






An Novel Optical Spectral Imaging System for Rapid Imaging of Breast Tumor Margin

Nimmi Ramanujam, Ph.D.

Dept. Biomedical Engineering
Duke University




Breast Conserving Surgery

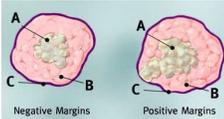


- ~280,000 women diagnosed annually ¹
- ~170,000 undergo breast conserving surgery ²

Resect tumor with surrounding normal tissue with clear margin: >2 mm of normal tissue ⁴

Up to 60% of BCS patients have positive margins after surgery ⁶

Close or positive margin is predictive of local recurrence ⁵



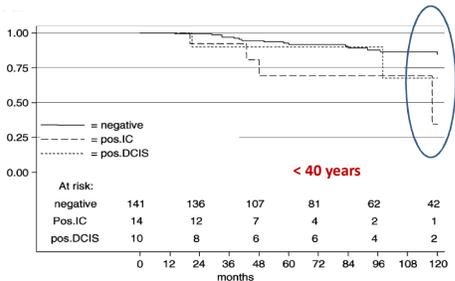
Cross-section of excised sample ³
 A: cancer cells
 B: normal cells
 C: margin of lumpectomy

Negative Margins Positive Margins

[1] National Cancer Institute, *Breast Cancer*
 [2] MC Lee et al., *Breast J*, 15 (2009)
 [3] Bryson, *Images of Breast Cancer*,
 [4] TL Huston et al., *Am J Surg*, 192 (2006)
 [5] Kunos et al., 2006.
 [6] McCahill, 2012.




Local Control of Breast Cancer



< 40 years

At risk:	0	12	24	36	48	60	72	84	96	108	120
negative	141	136	107		81	62	42				
Pos.IC	14	12	7		4	2	1				
pos.DCIS	10	8	6		6	4	2				

months

Acts Oncologica, 2007; 46: 172180

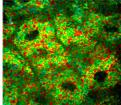



Emerging Optical Technologies for Margin Assessment

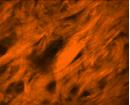
Reflectance/Fluorescence <ul style="list-style-type: none"> • Bigio • Feld • Ramanujam • Pogue • Mahadevan-Jansen 	Raman <ul style="list-style-type: none"> • Haka • Mahadevan-Jansen 	OCT <ul style="list-style-type: none"> • Boppart • Fujimoto • Bouma • Tearney
---	---	--



Tissue vasculature & oxygenation



Cell size & density



Collagen density



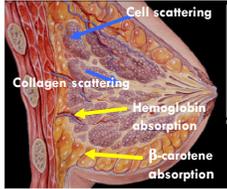
Adipose content (β-carotene)

¹Volynskaya, 2008; Breslin, 2004; Palmer, 2003, 2006; Zhu, 2005, 2006, 2008; Keller, 2010; Majumder, 2008; Brown, 2009; Kennedy, 2010; Palmer, 2003; Demos, 2006; Haka, 2009; Haka, 2006; Haka, 2005; Nguyen, 2009; Hsiung, 2007; Brown, 2009; Bigio, 2003; Bigio, 2000; Ghosh, 2001; Laughney, 2010.




Optical sources of contrast in the breast

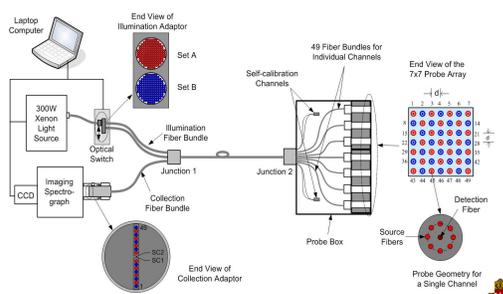
Source of Contrast ¹	VIS DRS	NIR DRS	FL SPX	Raman SPX	OCT
HbO ₂	↓	↓			
HbH	↑	↑			
Heme				↑	
Carotenoids	↓			↓	
Lipids		↓		↓	
Water		↑			
Scattering	↑	↑			↑
Collagen			↑		



