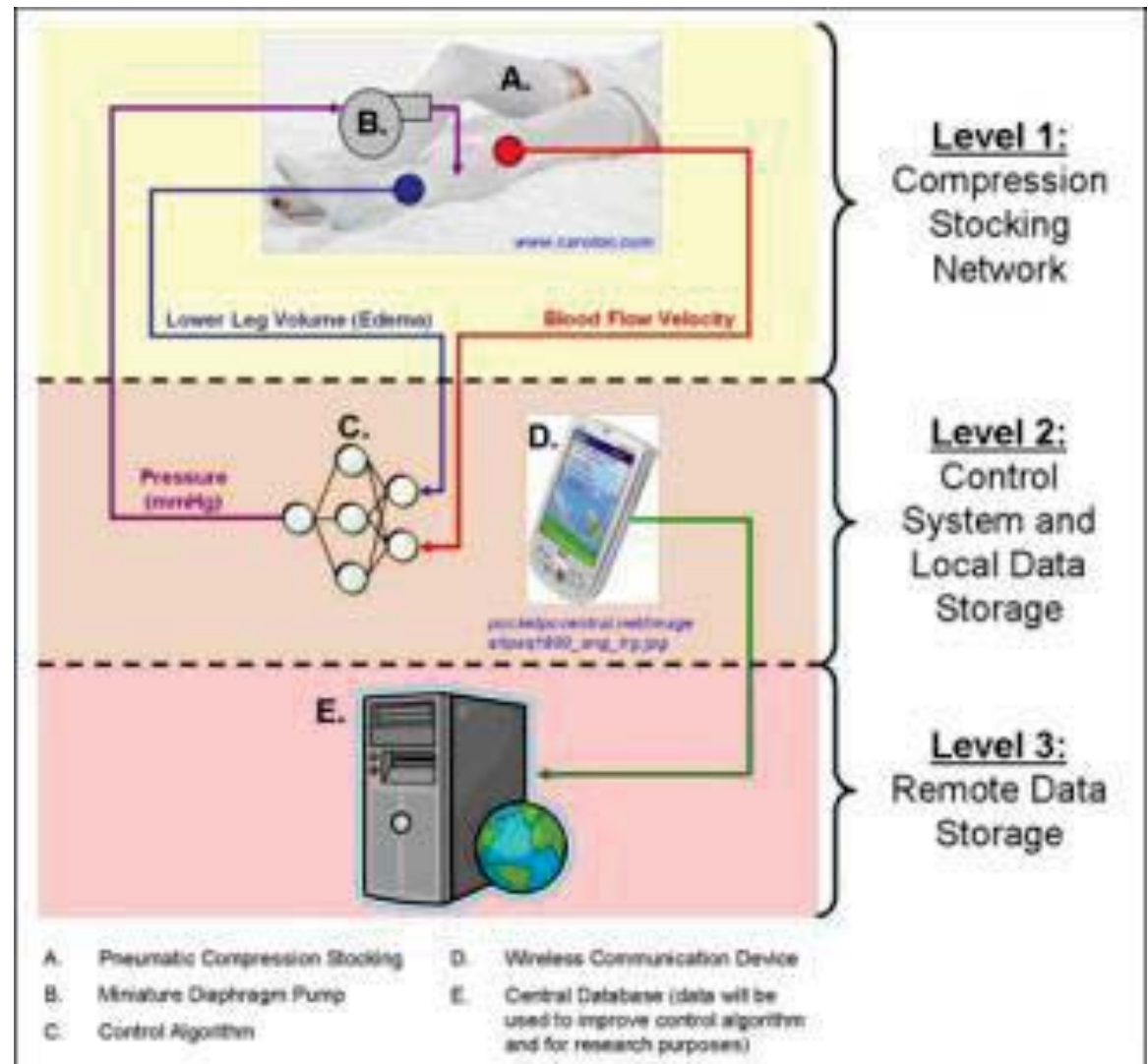
- "Pillcam"
  - Israeli Manufactured
  - Passive robot (1.1cm x 2.6cm)
- Scoula Superiore Santa Anna (Dario)
  - Capsule robot
  - Legged robot
- ETH (Nelson)
  - Microrobotics & nanorobotics
  - Eye surgery application
- **JHU (Taylor)**
  - Eye surgery

Future - Patient Monitoring

- Bioinformatics
- Wearable computing:
  - Wound Care
  - Lymphodema
  - Ulcers
- New wireless system
- Medical robotic cart
- Carolon Inc.

Level 1: Compression Stocking Network

Level 2: Control System and Local Data Storage

Level 3: Remote Data Storage

A. Pneumatic Compression Stocking
B. Miniature Diaphragm Pump
C. Control Algorithm
D. Wireless Communication Device
E. Central Database (data will be used to improve control algorithm and for research purposes)

Lower Leg Volume (Edema)
Blood Flow Velocity
Pressure (mmHg)

