

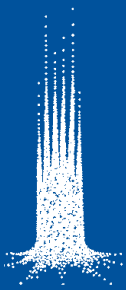
Eliminating systematic calibration errors in tissue spectroscopy with a Monte Carlo model and self-calibrating reflectance probe

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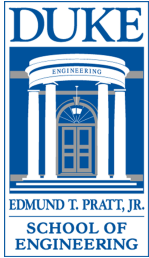
Duke University

SPIE Photonics West 2010 - BIOS
January 23, 2010

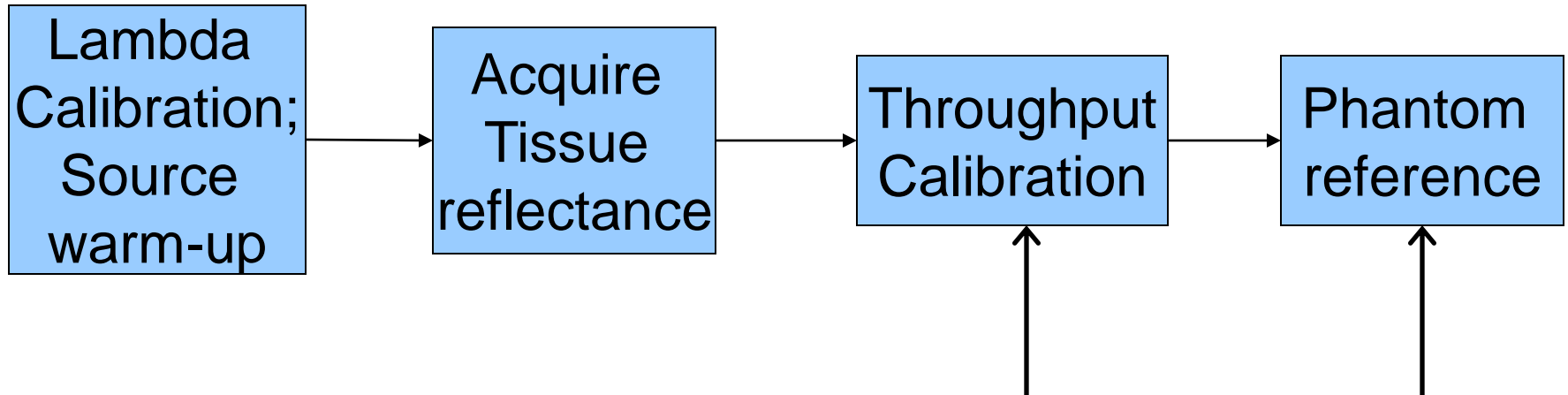


Disclosure: JQB, BY, and NR are affiliated with Endls Optics, Inc. a small business concern with an option to license portions of the technology presented today



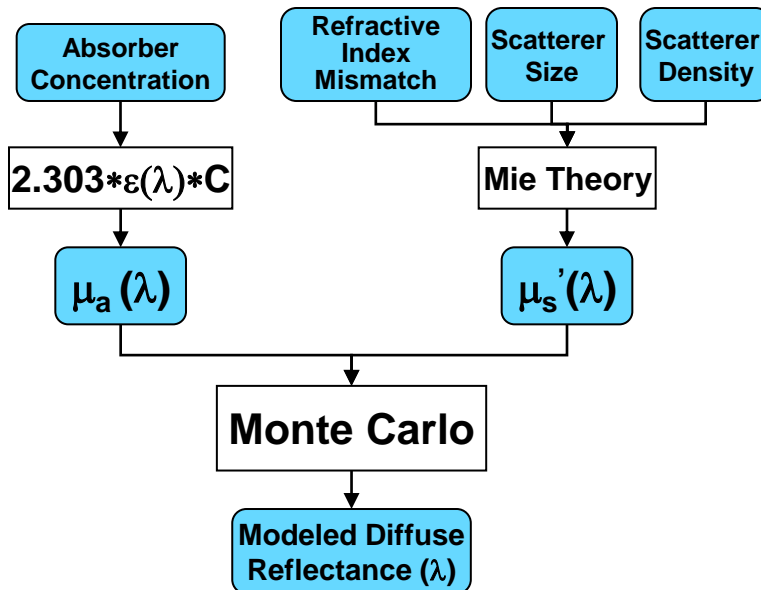


System calibration in the clinic – A Typical Example

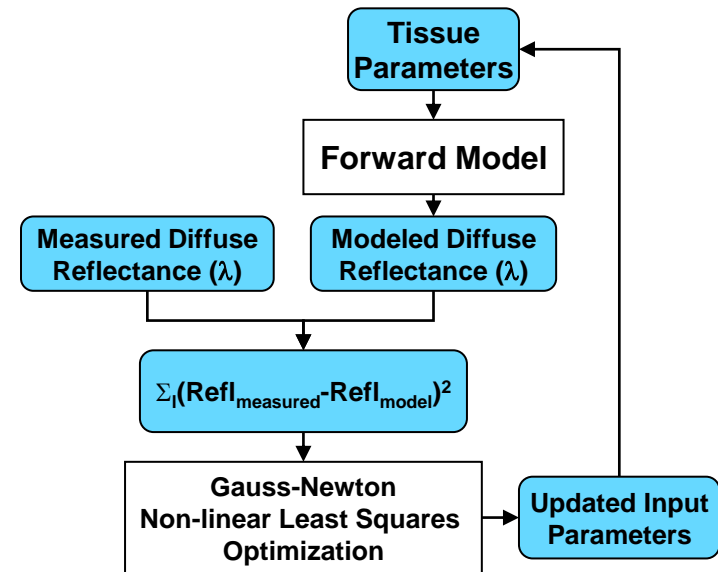


- Time gap between tissue measurement and calibration measurement
- Variability in calibration measurement
- Lack of phantom characterization tools at clinical site
- Same phantom “recipe” can produce different results in different hands

