Augmenting Biopsy Sensitivity through Needle OCT Imaging

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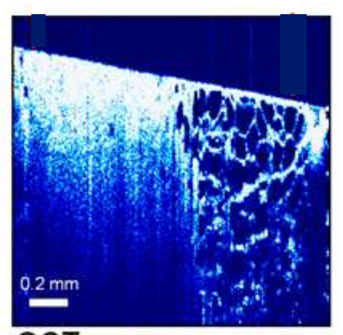
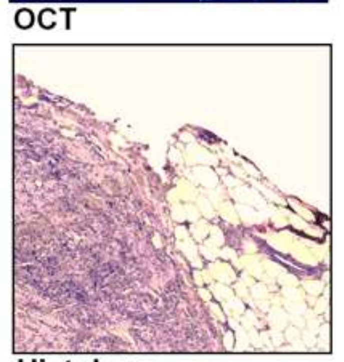
Abstract

Biopsy needles are limited by a lack of optical information. Previous solutions involving optical coherence tomography in a needle incorporated moving parts to obtain the lateral resolution. The chosen solution relies on a transmission grating (eliminating moving components such as gears) to direct beams of light to generate a field of view. Future work will involve further maximizing lateral resolution and reduce the incidence of false negatives in biopsy procedures.

Background



OCT



Histology

Current biopsy procedures:

- Low sensitivities
- No optical information about the tissue sample

OCT :

- Offers a way to obtain two dimensional fine resolution [20 µm]
- Interferometry components provide depth
- Current lateral resolution obtained by moving parts

Applications:

- Detect cancerous tissue in otherwise homogeneous tissue

Figure 1: OCT scans of breast tumor tissue compared with stained histology; Zysk, 2006

Problem Statement

Improve biopsy procedures by providing optical information.

- Eliminate moving parts in needle:
  - Develop method for obtaining optimal 2D lateral resolution and field of view
  - Reduce incidence of false negatives
- Encapsulate all components in a needle

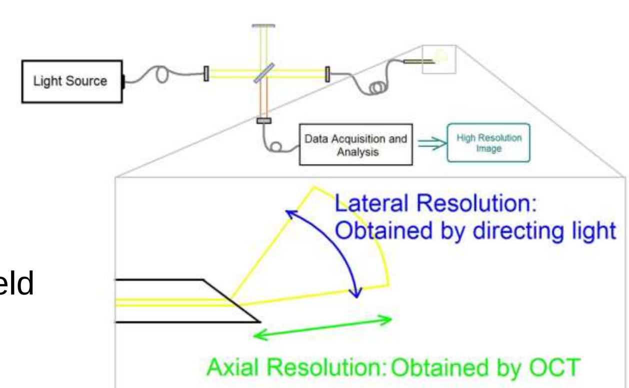


Figure 2: Schematic of imaging set-up

Current Product

Current designs are complex

- Involve moving components (e.g. gear and actuator) which provide 360° field of view

