# *A Self-Calibrating Fiber-Optic Probe for Tissue Optical Spectroscopy*

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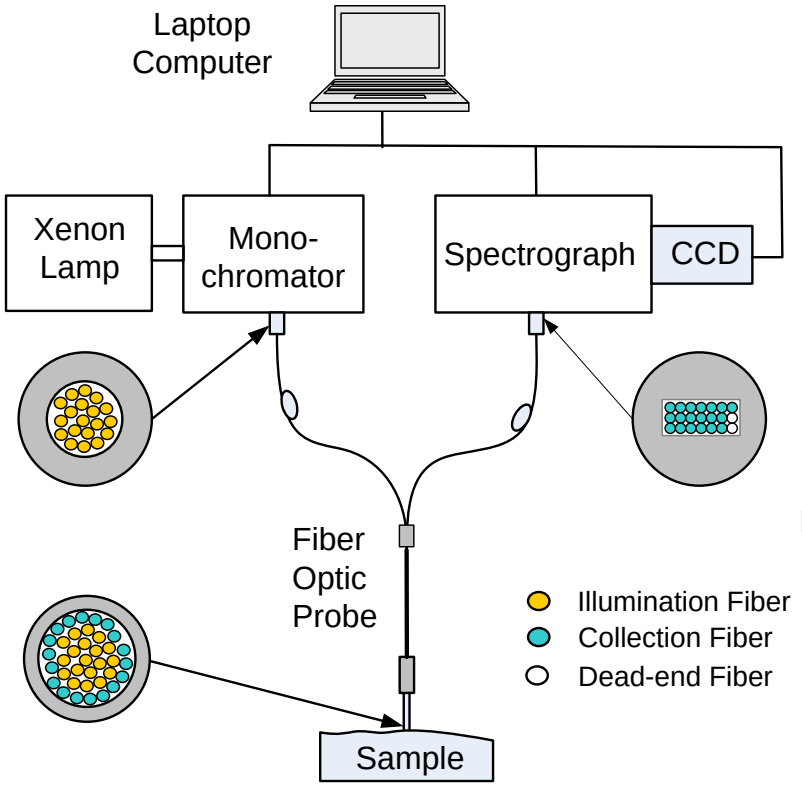
# Tissue Optical Spectroscopy

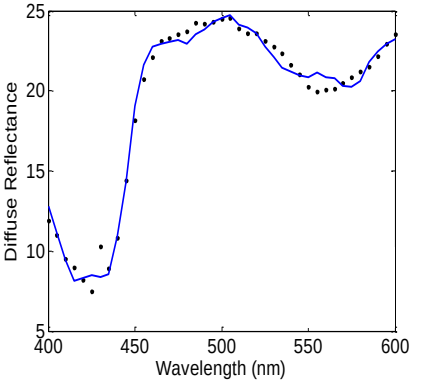
**Optical spectroscopy is sensitive to the absorption, scattering and/or fluorescence properties of biological molecules in tissue.**