Physically-Based Spectral Analysis



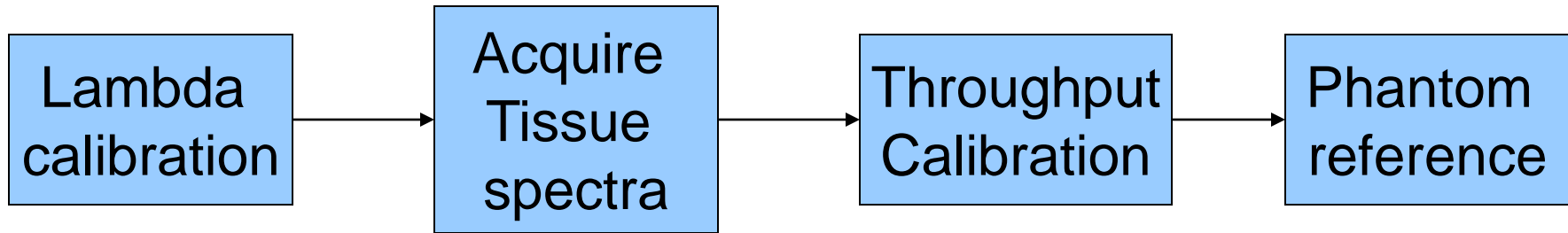
Forward model



Inverse model

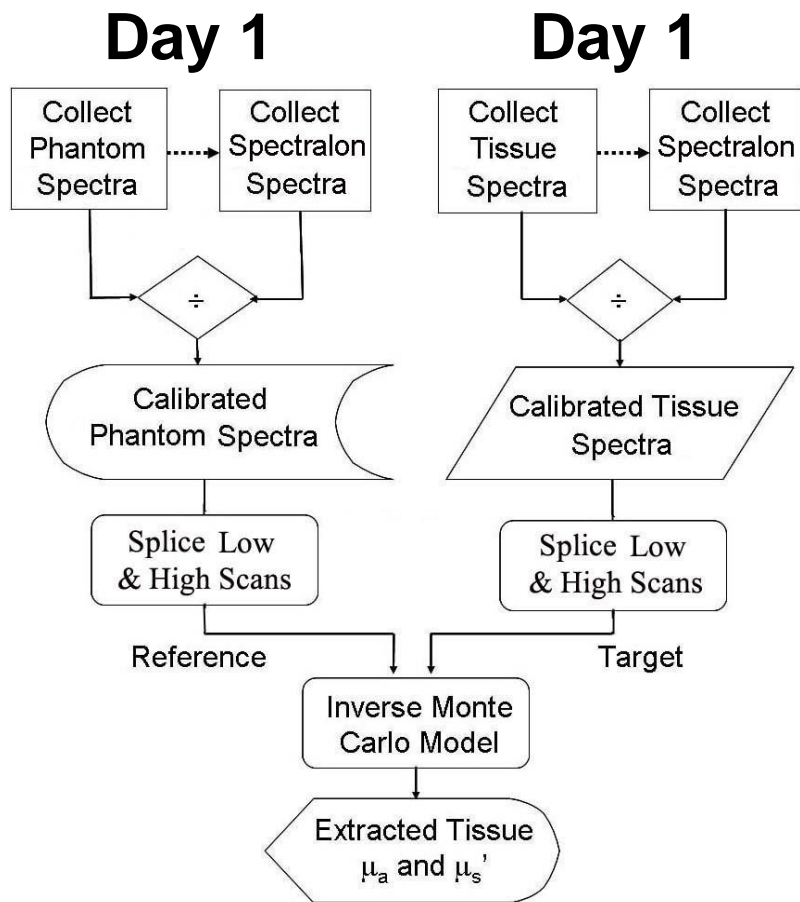
- Fast, scalable inverse MC model; outputs absorption and scattering properties of measured samples
- Extendable to any probe geometry; valid over wavelength ranges and sampling volumes used in our studies
- **Requires a single phantom reference measurement**

System calibration in the clinic – A Typical Example

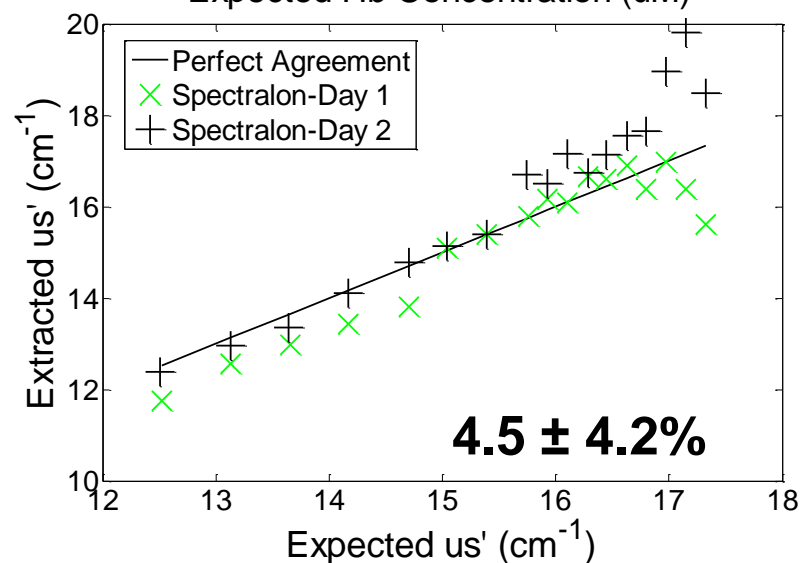
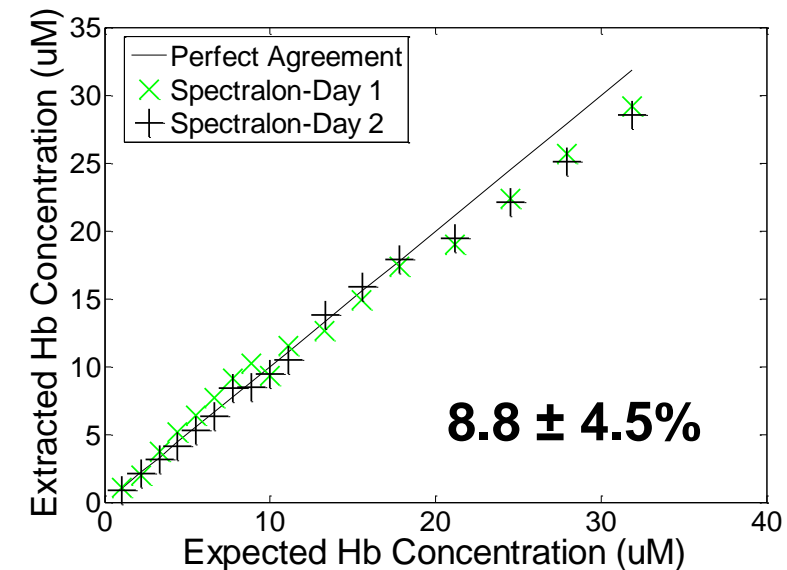


