BIOE 301

Lecture Seven

Four Questions

- What are the problems in healthcare today?
- Who pays to solve problems in healthcare?
- How can we use science and technology to solve healthcare problems?
- Once developed, how do new healthcare technologies move from the lab to the bedside?

Three Case Studies

- Prevention of infectious disease
  - HIV/AIDS
- Early detection of cancer
  - Cervical Cancer
  - Ovarian Cancer
  - Prostate Cancer
- Treatment of heart disease
  - Atherosclerosis and heart attack
  - Heart failure

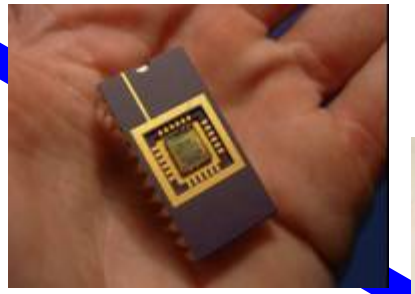
Today:

The process of developing
a new medical technology

Science of Understanding Disease

Bioengineering

Emerging Health Technologies



Preclinical Testing

Ethics of research

Clinical Trials

Cost-Effectiveness

Adoption & Diffusion

Abandoned due to:

- poor performance
- safety concerns
- ethical concerns
- legal issues
- social issues
- economic issues

Class Activity #1 – Gene Therapy

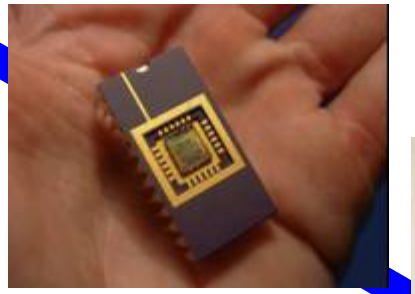
Directions:

- Place the articles in correct chronological order
  - Contextual clues in the selections
  - Your knowledge of the science of DNA and genes
  - Your recollection of events in the media.
- Articles reflect current thought for the time
- First article published in 1953; the last in 2003
- Discuss in group; come to consensus
- Choose one member of your group to speak
  - Did your ideas about the sequence match each other?
  - What clues or events prompted you to make choice?
- Do not discuss your ideas with other groups

Science of Understanding Disease

Bioengineering

Emerging Health Technologies



Preclinical Testing

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Abandoned due to:

- poor performance
- safety concerns
- ethical concerns
- legal issues
- social issues
- economic issues

Question:

- What is the difference between science and engineering?

Definitions

- Science
  - Body of knowledge about natural phenomena which is:
    - Well founded
    - Testable
  - Purpose is to discover, create, confirm, disprove, reorganize, and disseminate statements that accurately describe some portion of physical, chemical, biological world
- **"Science** is the human activity of seeking natural explanations for what we observe in the world around us."

Definitions

- Engineering
  - Systematic design, production and operation of technical systems to meet practical human needs under specified constraints
    - Time
    - $$
    - Performance
    - Reliability
- “Engineering. . . in a broad sense. . . is applying science in an economic manner to the needs of mankind “

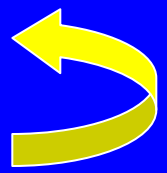
Definitions

- What is the difference between science and engineering?
  - Science
    - Inquiry to better understand world around us
    - No practical goal necessary
  - Engineering
    - Use of science to solve real world problem in practical way

Engineering Design Method

- Fashioning a product made for a practical goal in the presence of constraints
- Six design steps:
  - 1. Identify a need
  - 2. Define the problem (goals, constraints)
  - 3. Gather information
  - 4. Develop solutions
  - 5. Evaluate solutions
  - 6. Communicate results
    - Papers, patents, marketing

SPECS →



Refine Design

Journal Article

[CANCER RESEARCH 63, 1999–2004, May 1, 2003]

Advances in Brief

Real-Time Vital Optical Imaging of Precancer Using Anti-Epidermal Growth Factor Receptor Antibodies Conjugated to Gold Nanoparticles[1]

Konstantin Sokolov, Michele Follen, Jesse Aaron, Ina Pavlova, Anais Malpica, Reuben Lotan, and Rebecca Richards-Kortum[2]

Departments of Imaging Physics [K. S.], Pathology [A. M.], and Thoracic Head & Neck, Medical Oncology [R. L.] and Center for Biomedical Engineering [M. F.], University of Texas M. D. Anderson Cancer Center, Houston, Texas 77030, and Department of Biomedical Engineering, University of Texas, Austin, Texas 78712 [J. A., I. P., R. R-K.]

Abstract

Recent developments in photonic technology provide the ability to noninvasively image cells *in vivo*; these new cellular imaging technologies have the potential to dramatically improve the prevention, detection, and therapy of epithelial cancers. Endoscope-compatible microscopies, such as optical coherence tomography and reflectance confocal microscopy, image reflected light, providing a three-dimensional picture of tissue microanatomy with excellent spatial resolution (1–10 μm). However, their ability to image molecular biomarkers associated with cancer is limited. Here, we describe a new class of molecular specific contrast agents for vital reflectance imaging based on gold nanoparticles attached to probe molecules with high affinity for specific cellular biomarkers. The application of gold bioconjugates for vital imaging of precancers is demonstrated using cancer cell suspensions, three-dimensional cell cultures, and normal and neoplastic fresh cervical biopsies. We show that gold conjugates can be delivered topically for imaging throughout the whole epithelium. These contrast agents have potential to extend the ability of vital reflectance microscopies for *in vivo* molecular imaging. They can potentially enable combined screening, detection, and therapy of disease using inexpensive imaging systems; such tools could allow mass screening of diseases such as cancer in resource-poor settings.

such, they are ideally suited for early screening and diagnosis of superficial disease.

Tissue reflectance is produced by refractive index mismatches; sources of contrast in OCT and RCM images include structures with increased refractive index such as mitochondria, nuclear chromatin, and melanin (2, 3). Nonspecific contrast agents, such as AA, can perturb the nuclear refractive index distribution, increasing the ability to visualize cellular anatomy (6). Whereas OCT and RCM provide images of tissue microanatomy, their ability to image molecular changes associated with carcinogenesis is limited.

In the last few years, global analysis of gene expression by genomic and proteomic approaches has led to the discovery of new cancer-related genes, proteins, and biomarkers. Currently, most of these biomolecular signatures can only be assessed through invasive, painful biopsy. The ability to noninvasively image the expression of these biomarkers could translate into improved ability to screen and detect neoplastic changes, better ability to select and monitor therapy, and new tools to understand the pathobiology of the disease.

Here, we demonstrate a new class of molecular specific contrast agents for vital optical imaging of precancers and cancers, based on gold nanoparticles conjugated to probe molecules with high affinity

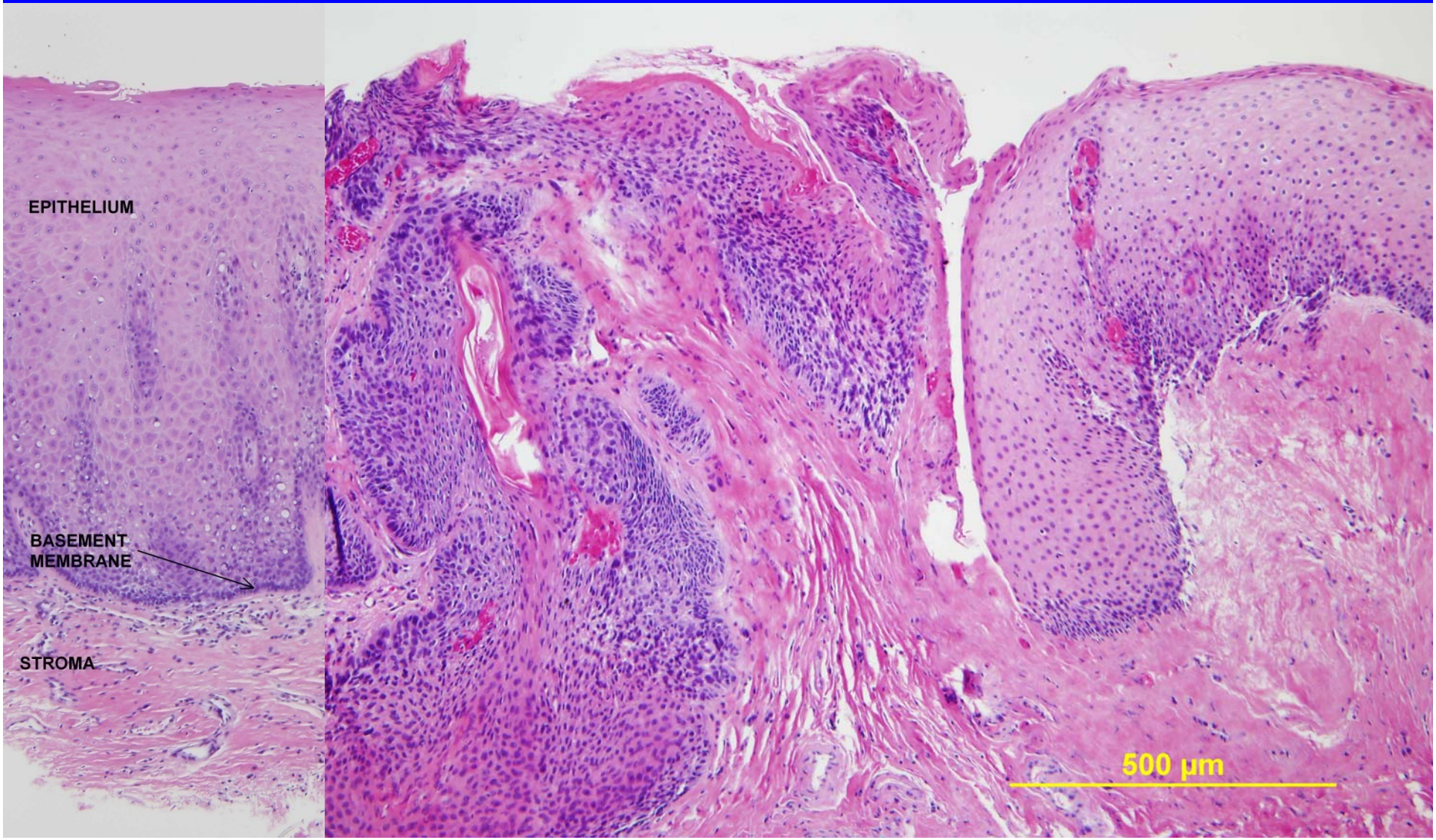
Patent

- www.uspto.gov
- Diagnostic Imaging Patent

Example: Oral cancer detection

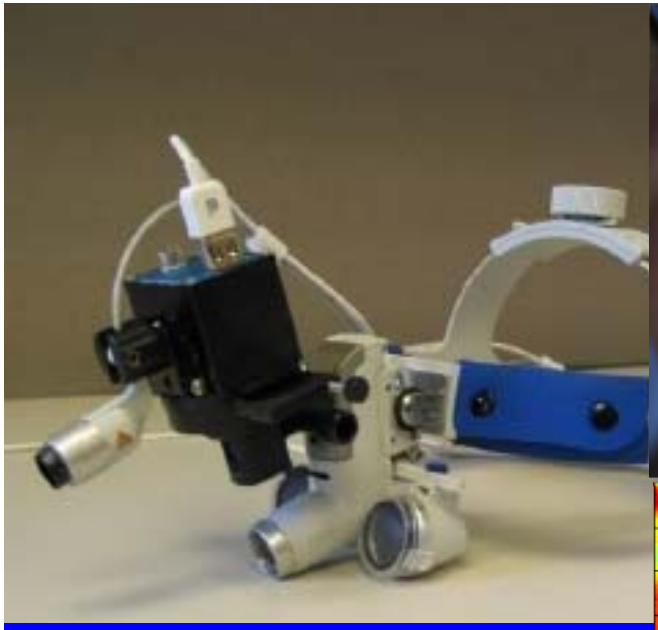
- Science of precancer
- Engineering solutions for precancer detection
  - 1. Identify a need
  - 2. Define the problem (goals, constraints)
  - 3. Gather information
  - 4. Develop solutions
  - 5. Evaluate solutions
  - 6. Communicate results