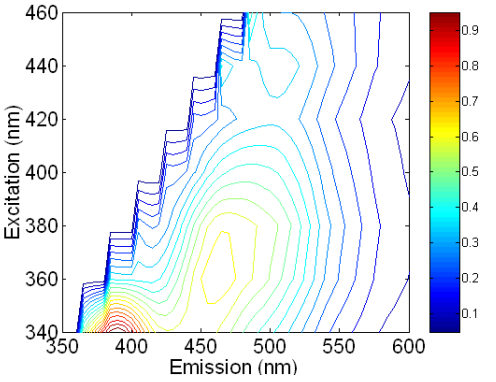

**Tissue Optical and Physiological Properties**

**Scalable Monte Carlo Model**

Diffuse Reflectance



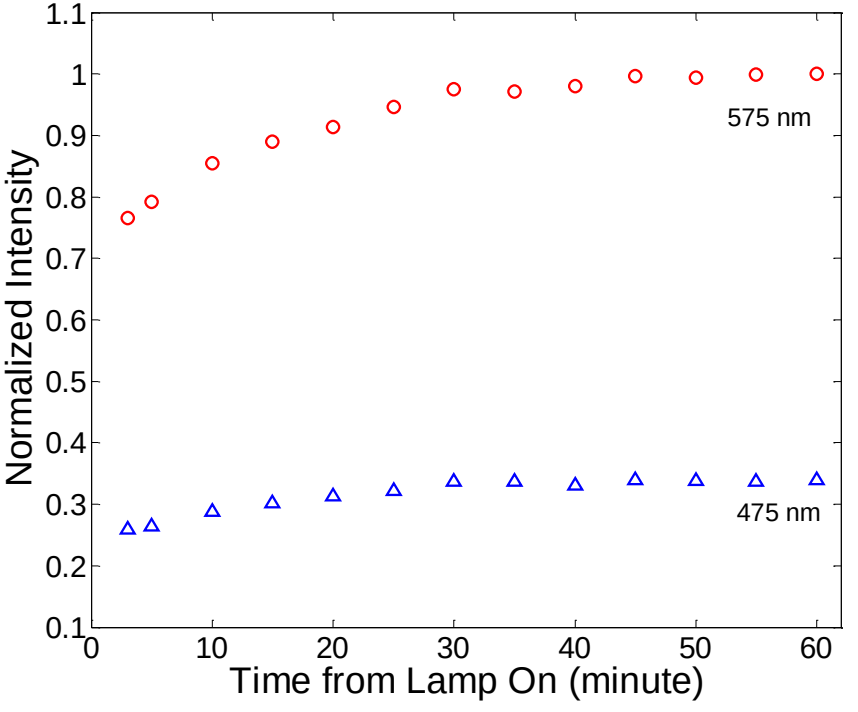

Fluorescence EEM

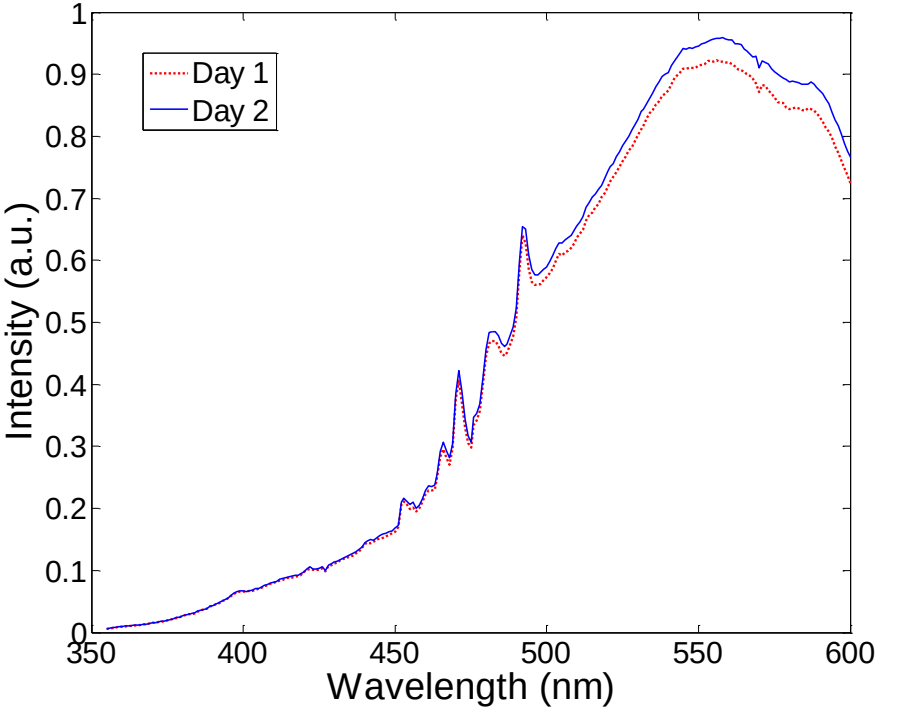



[1]Zhu C, et al., JBO 10(2): 24-32, 2005.

[2]Palmer GM, et al., Appl Opt, 45(5): 1062-1071, 2006.

