

GWIBE Symposium
04/07/08

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Endoscopic Optical Coherence Tomography

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Endoscopic OCT at GWU

- OCT imaging of the urinary bladder
- Texture analysis of OCT images for cancer detection and staging
- Basic research in new scanning probes using MEMS technology

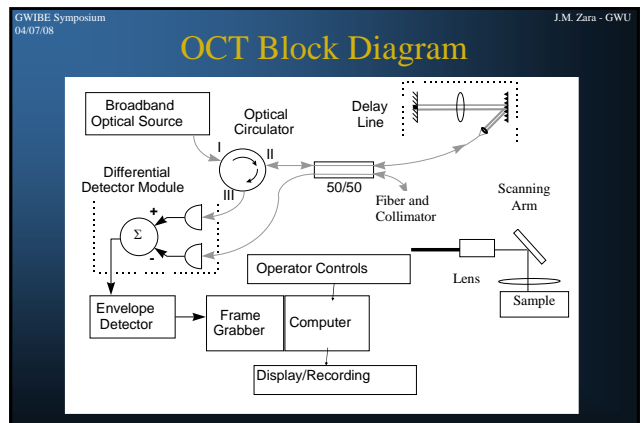
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Optical Coherence Tomography (OCT)

- Imaging modality analogous to ultrasound or radar, but measures reflected infrared light
- As small as $4\ \mu\text{m}$ resolution, but only 2-3 mm of penetration in tissue
- Has cell level resolution, could be used as an 'Optical Biopsy' technique – more likely to be used to guide biopsy procedures
- Applications include eye, skin, intravascular (imaging arterial plaques) and endoscopic imaging (esophagus, cervix, mouth, bladder, etc.)

Zara JM, Lingley-Papadopoulos A, "Endoscopic OCT Approaches Towards Cancer Diagnosis." *IEEE Journal of Selected Topics in Quantum Electronics*, 14(1): 70-81, 2008.



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OCT in Bladder Cancer


- We are working with Dr. Michael Manyak and Imalux Corporation in a clinical trial to investigate the use of OCT in bladder cancer
- 24 Patients undergoing bladder biopsy were investigated (87 sites imaged).
- Both normal and suspicious areas of the bladder were photographed, imaged with OCT, and then biopsied.
- Biopsy results were compared with diagnoses from OCT images
- Results were promising, but diagnosis from OCT images can be problematic

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Imalux OCT Scanning

Prototype OCT Scanning Device



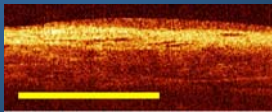
2.7 mm OD probe



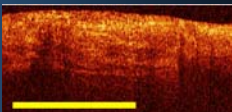
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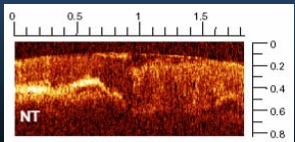
Tissue Layer Changes in OCT



Normal Bladder Image



Cancerous Bladder Tissue
(note loss of tissue structure)



Transition from Normal Tissue (left) to Carcinoma (right) in the Larynx

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OCT Imaging of Bladder Tissue

87 images evaluated, this data included:
16 papillary tumors, 36 suspicious areas, 35 suspected normal

| | |
|-------------------------|------------|
| Sensitivity | 100 % |
| Specificity | 77 % |
| PPV | 75 % |
| NPV | 100% |
| Accuracy | 92 % |
| PPV for invasion | 90% |

Manyak MJ, Gladkova ND, Makari JH, Shwartz A, Zagaynova EV, Zolfaghari L, Zara JM, Iksanov R, Feldchtein FI. "Evaluation of Superficial Bladder Transitional-Cell Carcinoma by Optical Coherence Tomography." *Journal of Endourology*, 19(5): 570-574, 2005.

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Texture Analysis of OCT Images

- Identification of precancerous and cancerous conditions in OCT images can be a difficult task
- We are investigating methods to examine the underlying texture of the OCT images to try and diagnose various conditions (dysplasia, inflammation, carcinoma in situ, invasive cancer, etc.)
- Early results are extremely promising

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Results of Algorithm

| Pathology Results | Decision | | Specificity | Sensitivity |
|----------------------------|---------------|-----------|-------------|-------------|
| | Non-Cancerous | Cancerous | | |
| Normal | 26 | 4 | 87% | |
| Exudative Inflammation | 21 | 3 | 88% | |
| Infiltrative Inflammation | 42 | 47 | 47% | |
| Dysplasia | 0 | 6 | | 100% |
| CIS | 0 | 9 | | 100% |
| Invasive Tumor | 1 | 14 | | 93% |
| Papillary Lesion | 2 | 7 | | 78% |
| Total Non-Cancerous | 89 | 54 | 62% | |
| Total Cancerous | 3 | 36 | | 92% |

Lingley-Papadopoulos A, Loew MH, Manyak MJ, **Zara JM**, "Computer Recognition of Cancer in the Urinary Bladder Using Optical Coherence Tomography and Texture Analysis." *Journal of Biomedical Optics*, in press.