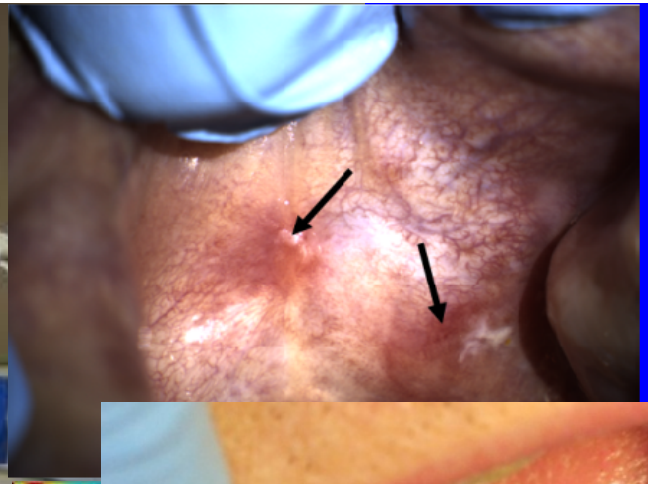
Histology of Oral Cancer

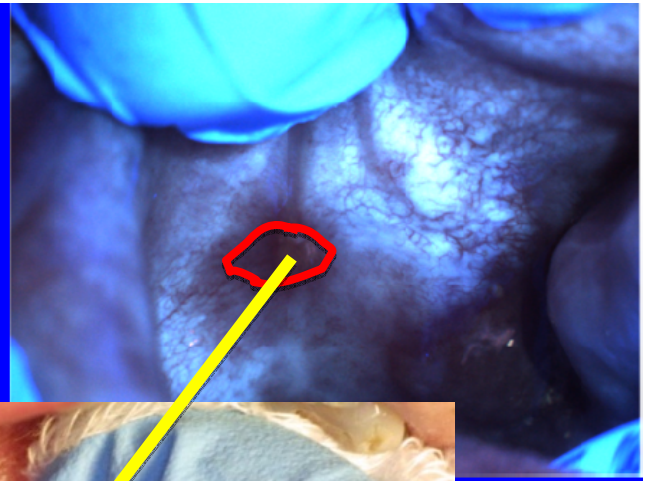


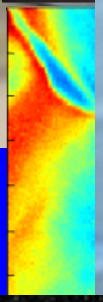
Clinical Needs

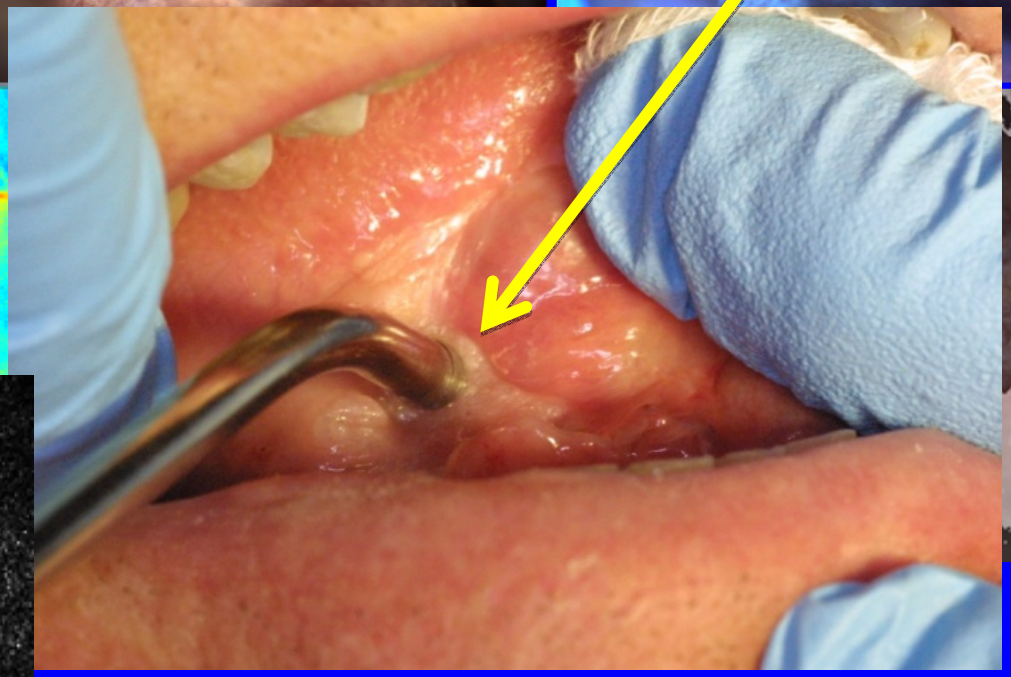
- High sensitivity and specificity
  - Relative to standard of care
  - Relative to clinical impression or gold standard
- Survey all tissue at risk
- Detect precursor or early disease