# Sources of Intensity Fluctuations



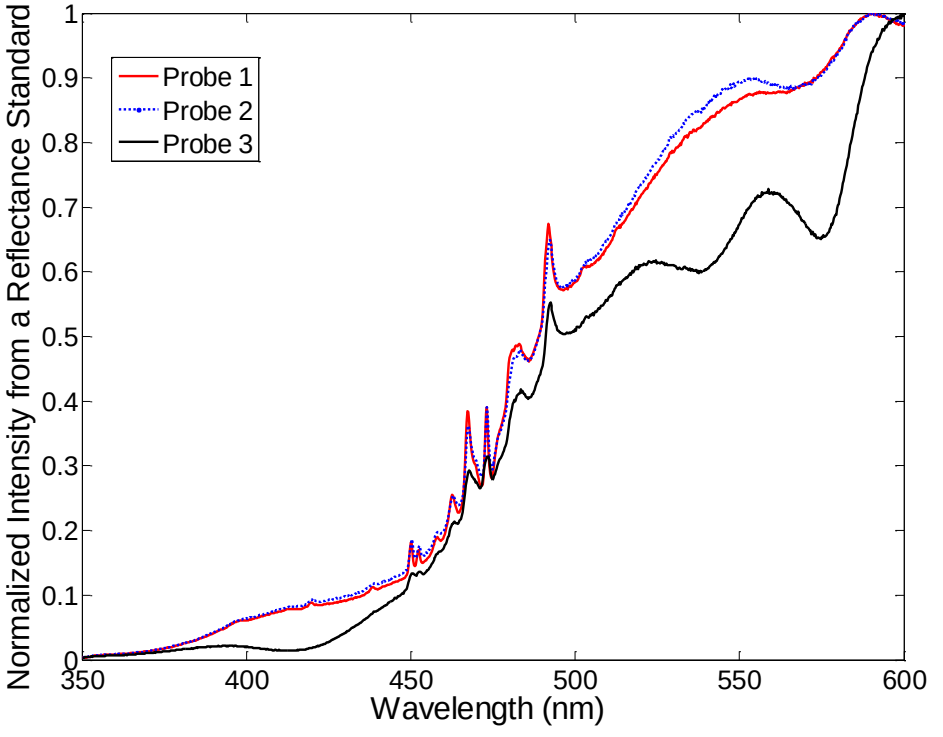



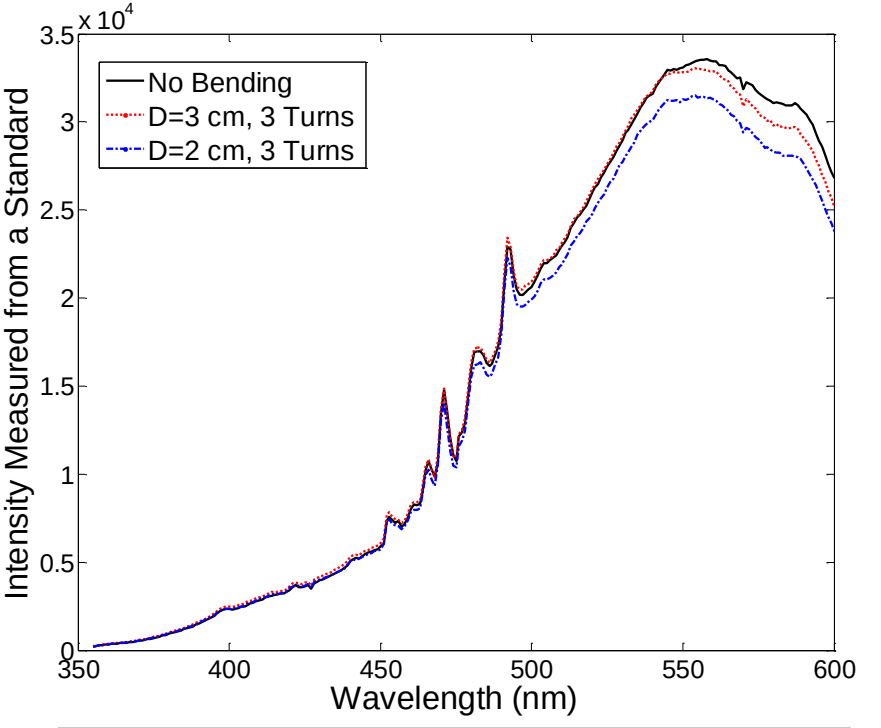

- **Lamp intensity fluctuates 25% from 3-60 minutes and 3% after 30 minutes for 575 nm.**
- **The ratio $I_{575}/I_{475}$ changes 4.4% after 30 minutes.**