Future – Venous Blood-flow Control

- Bio-impedance analysis
- CW ultrasound sensors
- New ultrasound sensor design & control
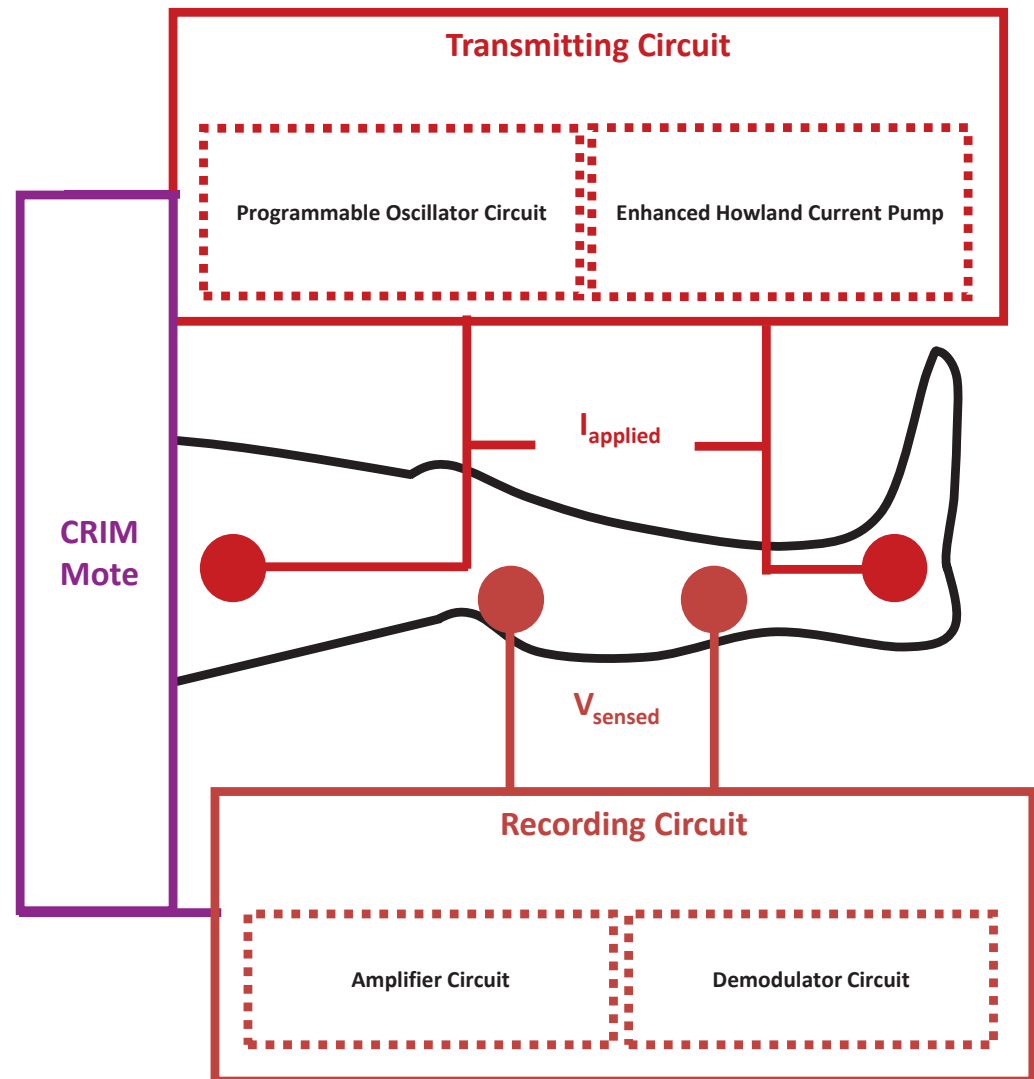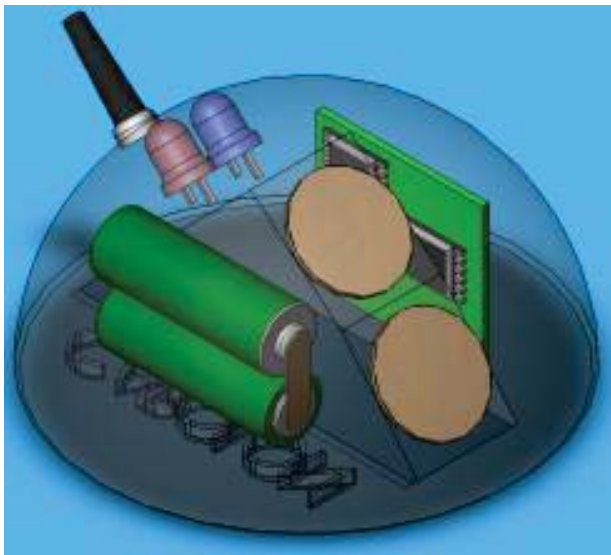
Future – 21st Century

- 21st Century will be the age of medical robotics
- Miniaturization:
  - imaging systems (XBOX, photogrammetry)
  - mechanisms (Planar designs)
  - optics (LED's)
  - microcontrollers (Raspberry PI)
  - trochars
- 10mm footprint
- Wireless and localized control
- Electrostatic drives
- Re-design of operating theaters

Camera calibration: To make accurate measurements and assure precise visual feedback, the camera has to be properly calibrated for its position and lens. A Matlab camera calibration toolbox developed by grad students at Cal Tech (http://www.vision.caltech.edu/bouguetj/calib_doc/) handily accomplishes this. Once the camera is calibrated, the computer can monitor the motion of the laser in real world coordinates.

Mirror calibration: The mirror has intrinsic nonlinear reflective properties associated with being a pseudo-stewart platform. When a user commands the mirror to a certain position then, there will be some error associated with the nonlinear distortion. Our goal in calibration of the mirror is to programatically compensate for the mirror's intrinsic distortion, allowing a user full, accurate control of the laser.

An exaggerated depiction of the distorted reflective range, modified to the ideal shape.

The figure shows the plots of various data collection trials for (a) uncorrected and (b) corrected coordinate commands. The programmatic correction was implemented to compensate for the mirror's natural tendency to stretch vertically. In this case, a linear compression was implemented on the visual y axis.