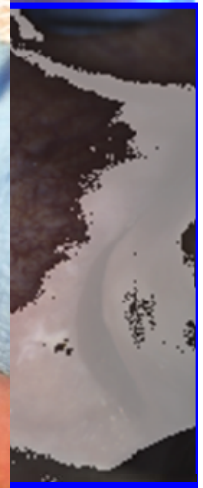


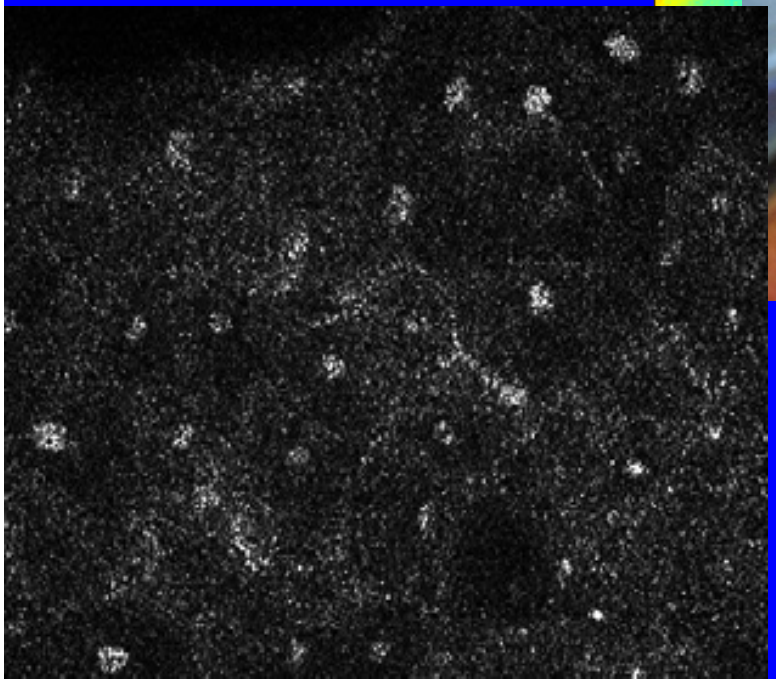








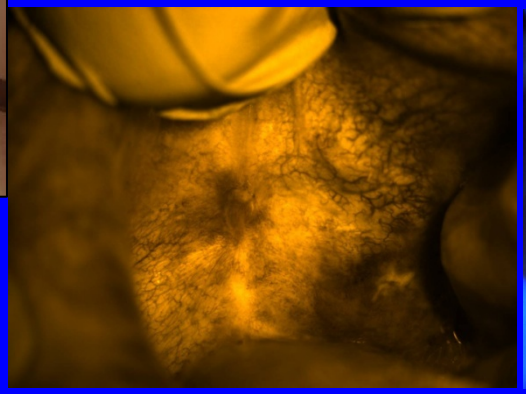


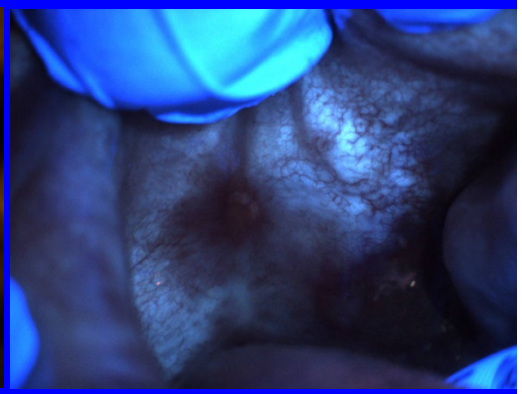


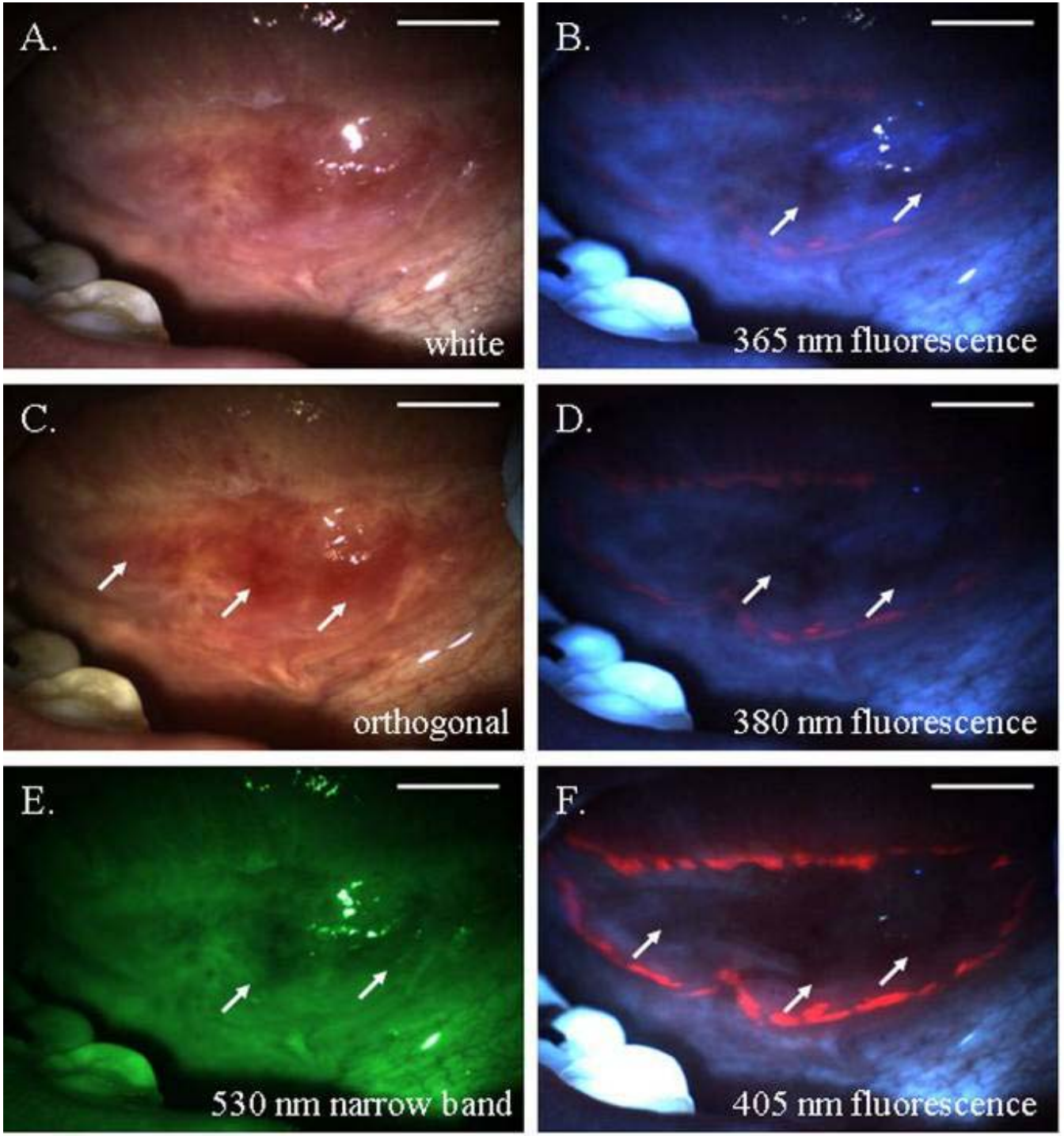
Multispectral Digital Microscope

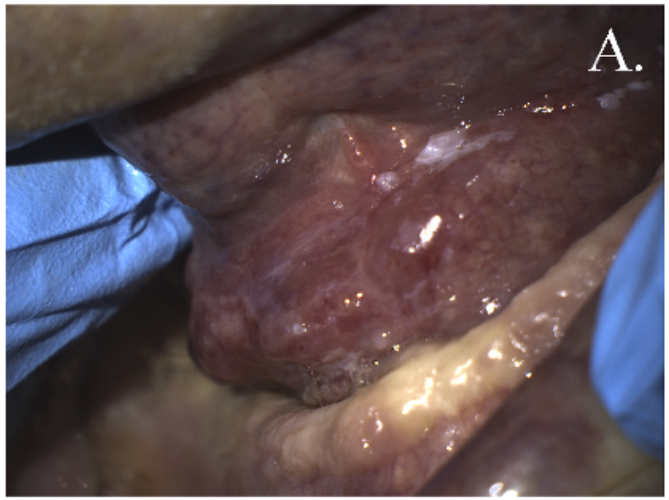
Imaging modes:

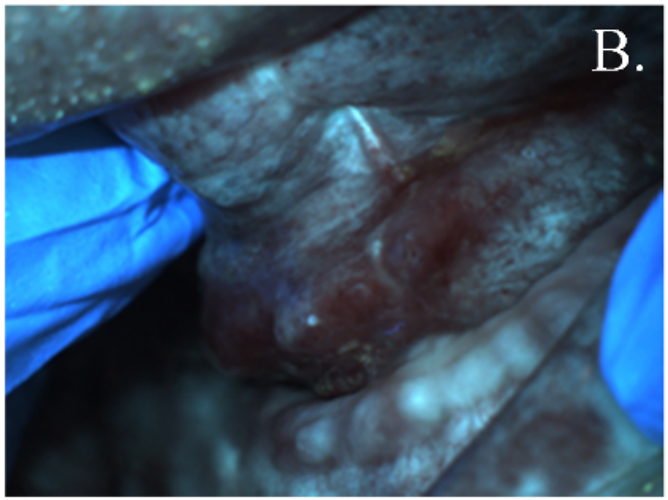
- Reflectance
  - Multispectral
  - Polarized
- Fluorescence

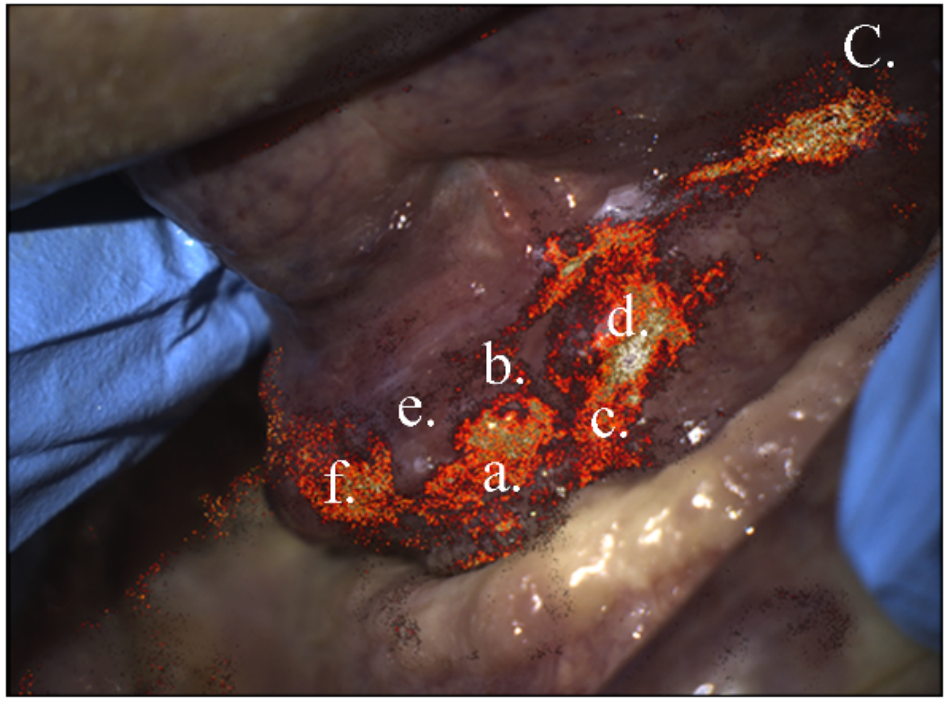





A.
white
B.
365 nm fluorescence
C.
orthogonal
D.
380 nm fluorescence
E.
530 nm narrow band
F.
405 nm fluorescence







Predicted Probability

50% 75% 100%

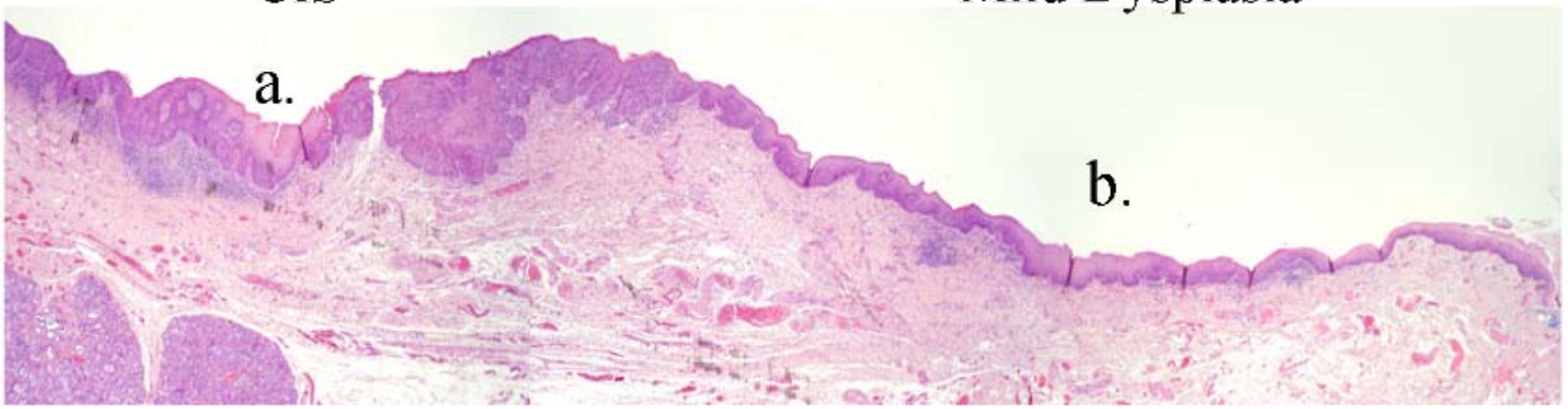
Site	Pathology
a.	CIS
b.	Mild Dysplasia
c.	CIS
d.	CIS
e	Normal
f.	CIS

CIS

Mild Dysplasia

a.

b.



CIS

CIS

Normal

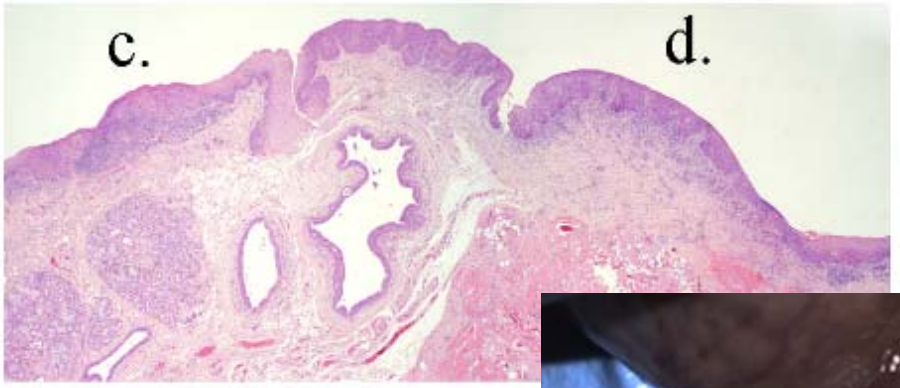
CIS

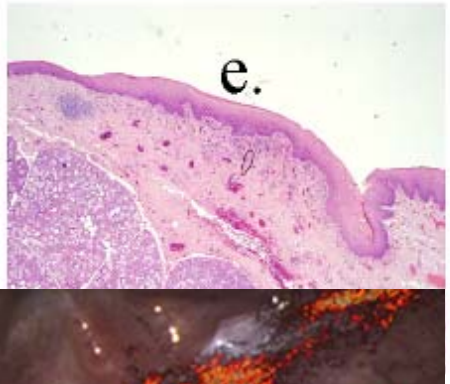
c.

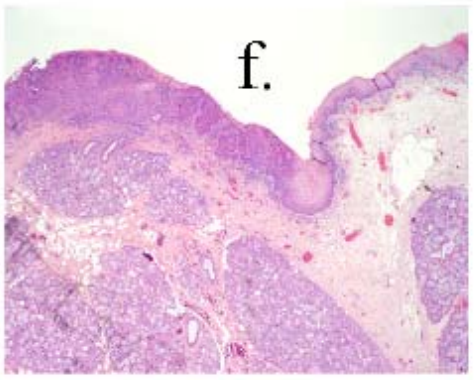
d.