- **The lamp intensity varies as much as 6.8% from day to day**

**5% change in intensity → ~20% error in $\mu_a$ & $\mu_s$'**

# Sources of Spectrum Variations




- **Instrument: wavelength-dependence**
- **Devices: degradation over time**

**5% change in intensity → ~20% error in $\mu_a$ & $\mu_s$'**

- **Fiber bending loss during measurements**
- **> 6% at a diameter of 3cm**
- **> 11% at a diameter of 2cm**

# Traditional Calibration Methods & Limitations

| | Tissue Type | Calibration Method | Corrected for | | | | Warm-up NOT Required | Cal. Meas. NOT Required in Clinic |
|---|---|---|---|---|---|---|---|---|
| | | | Through-put | Day-to-Day | Real-time | | | |
| | | | | | Lamp Drift | Fiber Bend | | |
| Feld M.S.[1] | Colon polyps | Liquid phantom | Y | ? | N | N | N | N |
| Richards-Kortum R.[2;3] | Ovarian, Cervix | Liquid phantom | Y | ? | N | N | N | N |
| Thueler P.[4] | Stomach | Solid phantom | Y | Y | N | N | N | N |
| Foster T.[5] | Phantoms | Ref. fiber & liquid phantom | Y | Y | N | N | N | N |
| Our Group (Old)[6] | Breast, Cervix | Diffuse refl. Standard & Phantom | Y | Y | N | N | N | N |

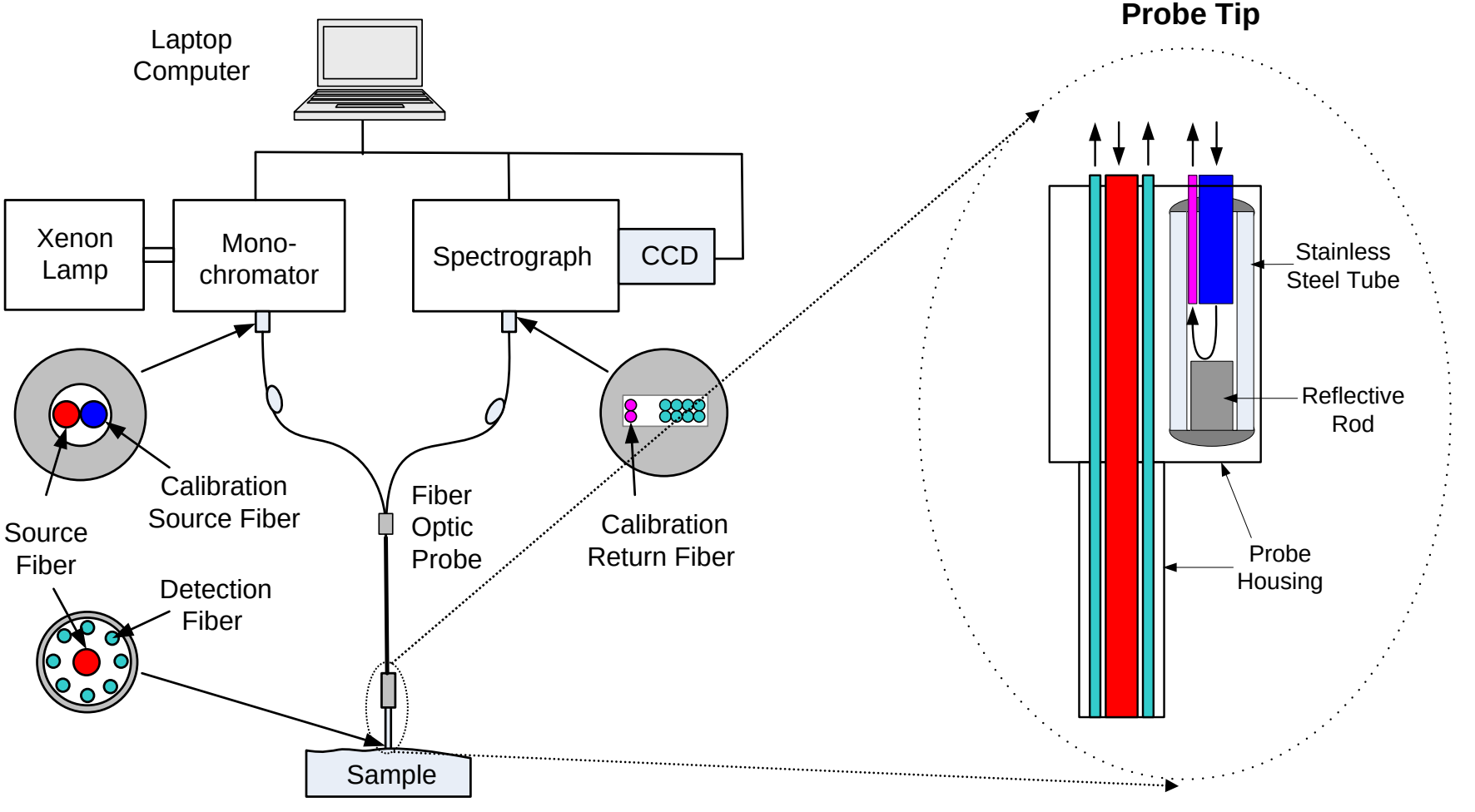
**A real-time, faster, more robust and accurate calibration approach is needed!**