- Inverse MC model obviates need for phantom measurement at each spectroscopy session
- **Key:** Requires accurate instrument calibration to account for spectral power distribution, wavelength response, and probe throughput
 - use a spectrally-flat reflectance standard

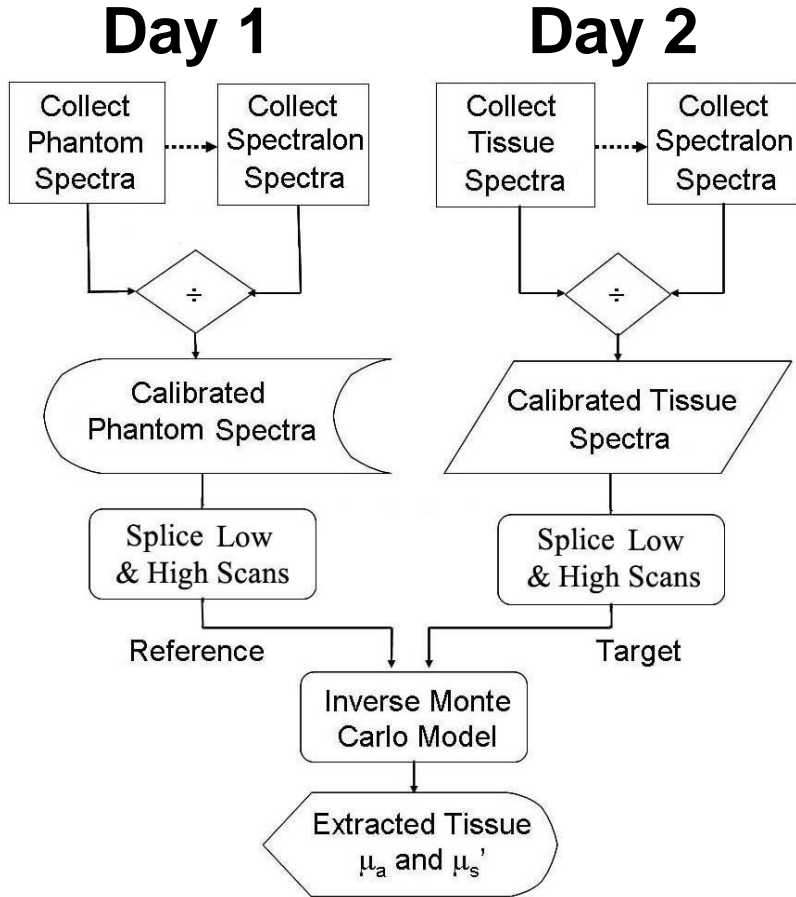
Phantom validation



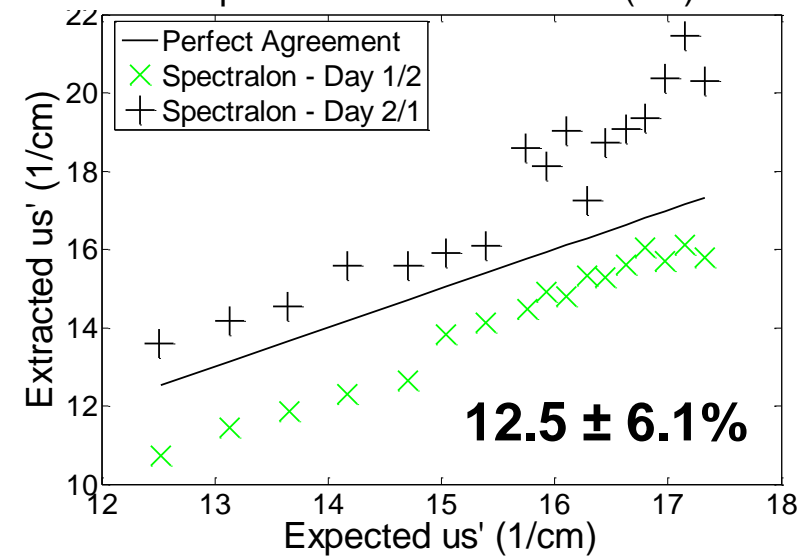
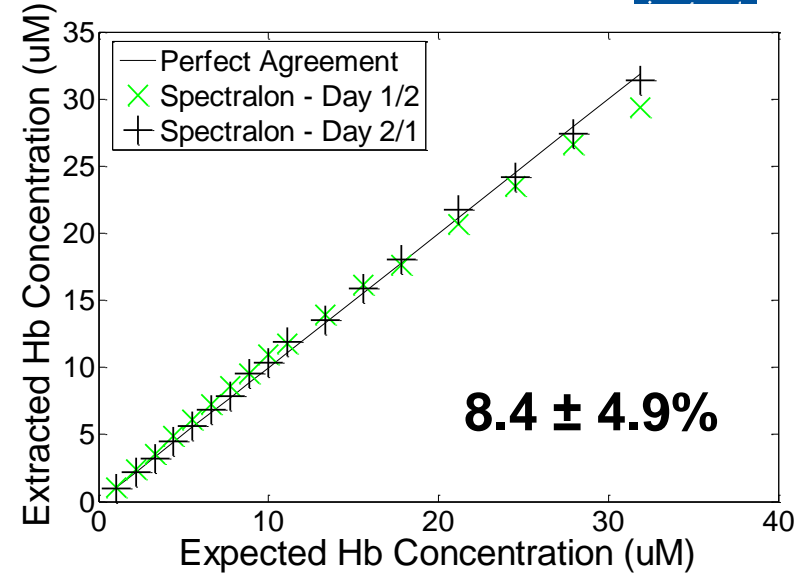
**Liquid phantoms – $1\mu\text{m}$ polystyrene spheres
and Human Hemoglobin**