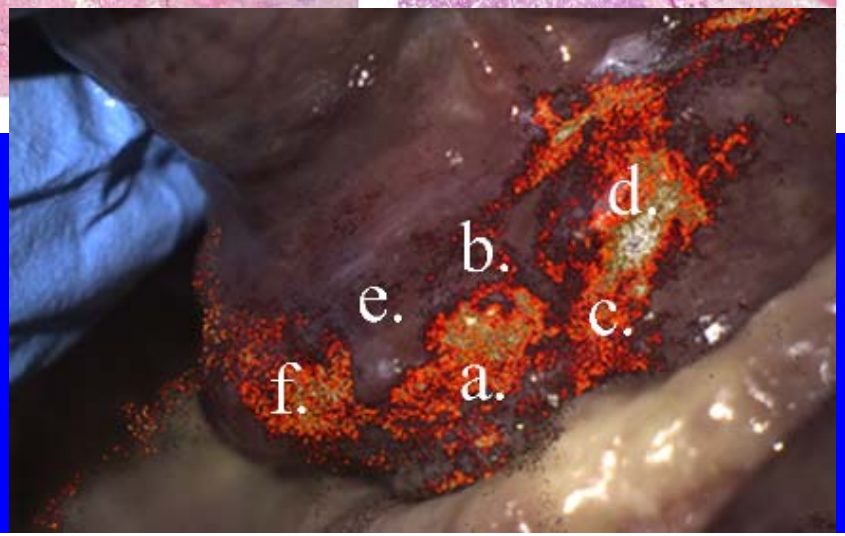
e.

f.







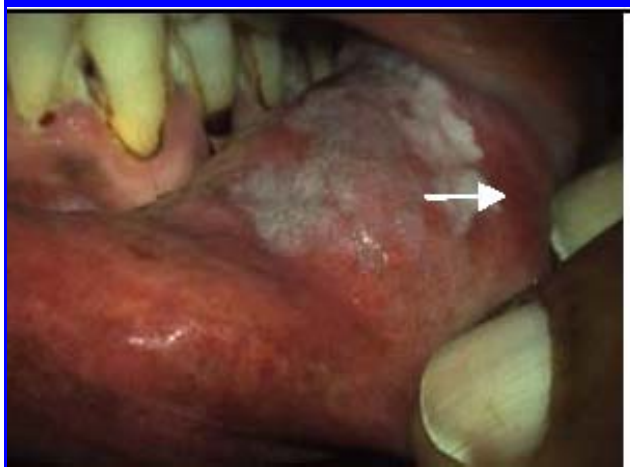


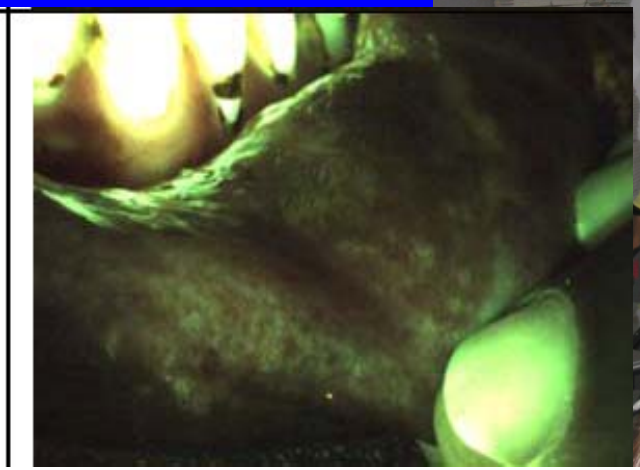
Portable Screening System

LED light source
Battery powered

3 Image Modes:
- White light
- Fluorescence
- Polarized

Records digital images





Typical Lesions of the Four Diagnostic Categories

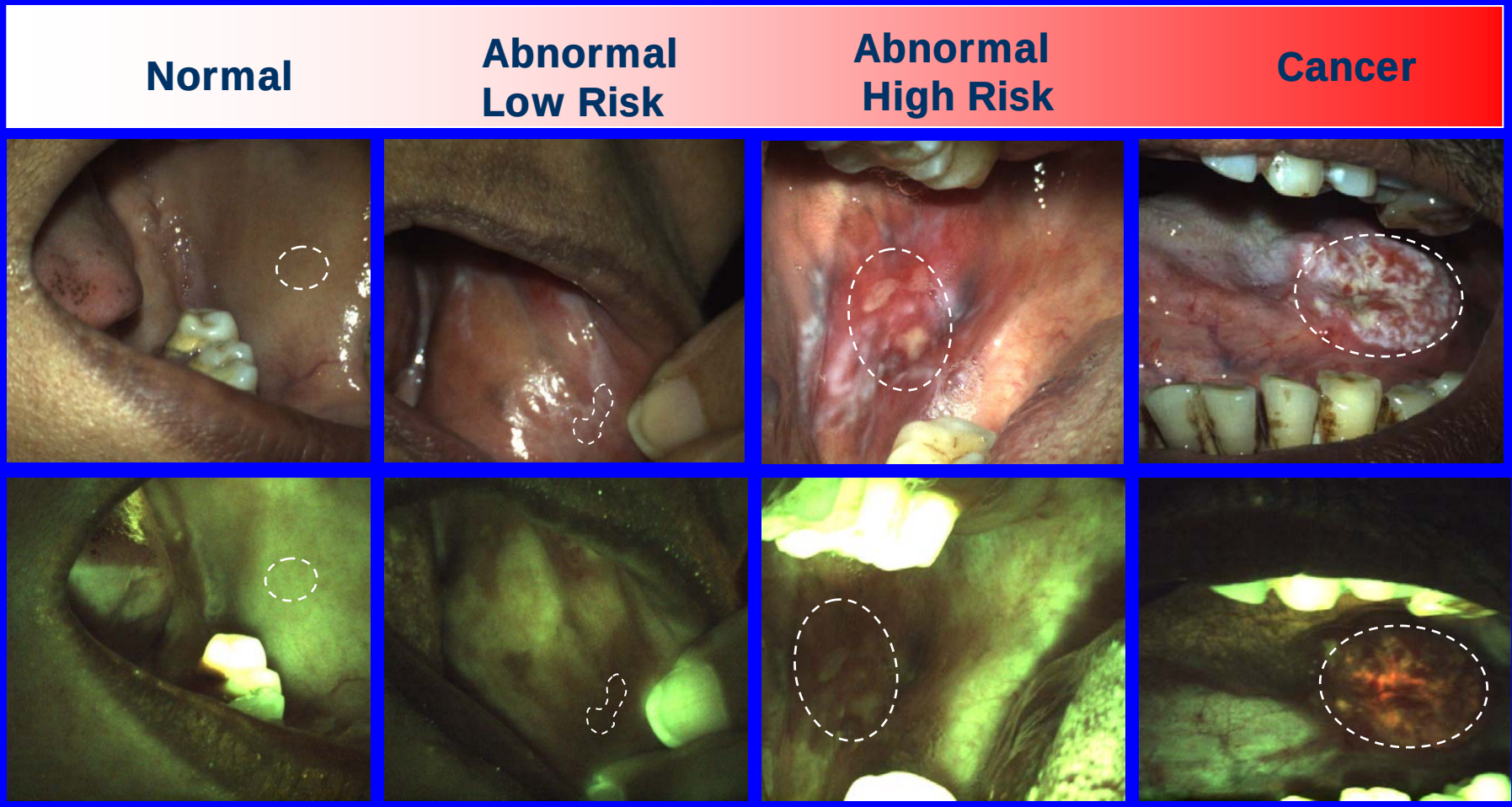
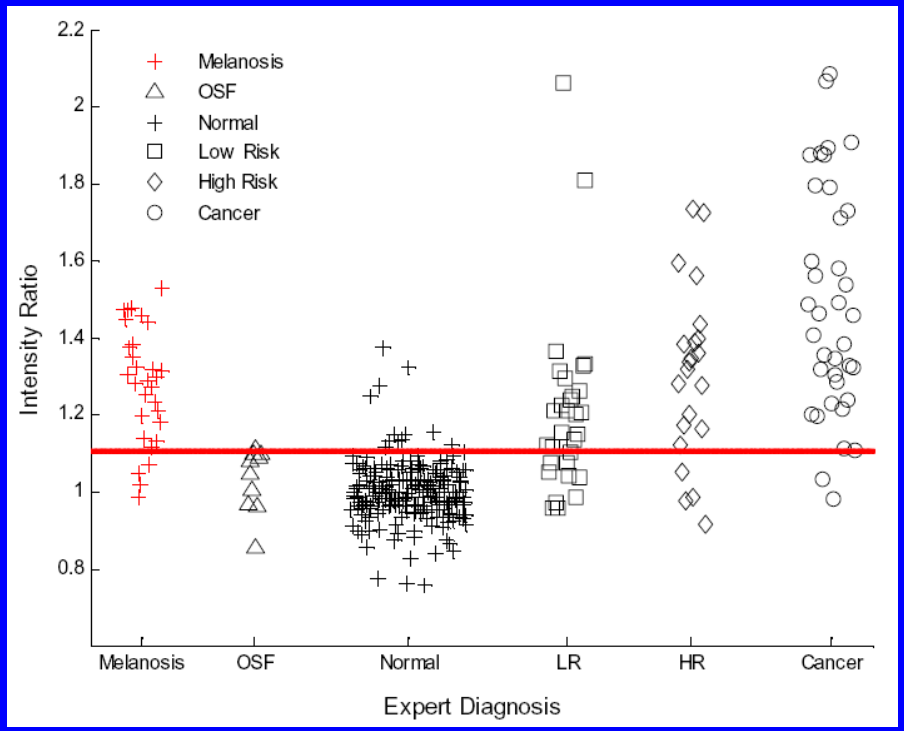
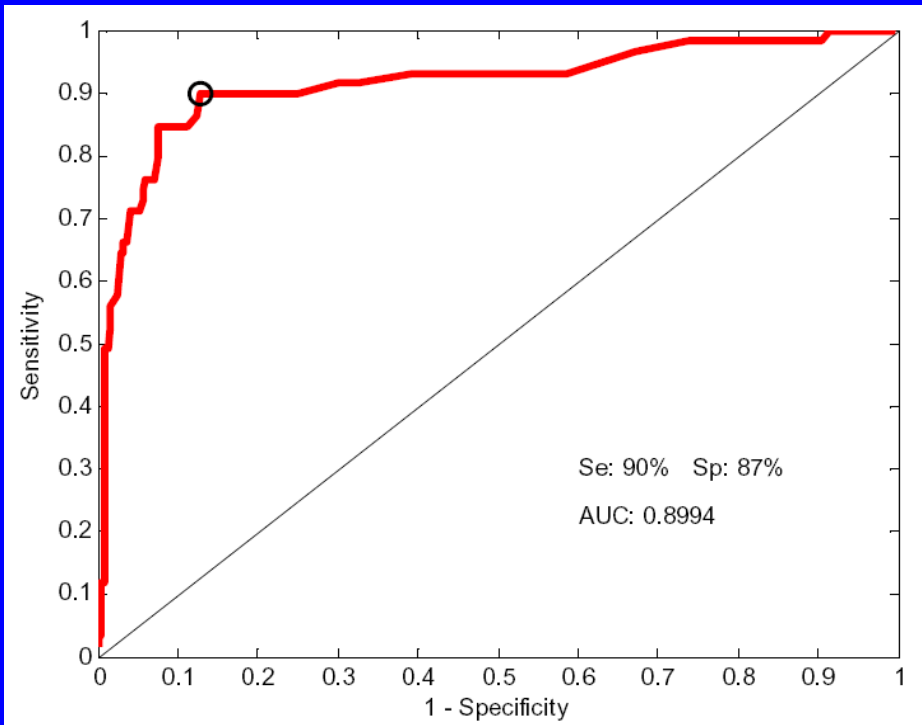