**Accuracy** **Efficiency**

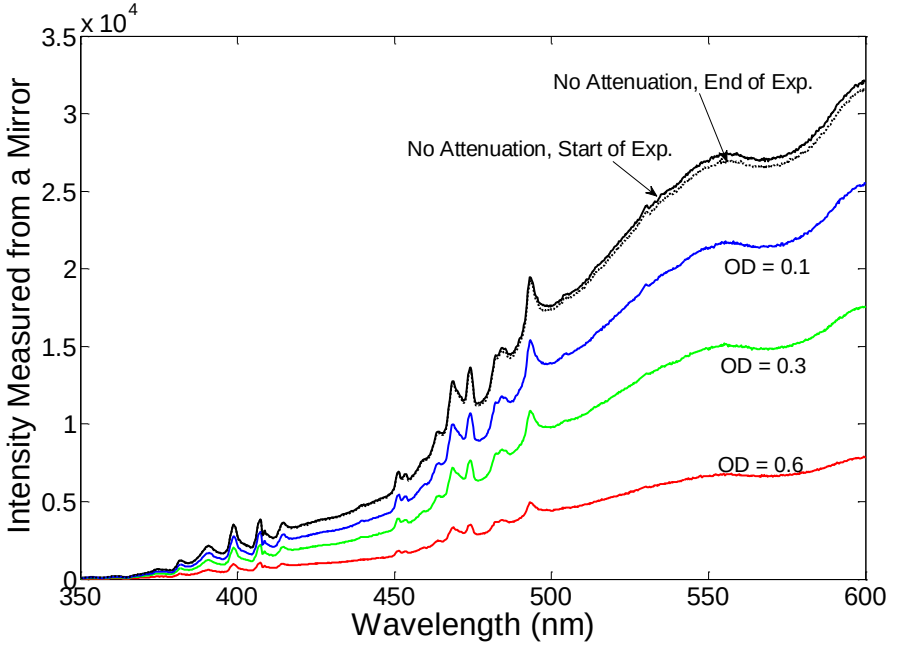

[1] Zonios G, et al., Appl. Opt. 38(31): 6628-37, 1999.
[2] Utzinger U, et al., Lasers Surg Med 28(1): 56-66, 2001.
[3] Mirabal YN, et al., JBO 7(4): 587-94, 2002.
[4] Thueler P, et al., JBO 8(3): 495-503, 2003.
[5] Nichols MG, et al., Appl. Opt. 36(1), 1997.
[6] Zhu C, et al., JBO 10(2): 24-32, 2005.