Phantom validation – system calibration introduces error



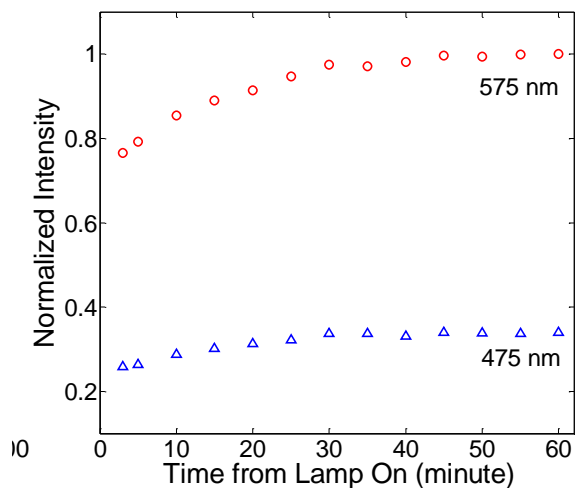
Liquid phantoms – $1\mu\text{m}$ polystyrene spheres and Human Hemoglobin



Sources of calibration error

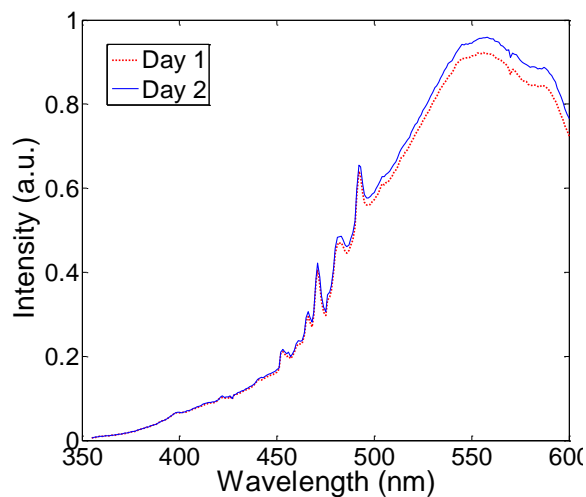


Light source fluctuations (e.g., lamp warm-up)