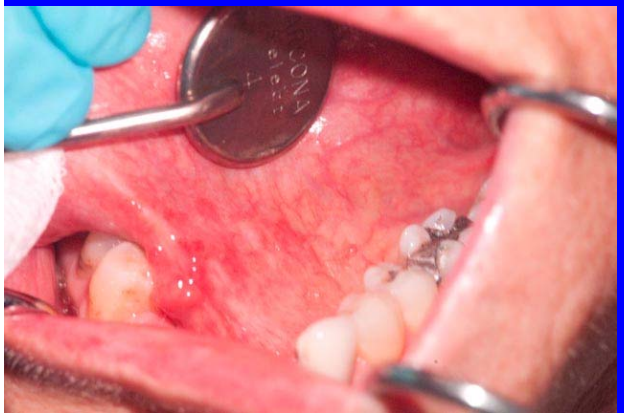
Image Analysis

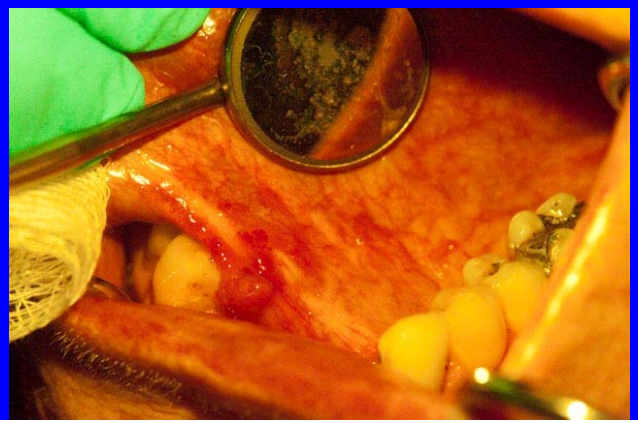
Normalized Ratio of Red to Green MFI

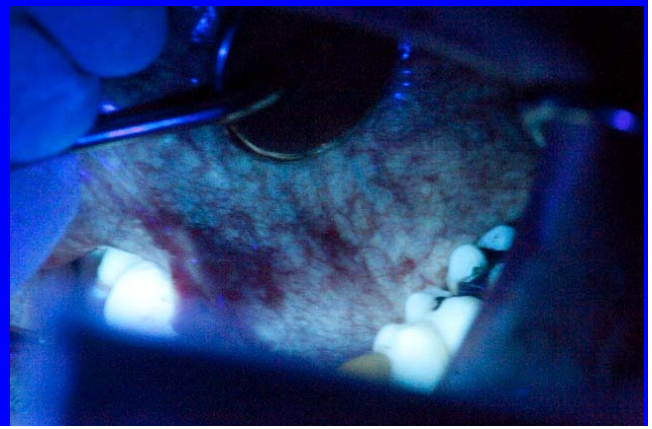


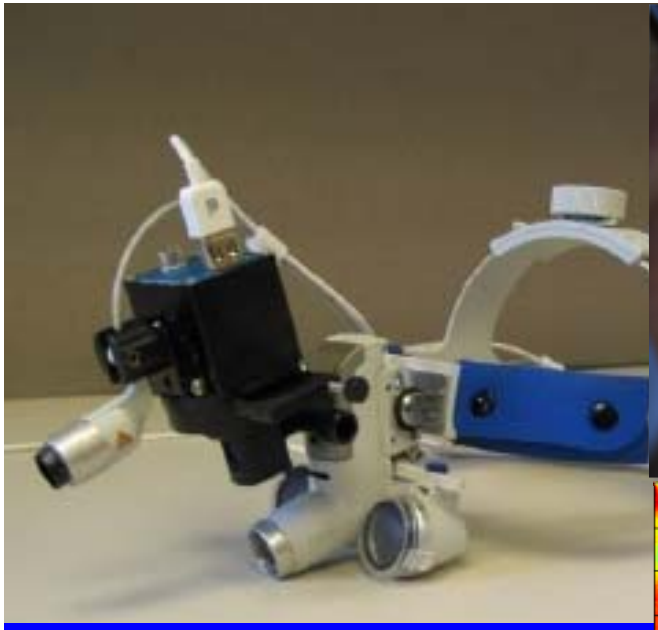


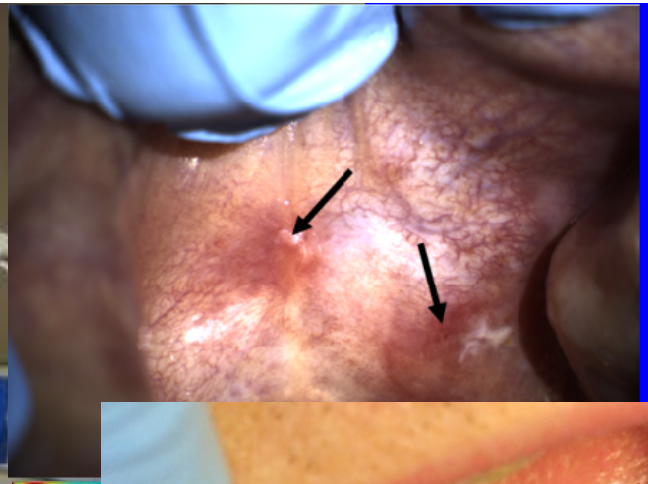
Commercial Device

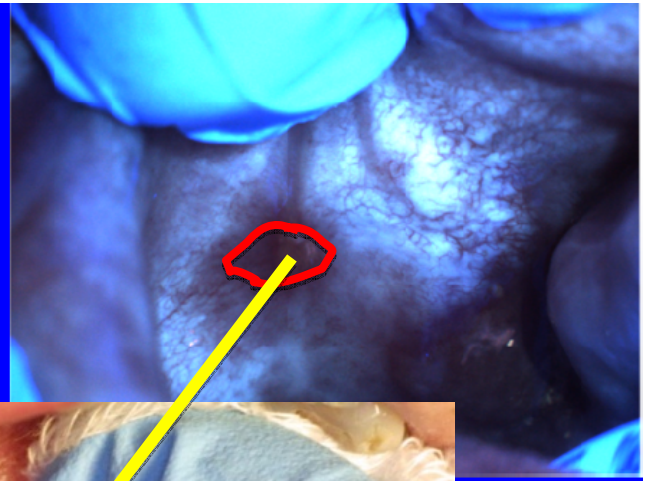


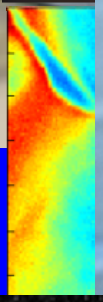


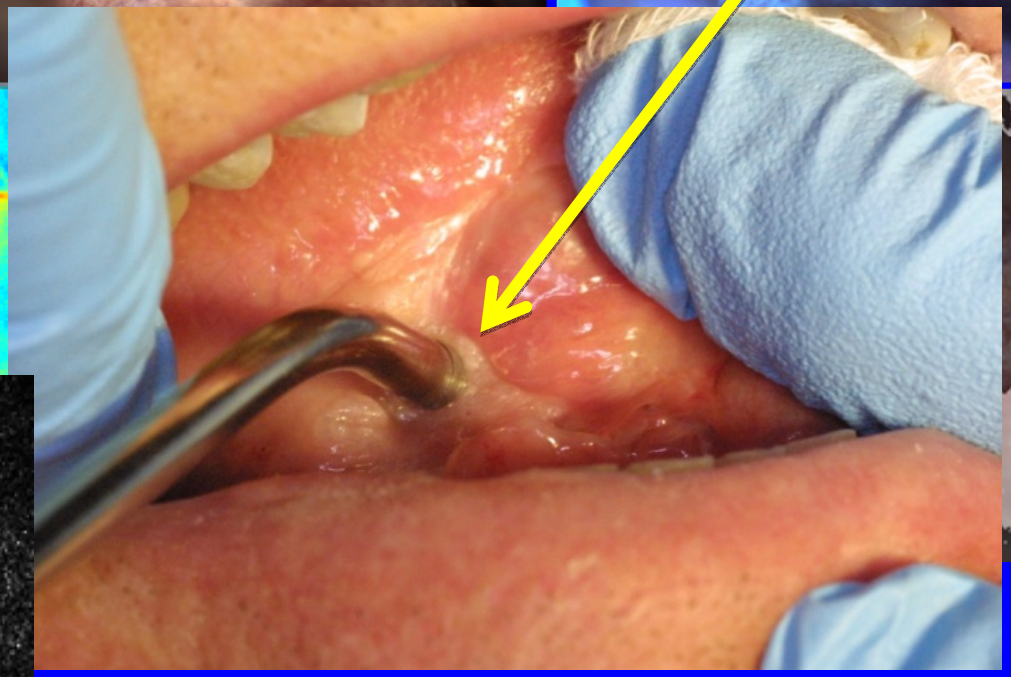


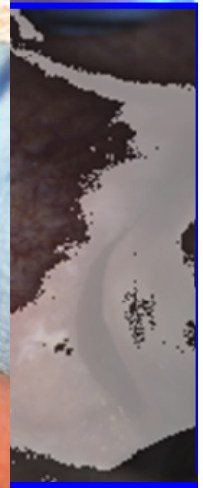