# Experimental Setup

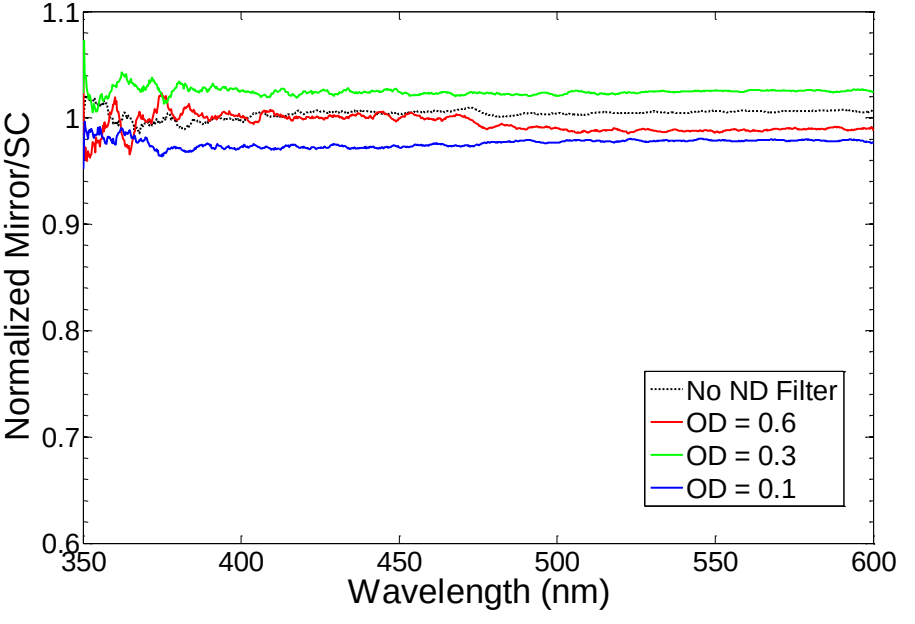
## Schematic of the System



# Correction for Intensity Variations



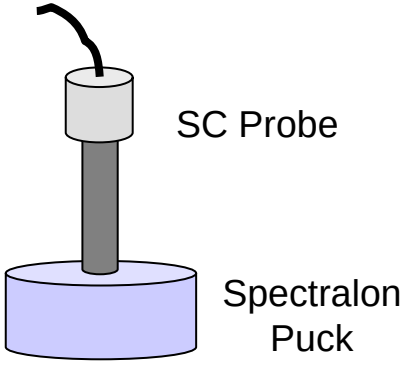

Raw spectra from a mirror at different levels of attenuation by an ND filter and no attenuation.




Ratio between mirror and self-calibration spectra normalized to the first scan (no filter).

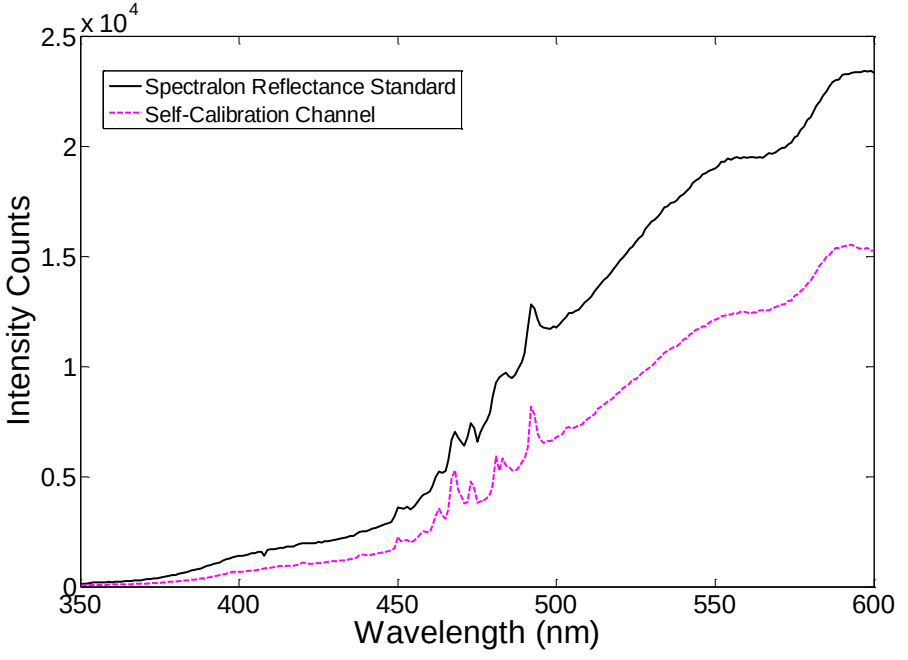
**The variation in the illumination intensity due to the ND filters is minimized to less than ±3%.**