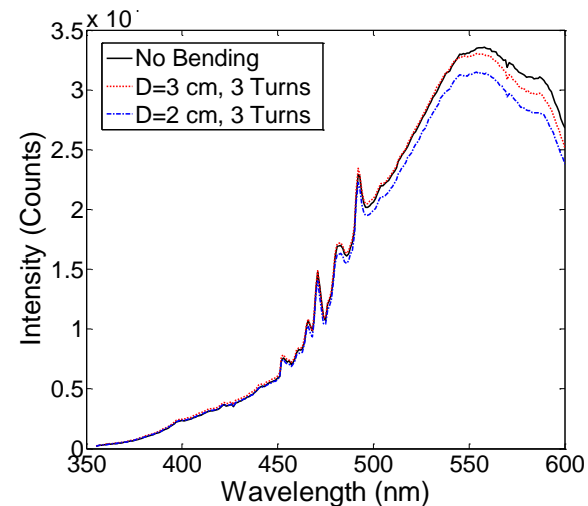
->20% variance

Day-to-day calibration errors



3-7% variance

Fiber bending errors



->11% variance

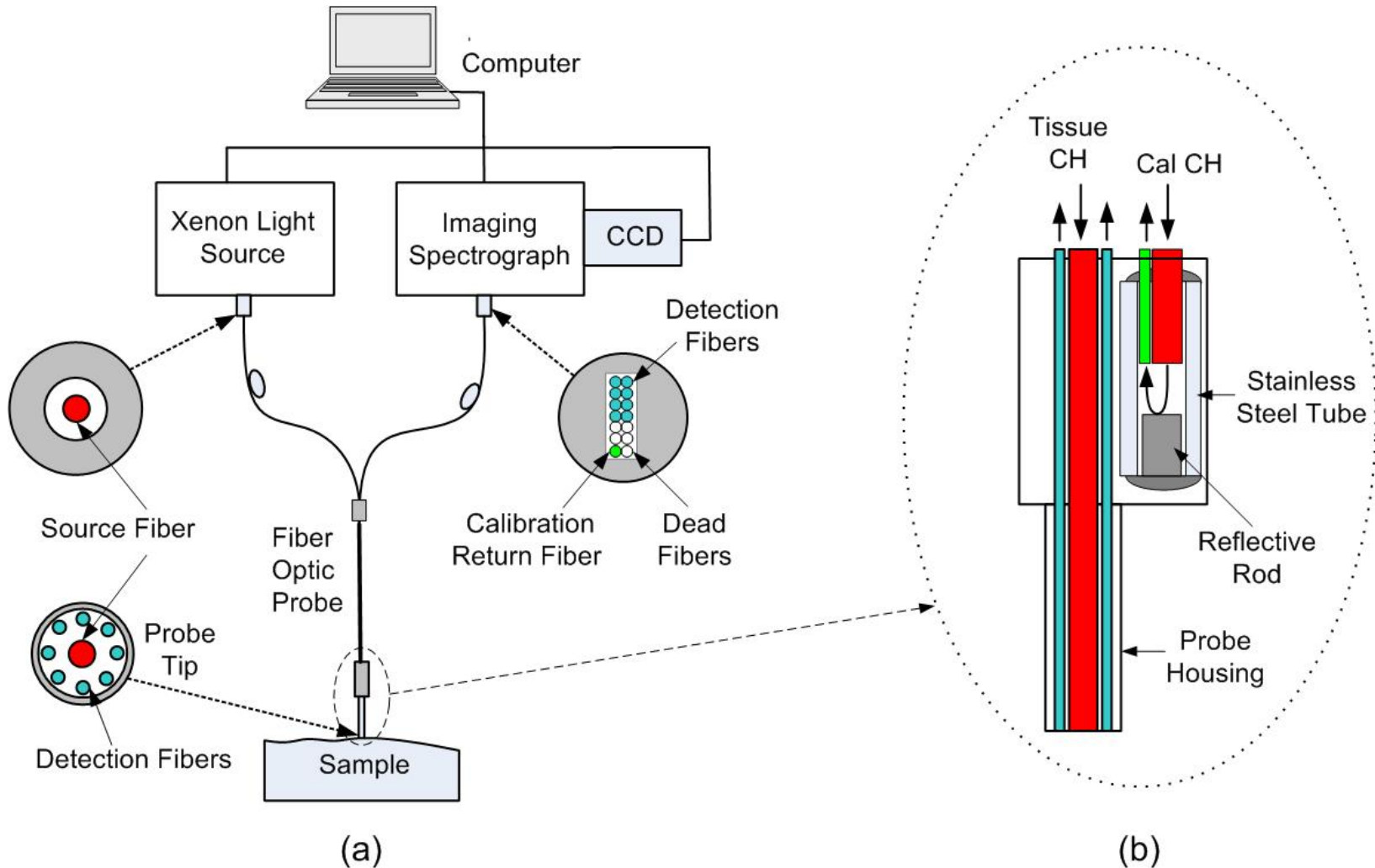


How can we eliminate these sources of error?

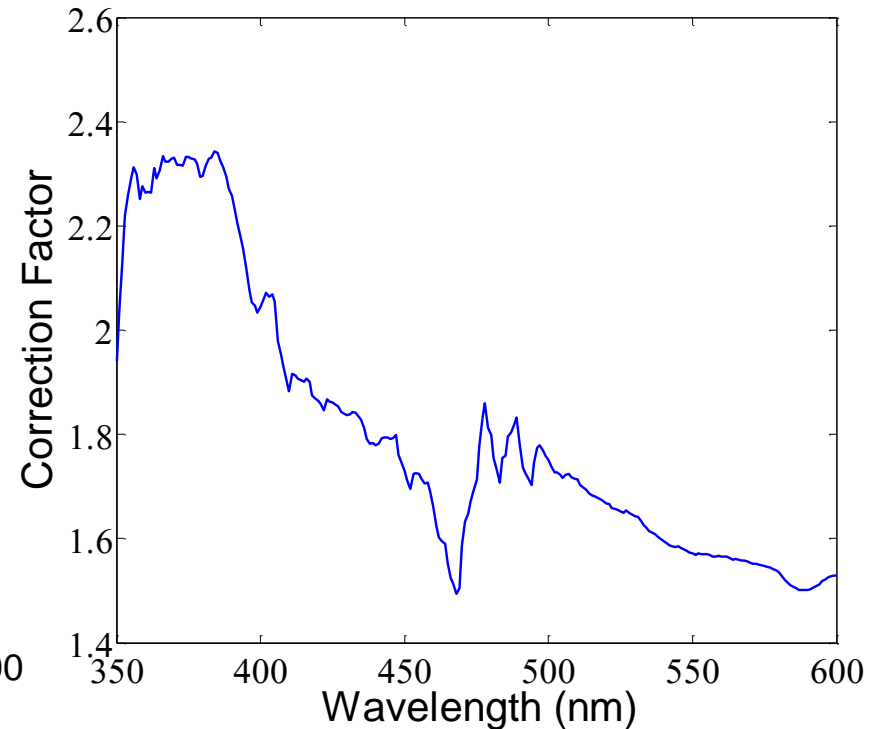
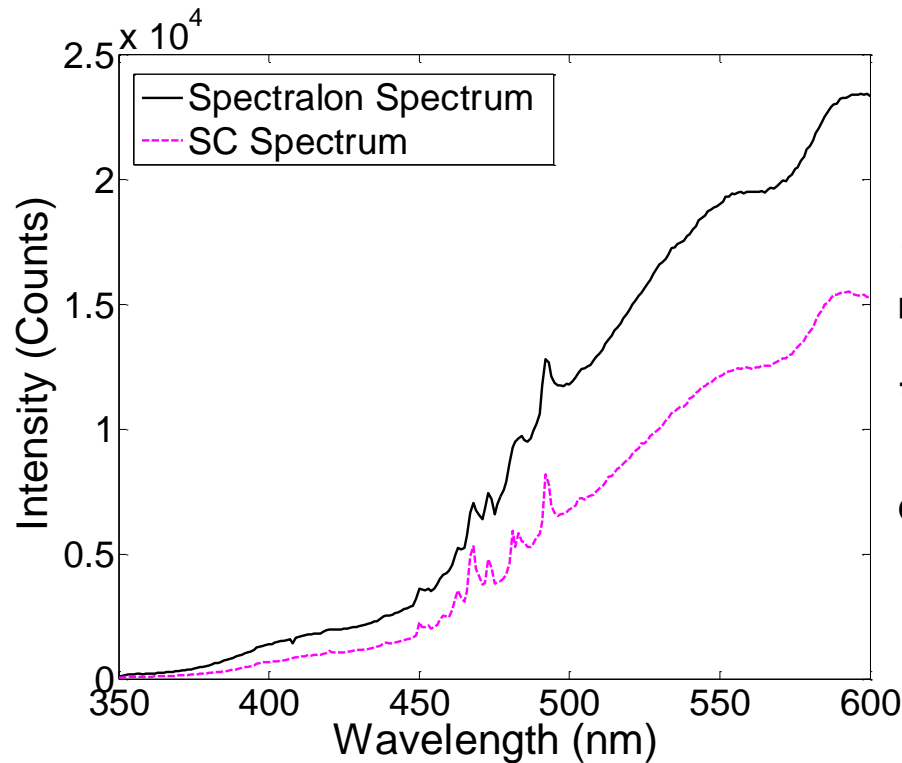