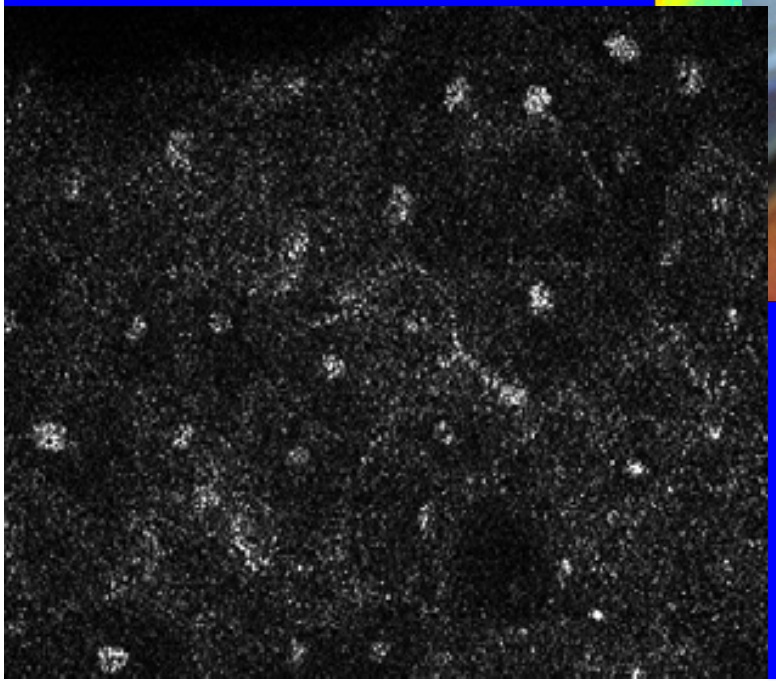




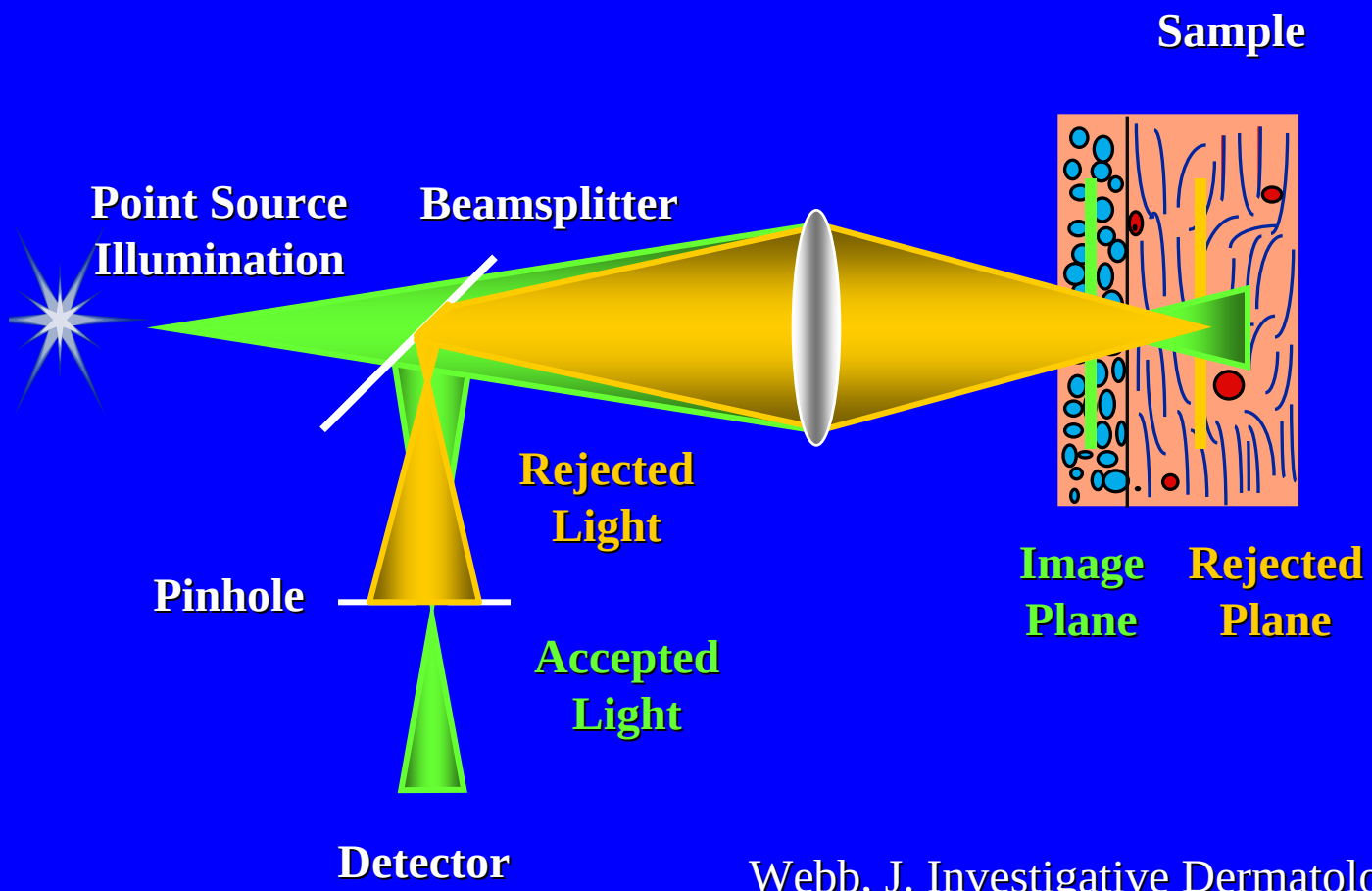






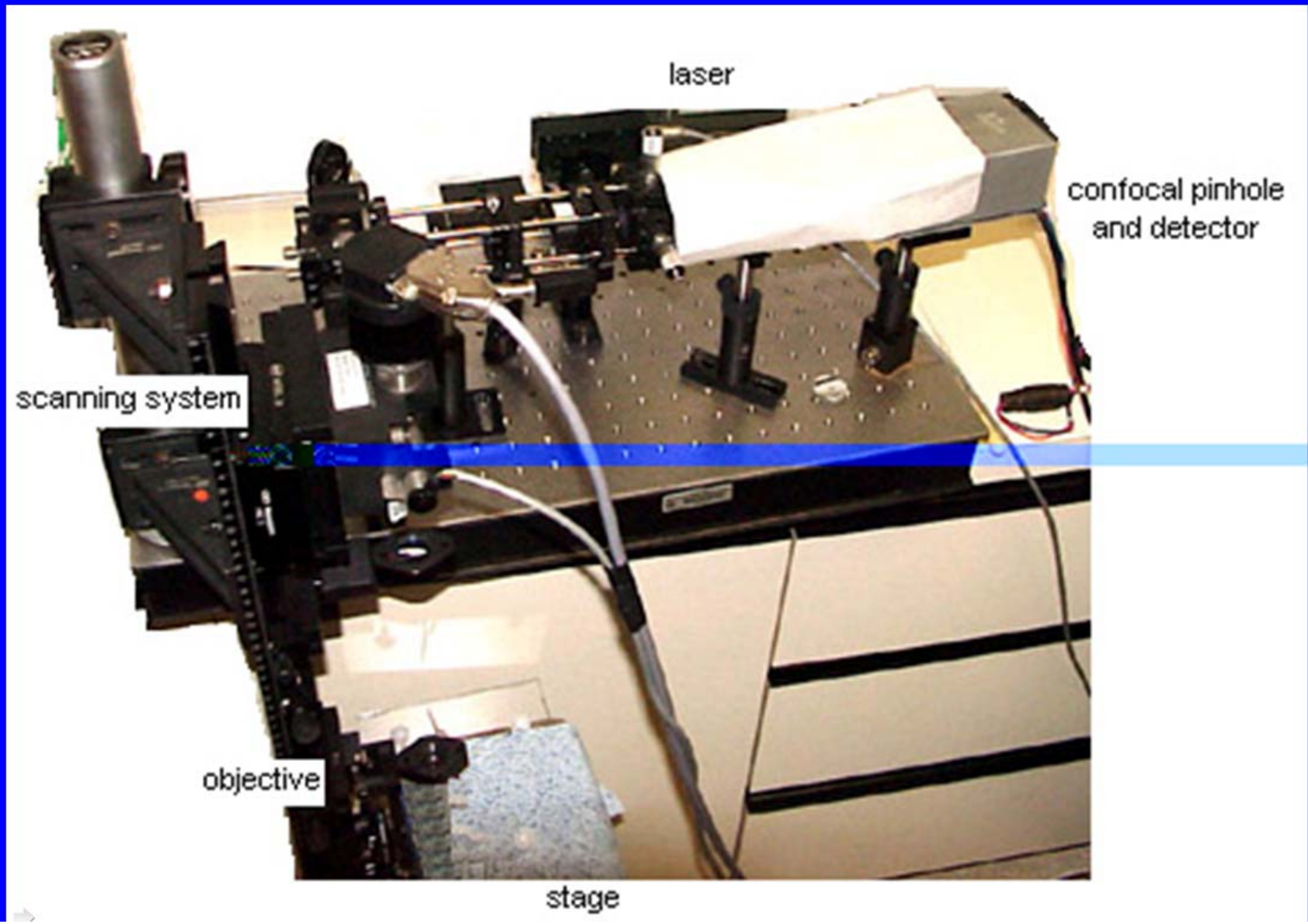


Technology: Confocal Microscopy

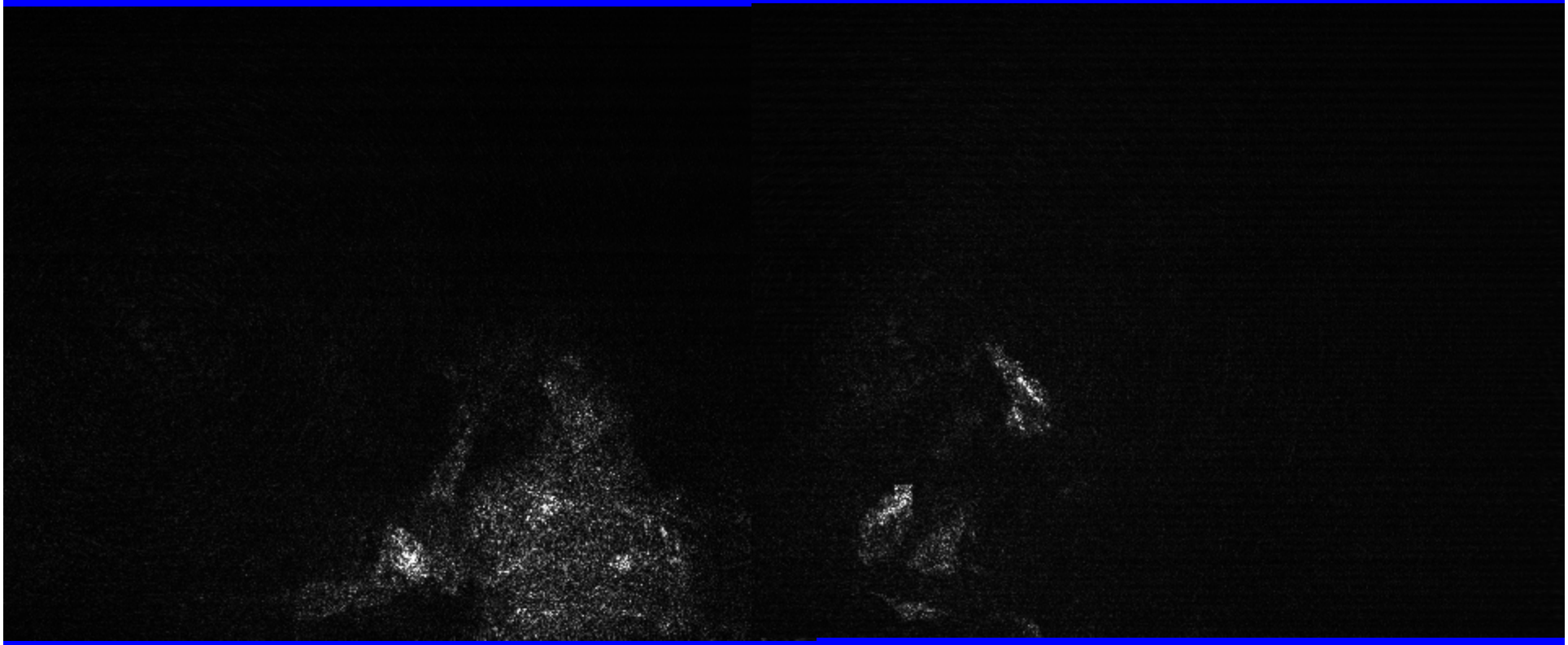


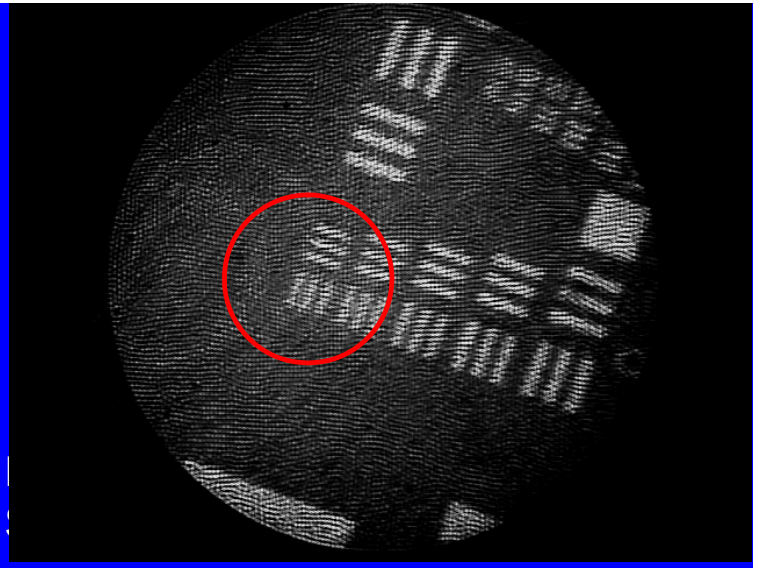
Webb, J. Investigative Dermatology,1995

Confocal Microscope



Imaging Endogenous Contrast





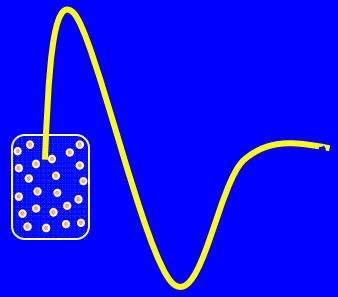
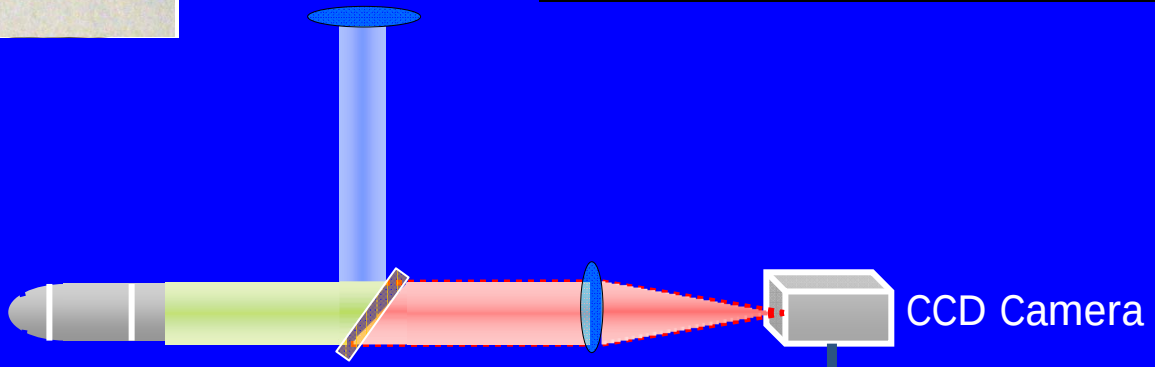


Image
Guide