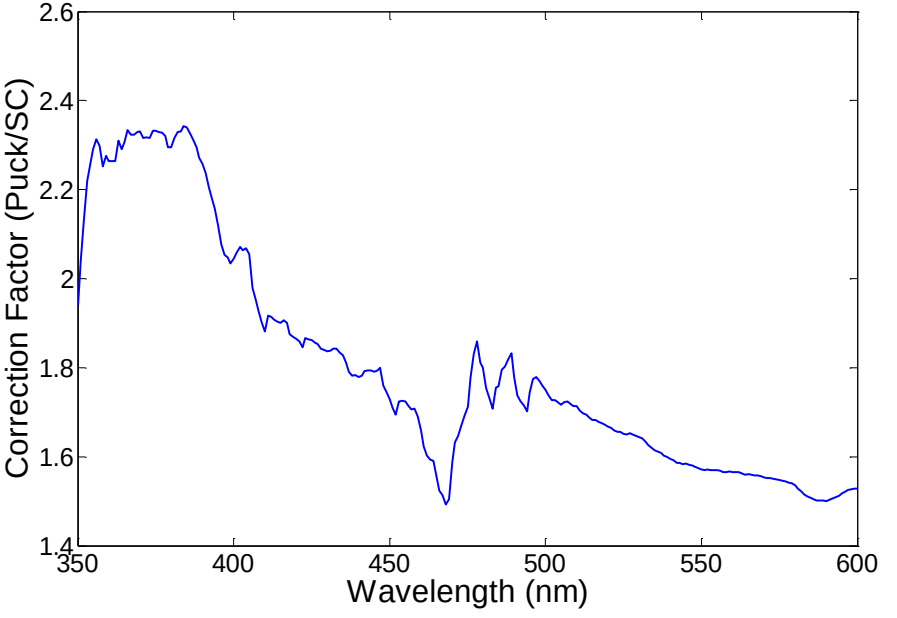
# Correction for Wavelength-Dependence




**Correction of the SC channel for wavelength response:**

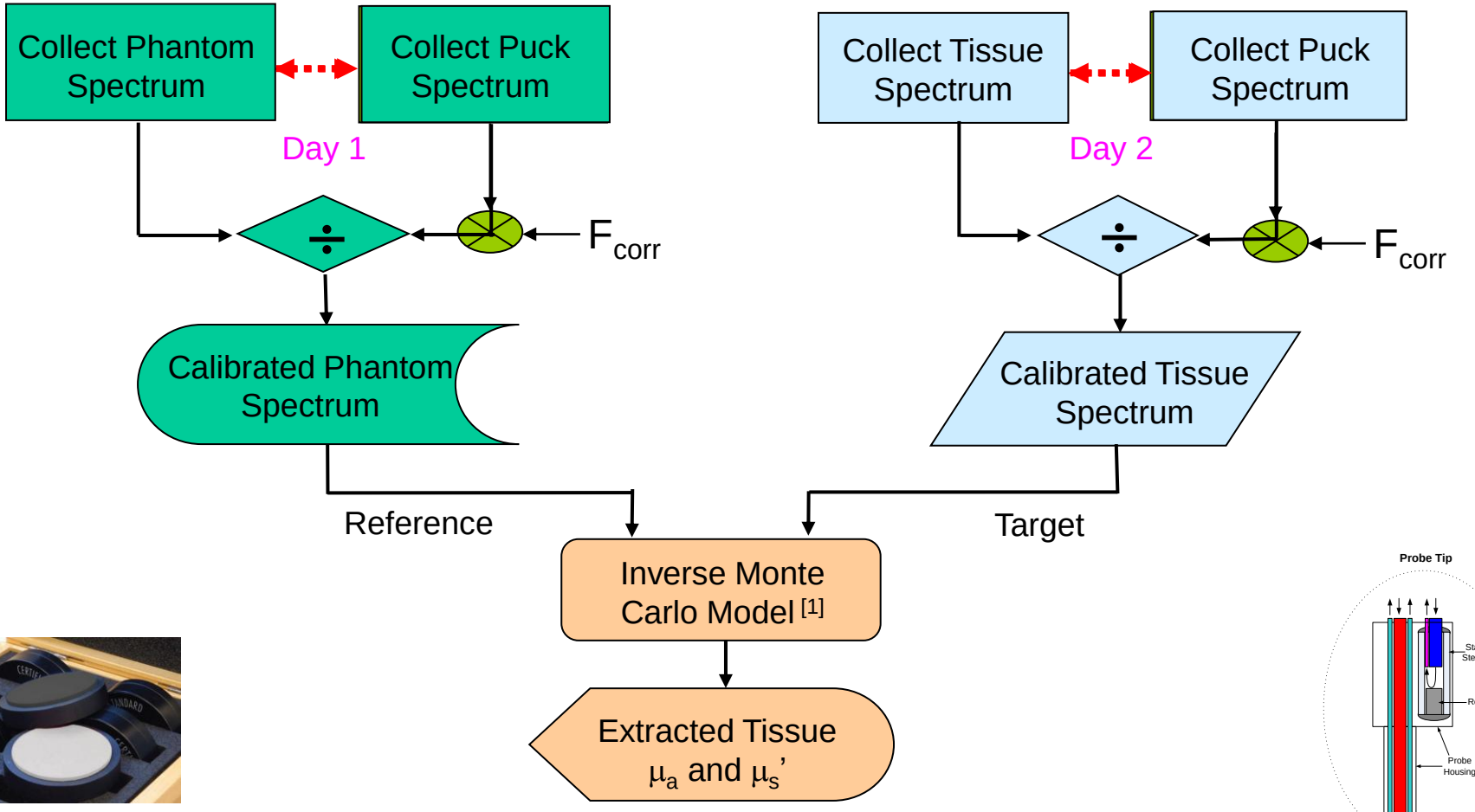
$$F_{corr}(\lambda) = \frac{R_{Puck}(\lambda)}{R_{SC}(\lambda)}$$