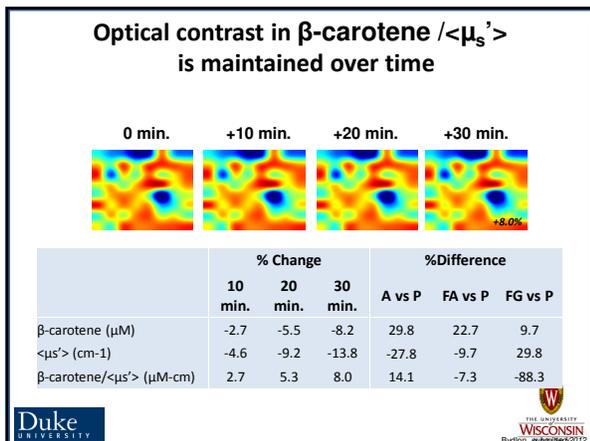
¹Volynskaya, 2008; Breslin, 2004; Palmer, 2003, 2006; Zhu, 2005, 2006, 2008; Keller, 2010; Majumder, 2008; Brown, 2009; Kennedy, 2010; Demos, 2006; Haka, 2005, 2006, 2009; Nguyen, 2009; Hsiung, 2007; Bigio, 2000, 2003; Ghosh, 2001; Laughney, 2010; Cerussi, 2006, 2007.

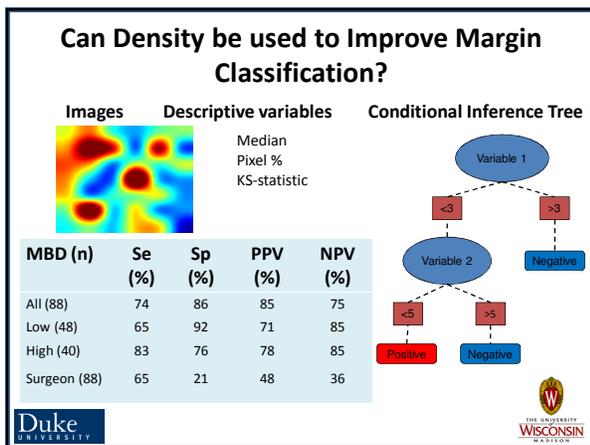


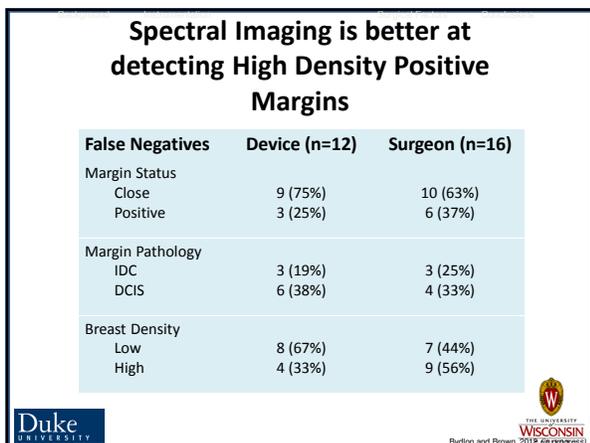

Quantitative Spectral Imaging Can Map Large Fields of View





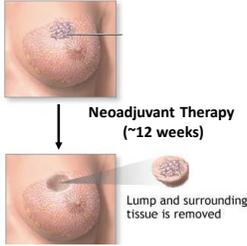







Where we are Headed.....

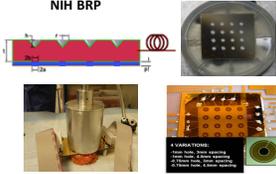
DOD Era of Hope Research Award



Neoadjuvant Therapy (~12 weeks)

Lump and surrounding tissue is removed

NIH BRP



VARIATIONS:
 • Different breast anatomy
 • Different lump locations
 • Different lump sizes
 • Different skin thickness



People

Collaborators

David Brizel MD (Radiation Oncology)
 Walter Lee, MD (Otolaryngology)
 Joseph Salama, MD (Radiation Oncology)
 Mark W. Dewhirst, Ph.D., DVM (Radiation Oncology)

Joseph Geradts, MD (Pathology)
 Lee G. Wilke, MD (Surgery)
 William Barry, Ph.D. (Biostatistics)
 Scott Pruitt, M.D. (Surgery)

Gregory Palmer, Ph.D. (Radiation Oncology)
 Nan Jokerst (Electrical Engineering)
 Thomas Kuech (Chemical Engineering, UW Madison)
 Leon Maccaughan (Electrical Engineering, UW Madison)

David Kirsch, Ph.D., MD (Radiation Oncology)
 Rebecca Willett, Ph.D. (Electrical and Computer Eng.)
 Rebecca Richards-Kortum, Ph.D. (BME, Rice)

Students

Jenna Mueller
 Fangyao Hu
 Torre Bydlon
 Stephanie Kennedy
 Henry Fu
 Justin Lo
 Amy Frees
 Christopher Lam
 Matthew Caldwell
 Brandon Nichols

Research Staff

Marlee Junker, MS
 J. Quincy Brown, Ph.D.
 Narasimhan Rajaram, Ph.D.
 Karthik Vishwanath
 Bing Yu, Ph.D.
 Christine Mulvey, Ph.D.