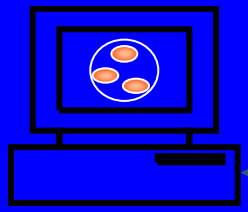


10X UPLAPO
Objective

Dichroic
Mirror

Tube Lens

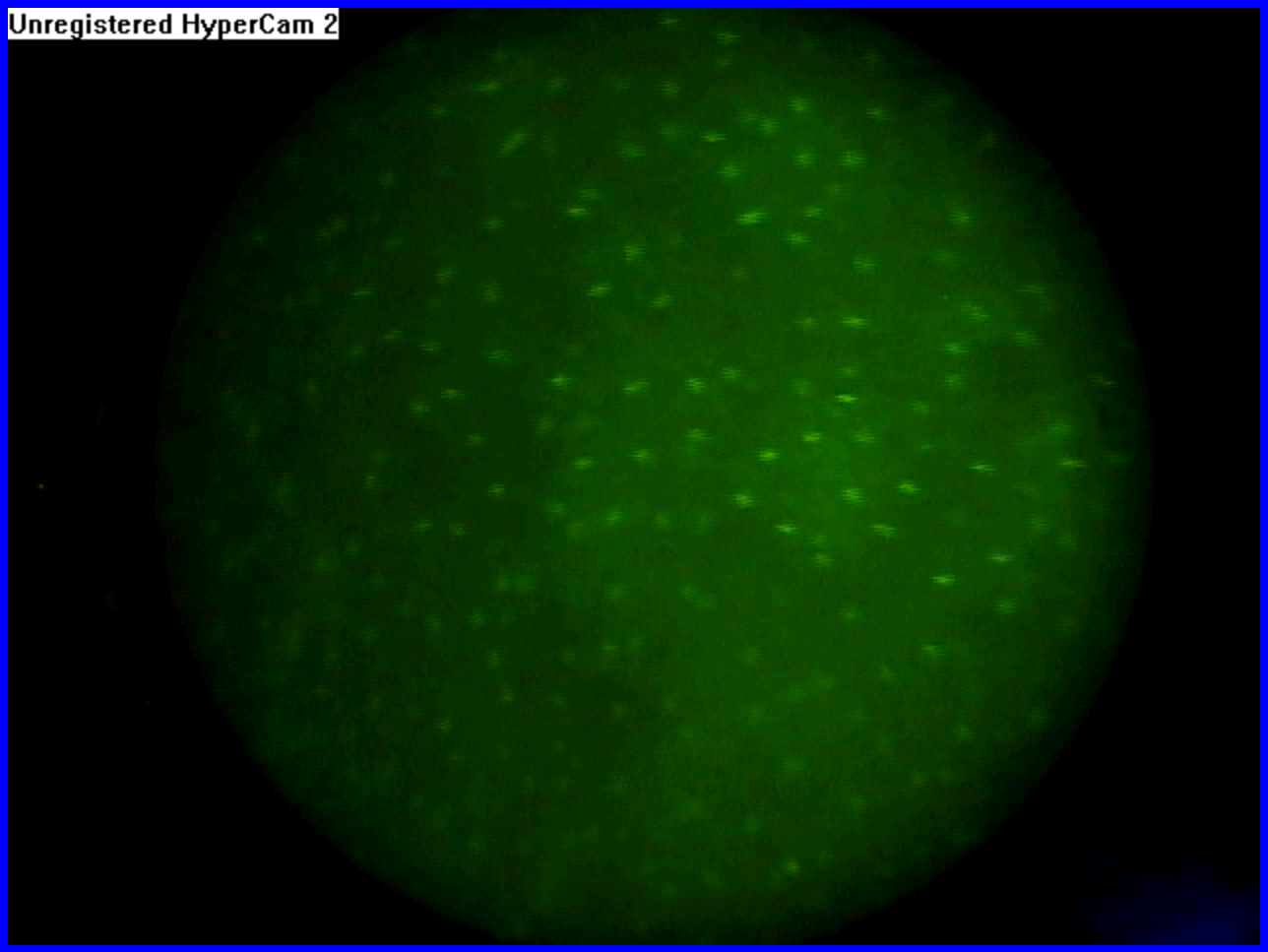
CCD Camera



Frame Grabber

Needle Biopsy

Needle Biopsy



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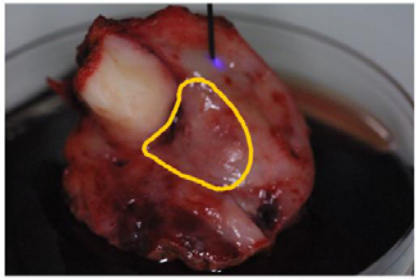
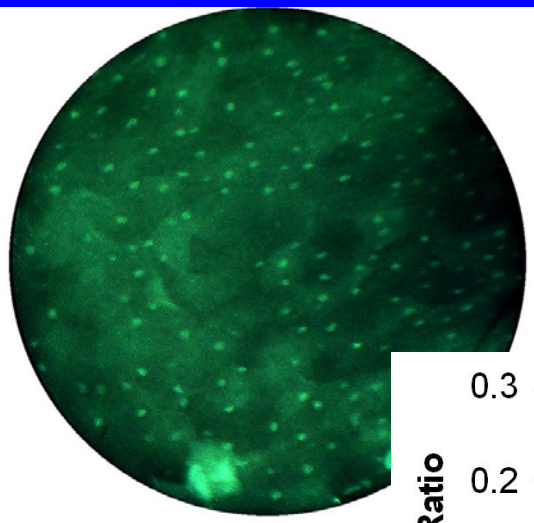
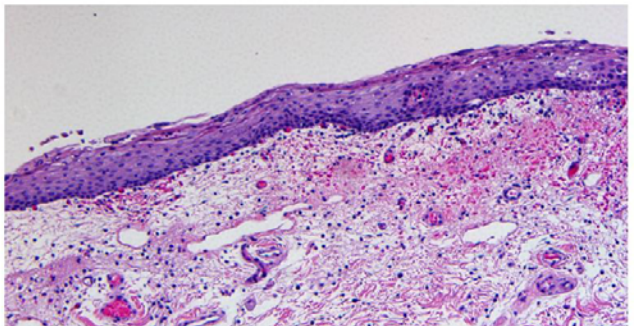
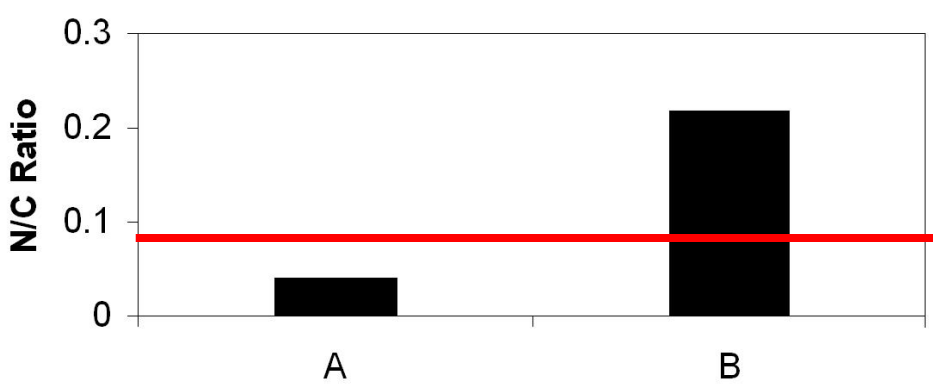
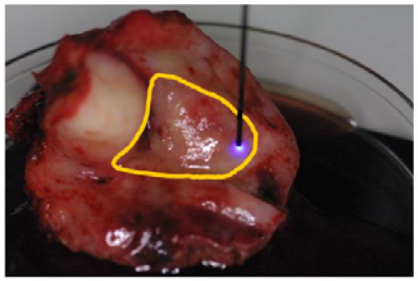