- Phantom reference variability
 - Use a single, well-characterized reference phantom measurement for relating diffuse reflectance to optical properties
- Calibration errors and temporal variations in source throughput
 - Take calibration standard measurement close in time to tissue measurement
 - Remove human component
- Fiber bending losses
 - Ensure that fibers are in same orientation for calibration standard and tissue measurement

Self-calibrating fiber optic probe

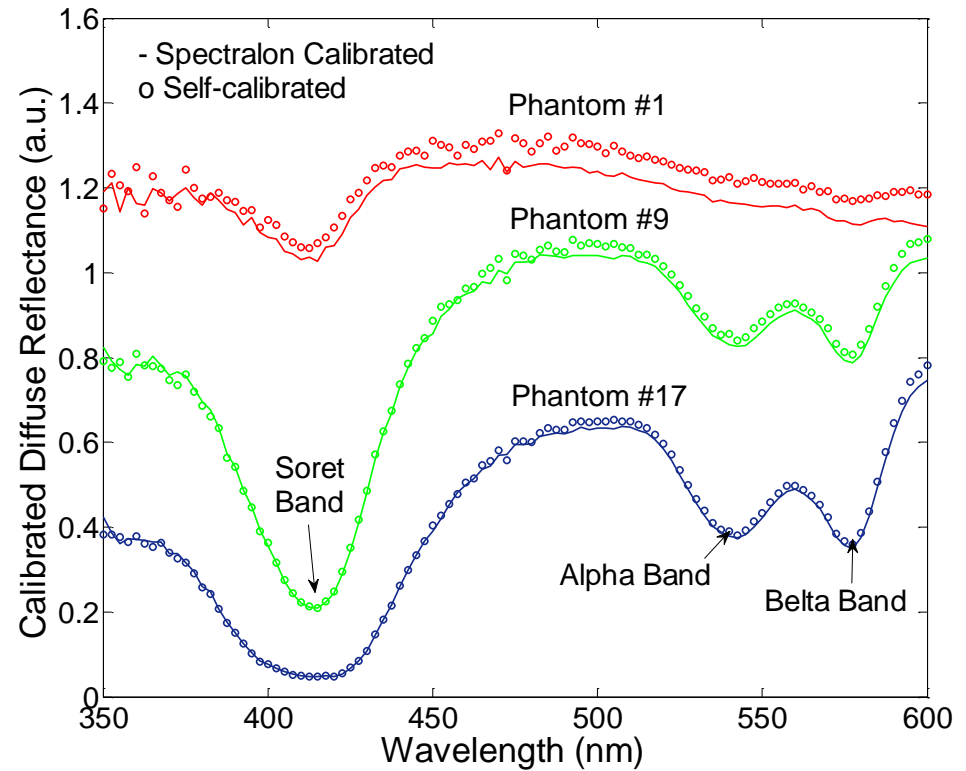
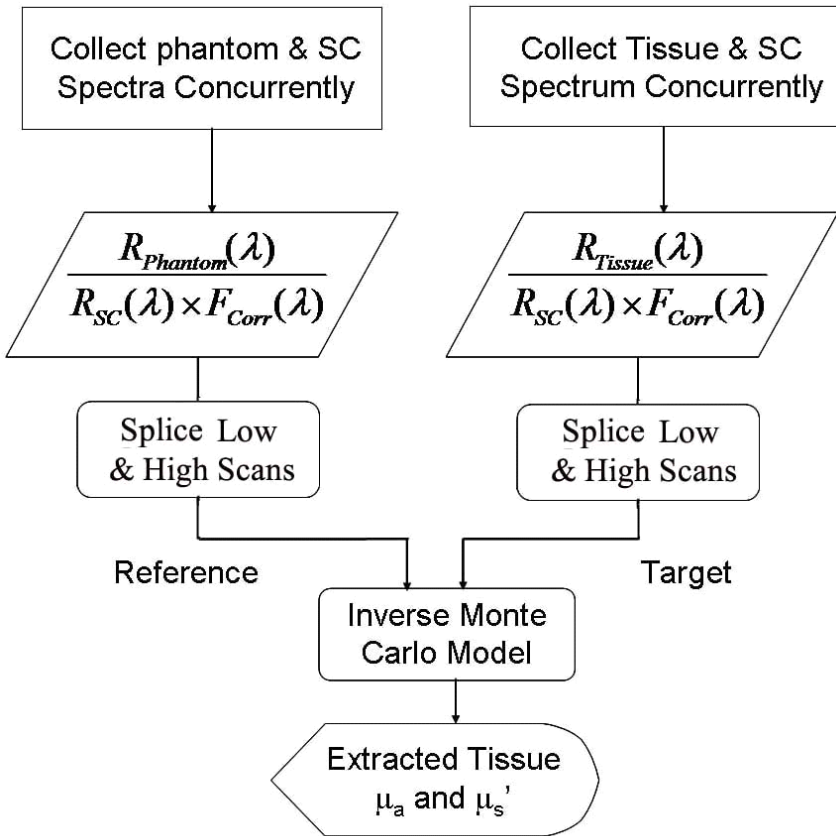