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Conclusions: Texture Analysis

- Viable method of OCT image evaluation
- Highly sensitive to distinguish dysplasia/CIS from normal
- Highly specific for normal and exudative inflammation
- Low specificity for diffuse inflammation vs cancer
- We are working on new "smart" algorithms that are not affected by variation in system parameters.

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Microfabricated Scanners in OCT

- MEMS devices are fabricated using photolithography so they can be made to be inexpensive and disposable for endoscopic and catheter applications
- Very small devices with low power consumption are possible for catheter and endoscopic applications
- A key size parameter is making probes small enough to pass through the accessory port of a standard endoscope (2.7-5 mm outer diameter)
- Reducing the cost of the probes has the potential to reduce the expense of patient care

Zara JM, Patterson PE, "Polyimide amplified piezoelectric scanning mirror for spectral domain optical coherence tomography." *Applied Physics Letters*, 89, 263901, 2006.

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Integrated Fabrication

Patterned Device on Wafer Prior to Back Etch

Completed Device After Back Etch

Actuator

Tilting Mirror

- Silicon wafer
- Sacrificial layer
- Variable thickness piezoelectric
- Piezoelectric or other mirror stiffener
- 3 μm polyimide
- 30 μm polyimide
- Gold

- Fabrication completed with support from the Army Research Laboratory in Adelphi, MD

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Microfabricated Imaging Probes

3 mm

1990

3 mm

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Device In Motion

1 mm

1 mm

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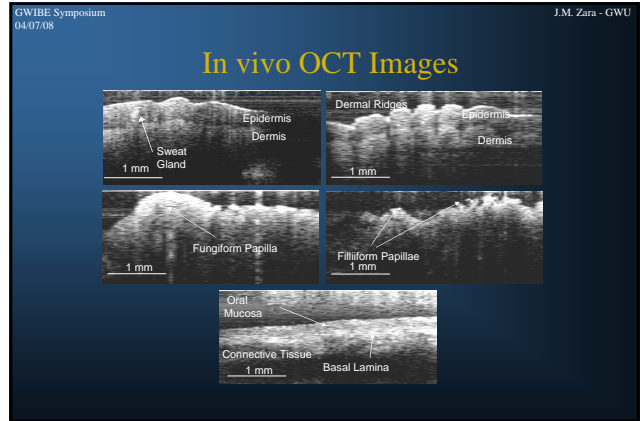
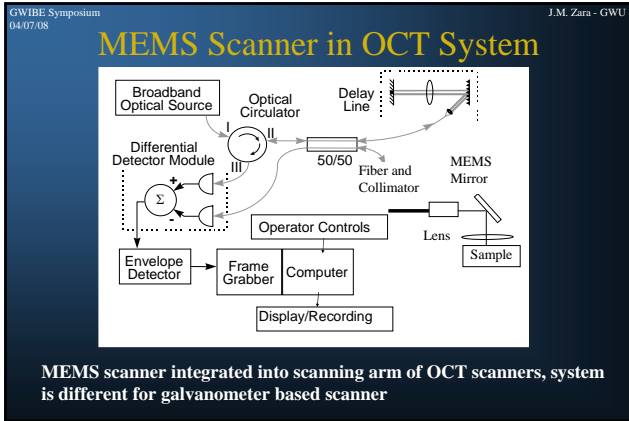
Encased Imaging Probe

Scanning Mirror

GRIN Lens / Prism

1.5 mm

Imaging Window



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- ### Summary
- Bladder cancer imaging with OCT has expanded to a multi-center imaging trial being run by Imalux.
 - Texture analysis of images is extremely promising and more robust algorithms are currently being developed.
 - Microfabricated imaging probes are being evaluated for scanning performance and ability to guide interventional procedures such as biopsy and laser ablation.

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- ### Acknowledgements
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