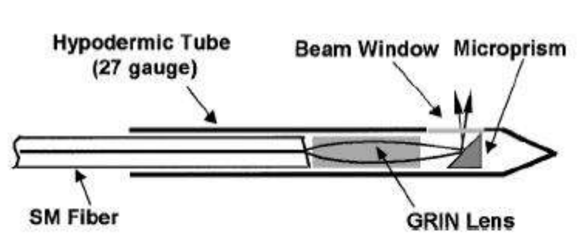


Figure 3: Moving Prism Design; Fujimoto, 2000

Final Design

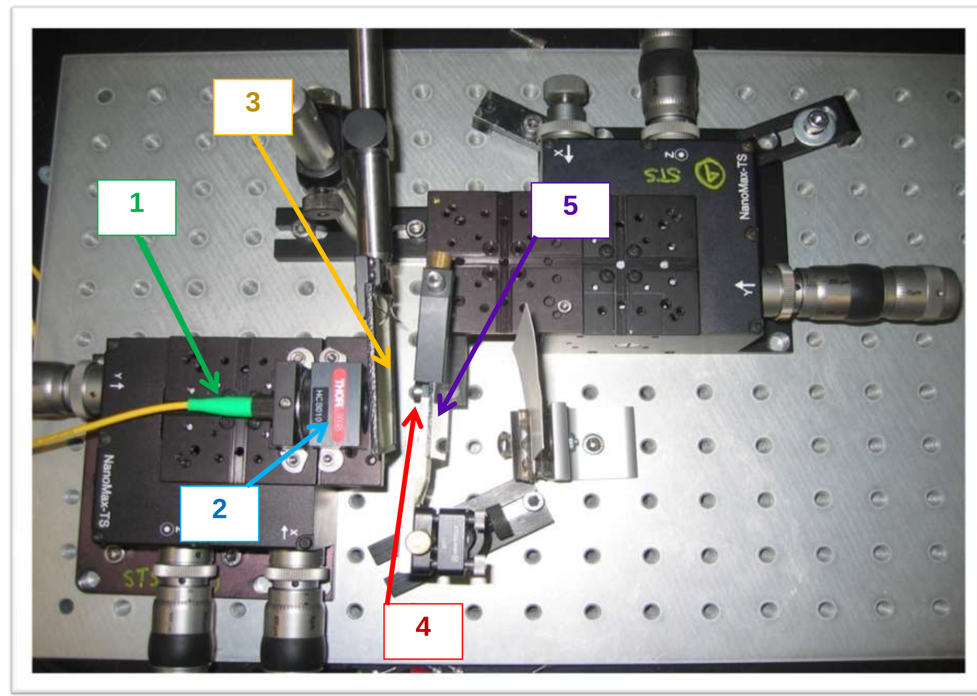


Figure 4:
1→ laser source
2→ collimating lens (f=4.5 mm)
3→ transmission grating
4→ collimating lens (f=4.5 mm)
5→ USAF Target Mirror

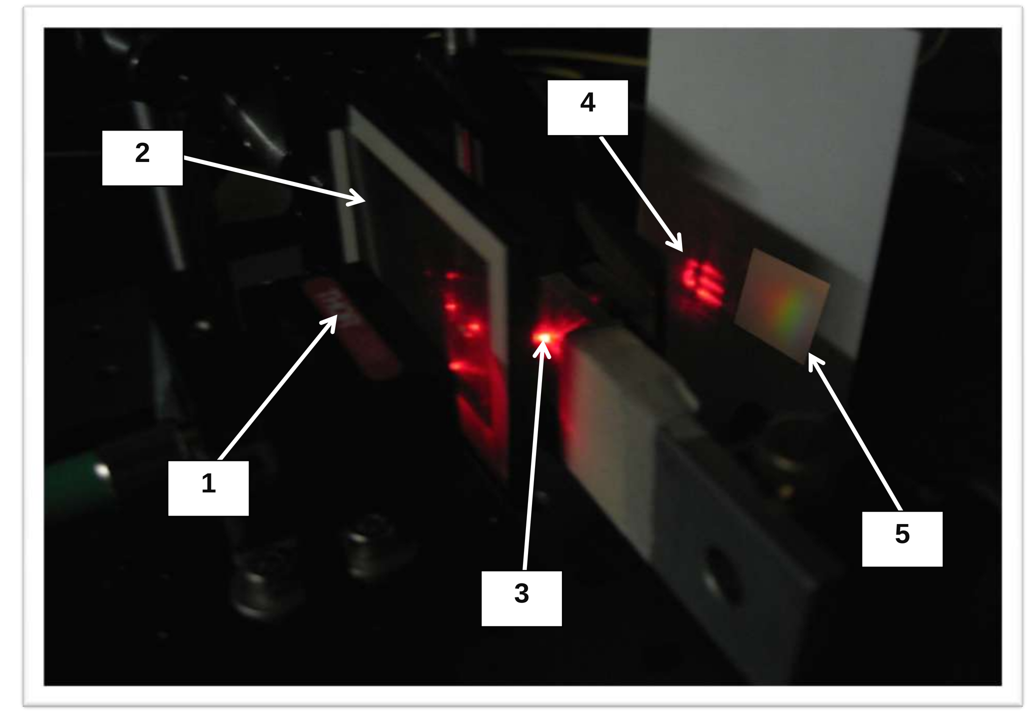


Figure 5:
1→ collimating lens (f=4.5 mm)
2→ transmission grating
3→ collimating lens (f=4.5 mm)
4→ First Order Image of USAF Target from 650 nm laser
5→ First Order Image of USAF Target from white laser

Components

A step-wise guide to obtaining the lateral resolution of an image.