Calibrating for wavelength response



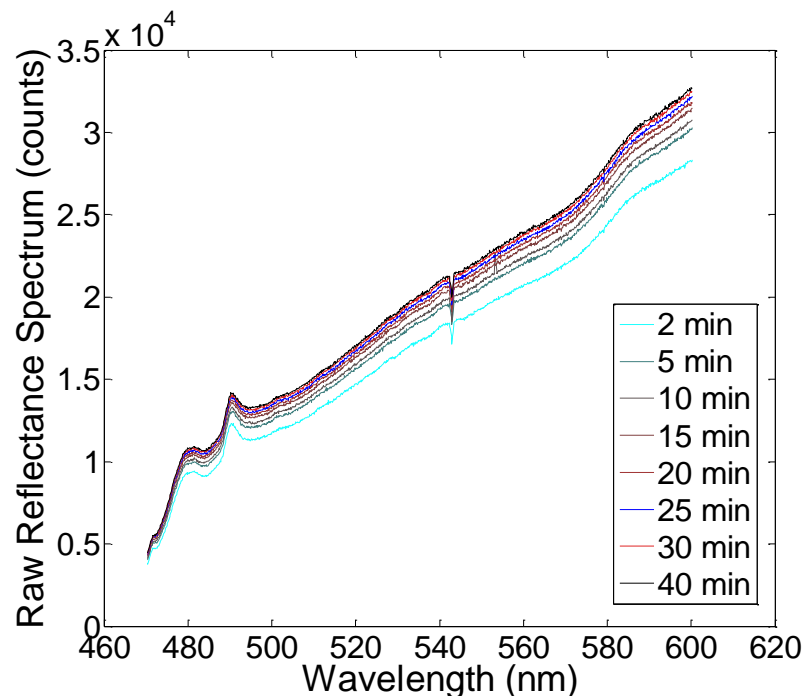
$$F_{corr}(\lambda) = R_{Spectralon}(\lambda) / R_{SC0}(\lambda)$$