a

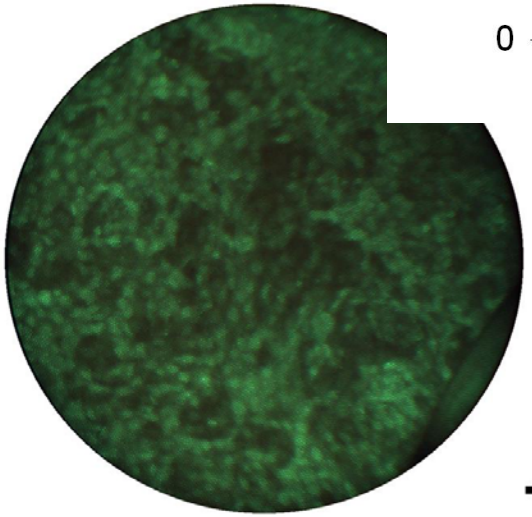


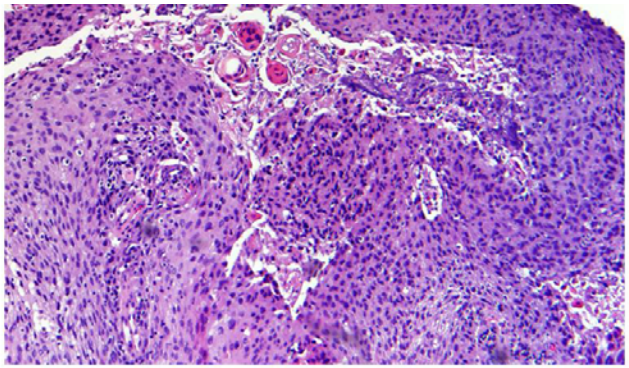




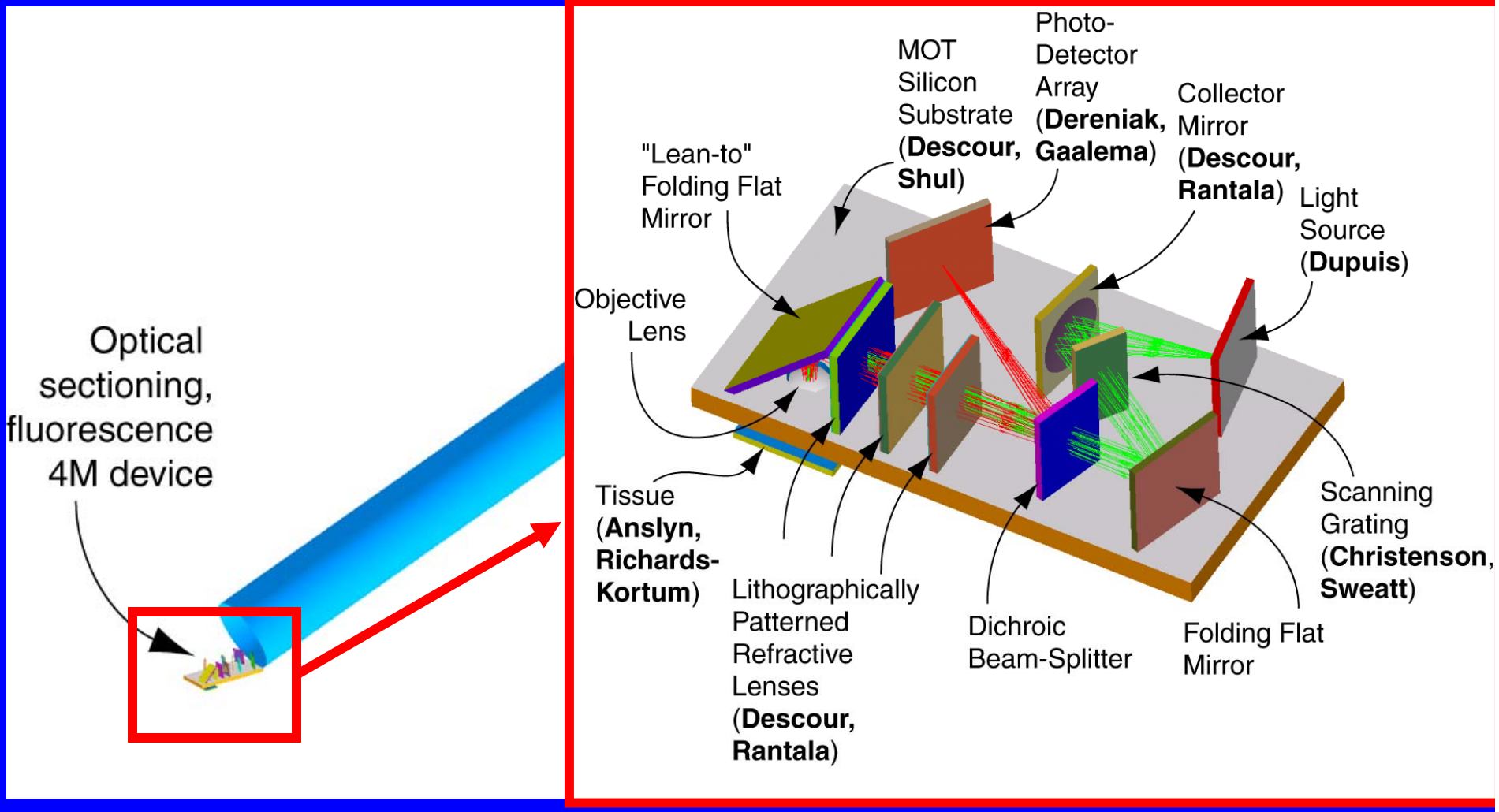


b

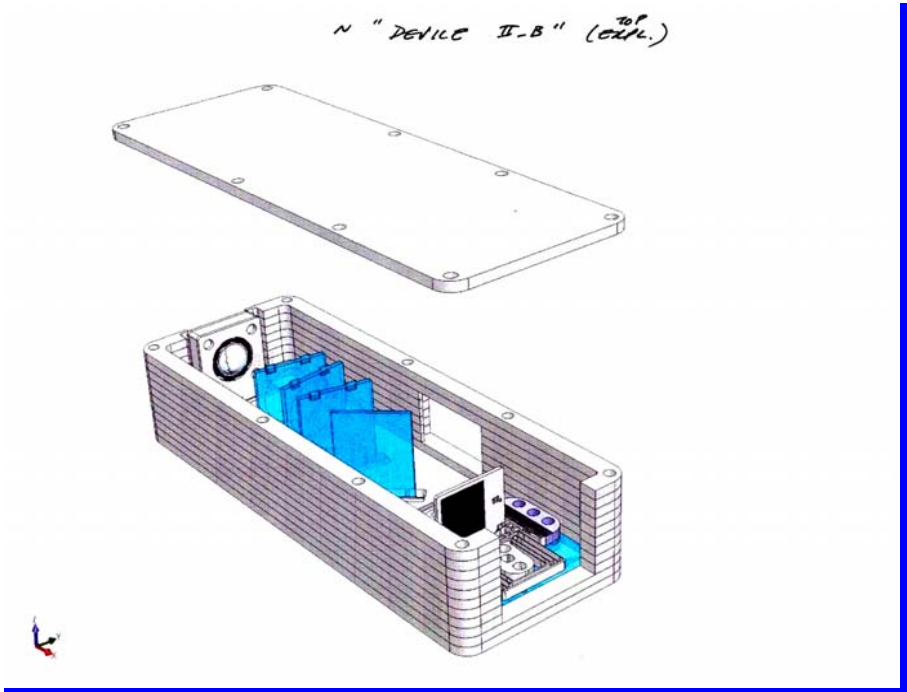


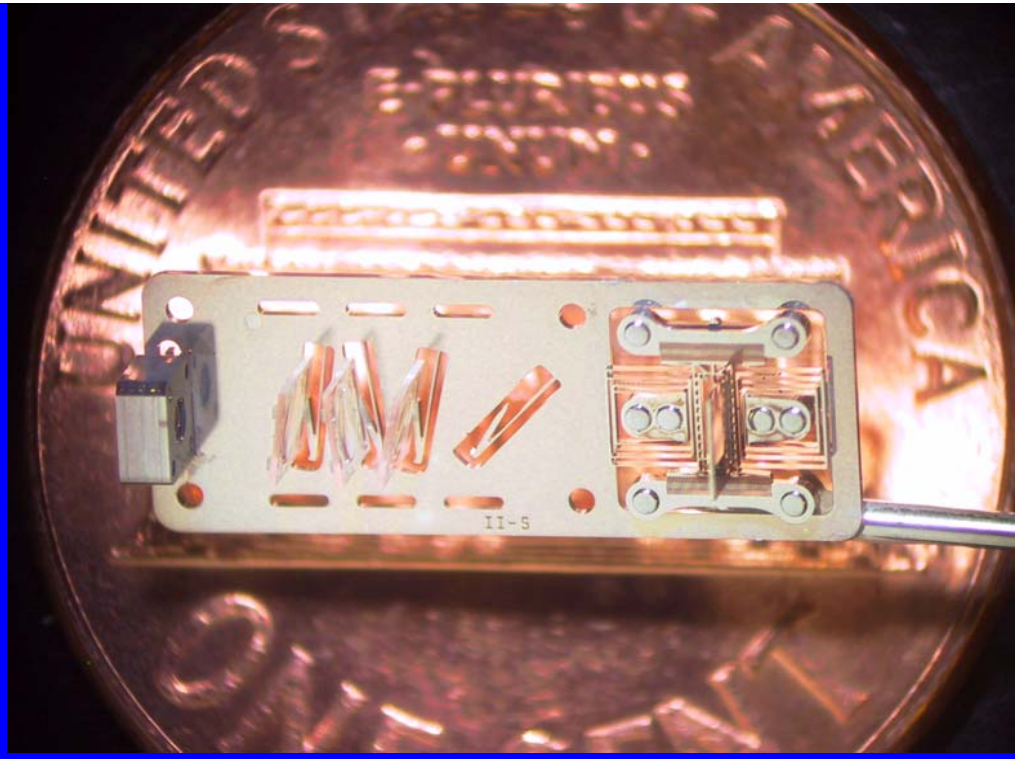


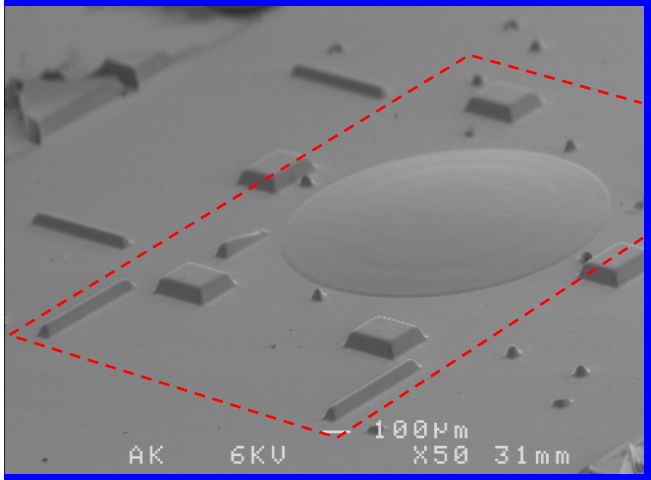
Miniature Microscopes



Collaboration with T. Tkaczyk


" DEVICE II-B " (CONT.)


II-5


100μm
AK 6KV X50 31mm

Example: Oral cancer detection

- Science of precancer
- Engineering solutions for precancer detection
  - 1. Identify a need
  - 2. Define the problem (goals, constraints)
  - 3. Gather information
  - 4. Develop solutions
  - 5. Evaluate solutions
  - 6. Communicate results

Three Case Studies

- Prevention of infectious disease
  - HIV/AIDS
- Early detection of cancer
  - Cervical Cancer
  - Ovarian Cancer
  - Prostate Cancer
- Treatment of heart disease
  - Atherosclerosis and heart attack
  - Heart failure

Assignments Due Next Time

- None!