Step 1
- Swept Wavelength Laser Source: 700-1400 nm
  - Range limited by absorption characteristics of water

Step 2
- Aspheric Lens: focal length 4.5 mm
  - Focuses (collimates) light

Step 3
- Transmission grating: 15000 lines/inch
  - Splits incoming light into orders based on interference patterns
  - Calculate resolution

$$R = mN \qquad R = \frac{\lambda}{(\lambda_2 - \lambda_1)} = \frac{\lambda}{\Delta\lambda}$$

Step 4
- Aspheric Lens 2: focal length 4.5 mm
  - Isolates 1st order from grating for best resolution

Step 5
- Target
  - Air force target to gauge resolving power

Step 6
- Spectral analysis
  - Decomposes backscatter to form image

Figure 6: Laser Broadband Source The fiber through which light is transmitted is also shown.
(http://www.ofr.com/Images/FO/fo-51d.jpg)

Figure 7: Aspheric Lens
(http://www.thorlabs.com/thorProduct.cfm?partNumber=C230TM-A)

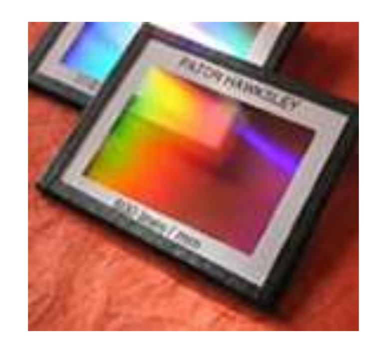


Figure 8: Transmission Grating
(http://www.patonhawksley.co.uk/IMAGES/trans.JPG)

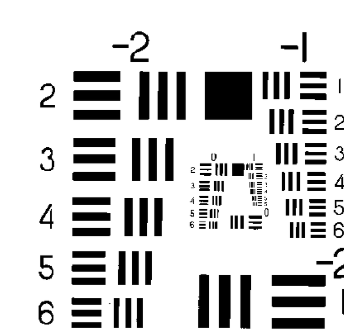


Figure 9: US Air Force target used to gauge resolution of image obtained
(www.distantfocus.com)

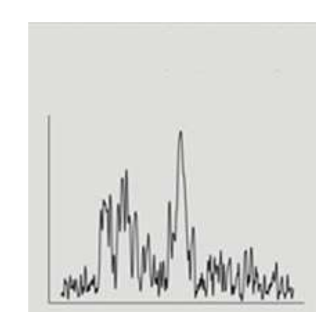


Figure 10: Example spectral output
http://spie.org/x8853.xml

Validation

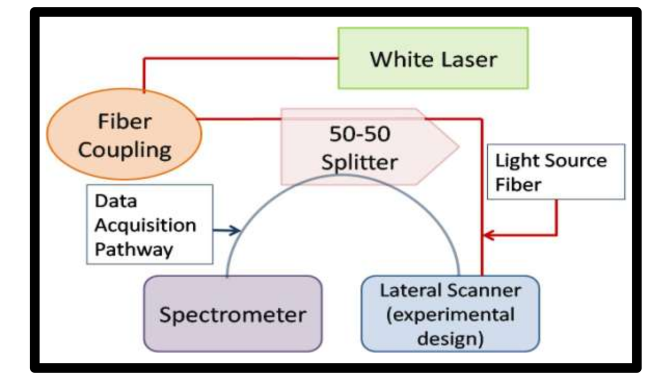


Figure 11: Image and data acquisition pathway

Figure 12: Optical spectrum analyzer. Note: Artificial data rendering to illustrate expected output

Validation Steps:

- White laser output is coupled into fiber
- 50-50 splitter separates beam and creates pathway into reference and sample beams (interferometer)
- 2D lateral sampling
- Backscatter is processed by spectrometer

Future Work

- Focus on improving:
  - Lateral resolution
- Miniaturization of parts
- Improving biopsy applicability
- Needle Encasing
- Decrease likelihood of false negatives

Figure 13: Current Biopsy Needle
(http://www.uresil.com/products/needles.htm)

References

Boppart, S. A. (2005). Optical coherence tomography.http://bil.nb.uiuc.edu/biophotonics/technology/oct/

Fujimoto, J, Boppart, S, Tearney, GJ, Bouma, B, Pitris, C, Brezinski, M. (1998). High resolution in vivo-intra-arterial imaging with optical coherence tomography. Heart, 82, 128-133.

Hwang, Joo et al. (2005). Optical coherence tomography imaging of the pancreas: A needle-based approach. *Clinical Gastroenterology and Hepatology, 3, 549-552.*

Xingde Li, Christian Chudoba, Tony Ko, Costas Pitris, and James G. Fujimoto. (2000). Imaging needle for optical coherence tomography. *Optics Letters, 25(20), 1520.*

Acknowledgments

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