Spectral calibration – SC vs. Spectralon

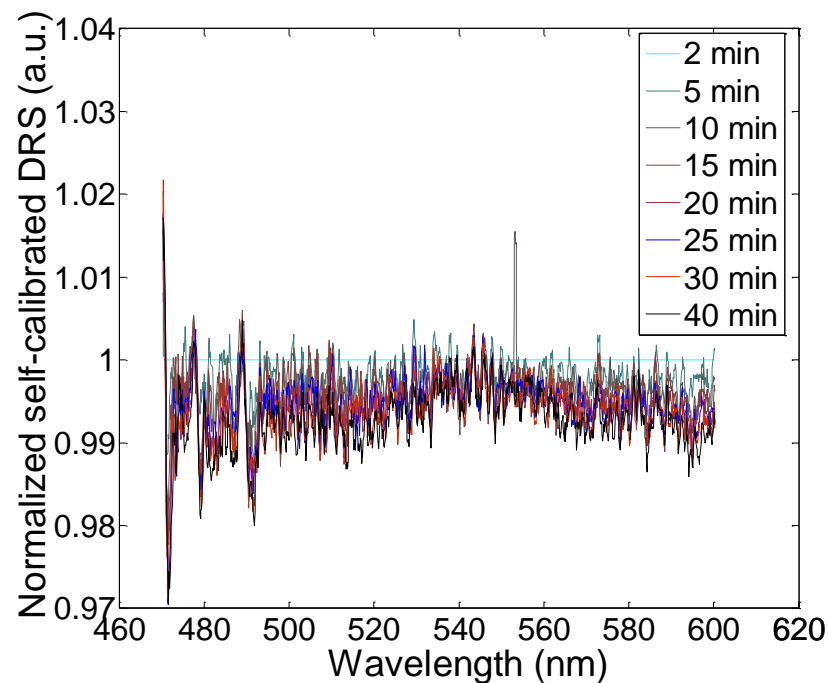


*Spectralon measurement after phantom #17, 45 minutes after phantom #1

Lamp warm-up



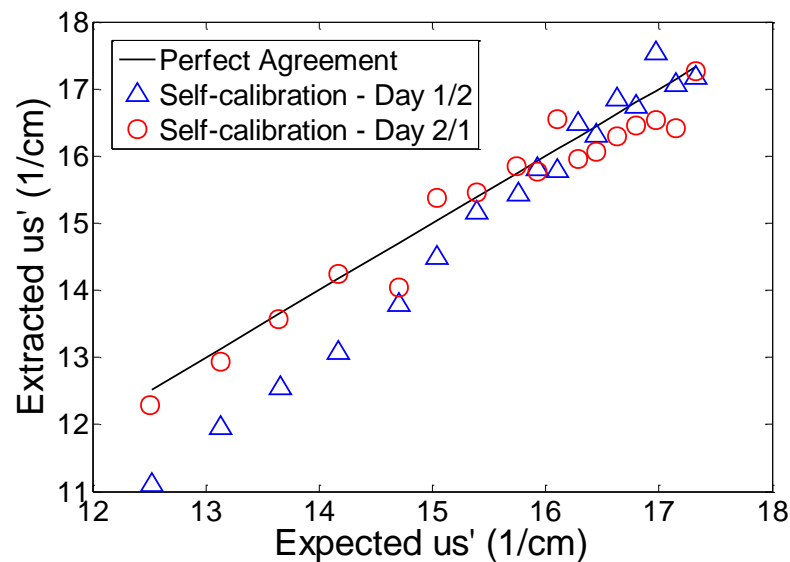
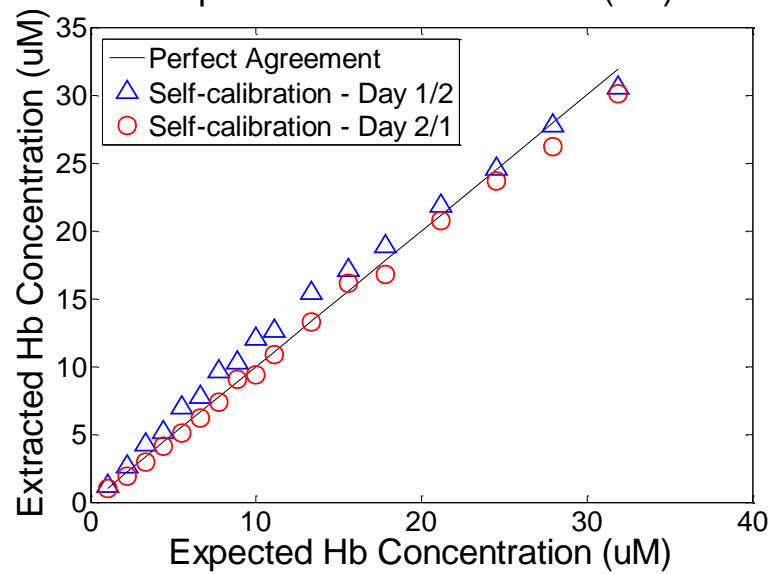
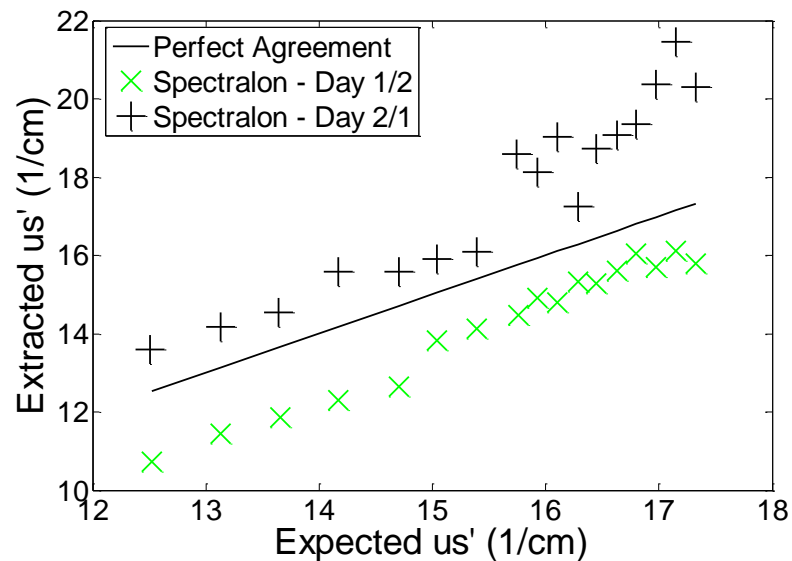
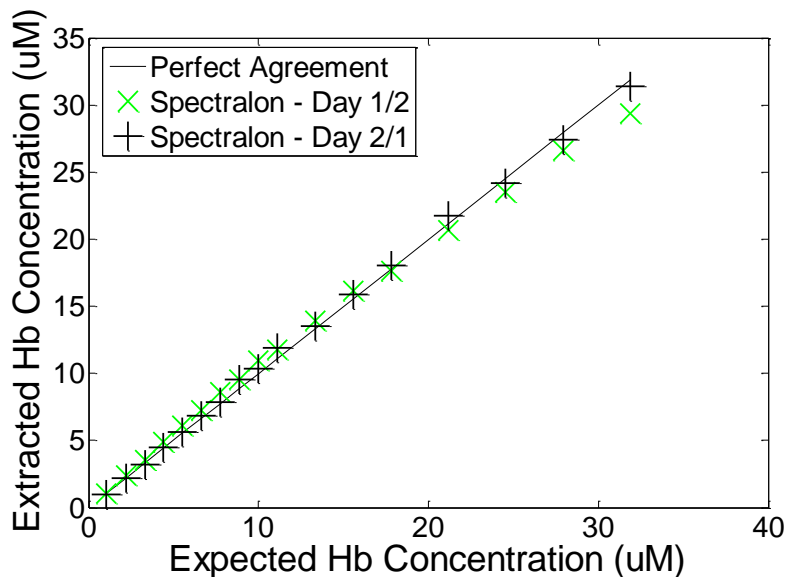
(a)

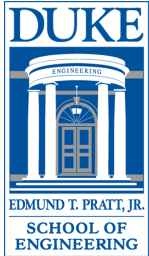


(b)

Error reduction: 20% to 1%

Day-to-day calibration errors

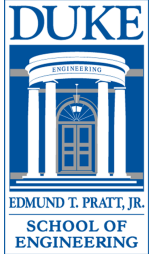




Accuracy comparison: SC vs. Spectralon



	Spectralon-Calibration				Self-Calibration			
Target / Reference	Day 1/1	Day 2/2	Day 1 /2	Day 2 /1	Day 1/1	Day 2/2	Day 1 /2	Day 2 /1
Error in [Hb]	6.9±8.1	8.8±4.5	8.4±4.9	4.5±1.5	8.5±8.6	7.6±8.1	7.0±4.4	8.6±3.9
Error in μ_s'	3.0±2.8	4.5±4.2	9.0±3.2	12.5±6.1	3.2±2.3	2.8 ±2.8	3.8±3.4	2.1±1.1

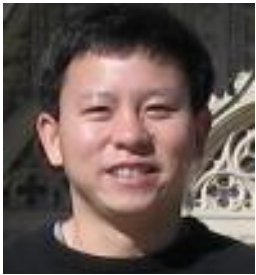


Summary and conclusions



- Mitigating calibration errors is critical for quantitative tissue spectroscopy
 - Comparison of results across instruments and clinical sites
- Inverse MC model obviates need for measuring a tissue phantom at each spectroscopy session
 - Reference phantom measured and characterized in a controlled environment
- Works best when throughput calibration is accurate
 - Self-calibration probe improves accuracy of calibration over current methods
 - Saves time in the clinic

Acknowledgements



Bing Yu



Henry Fu

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DOD Era of Hope Scholar Award

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