# Data Analysis Procedures

## Calibration with Spectralon Reflectance Standard (Puck)



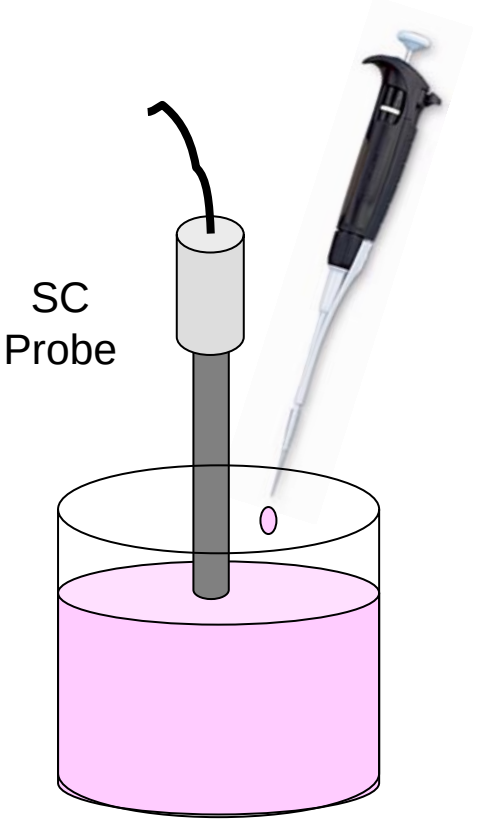






[1]Palmer GM, et al., Appl. Opt., 45(5): 1062-1071, 2006.

# Phantom Experiments



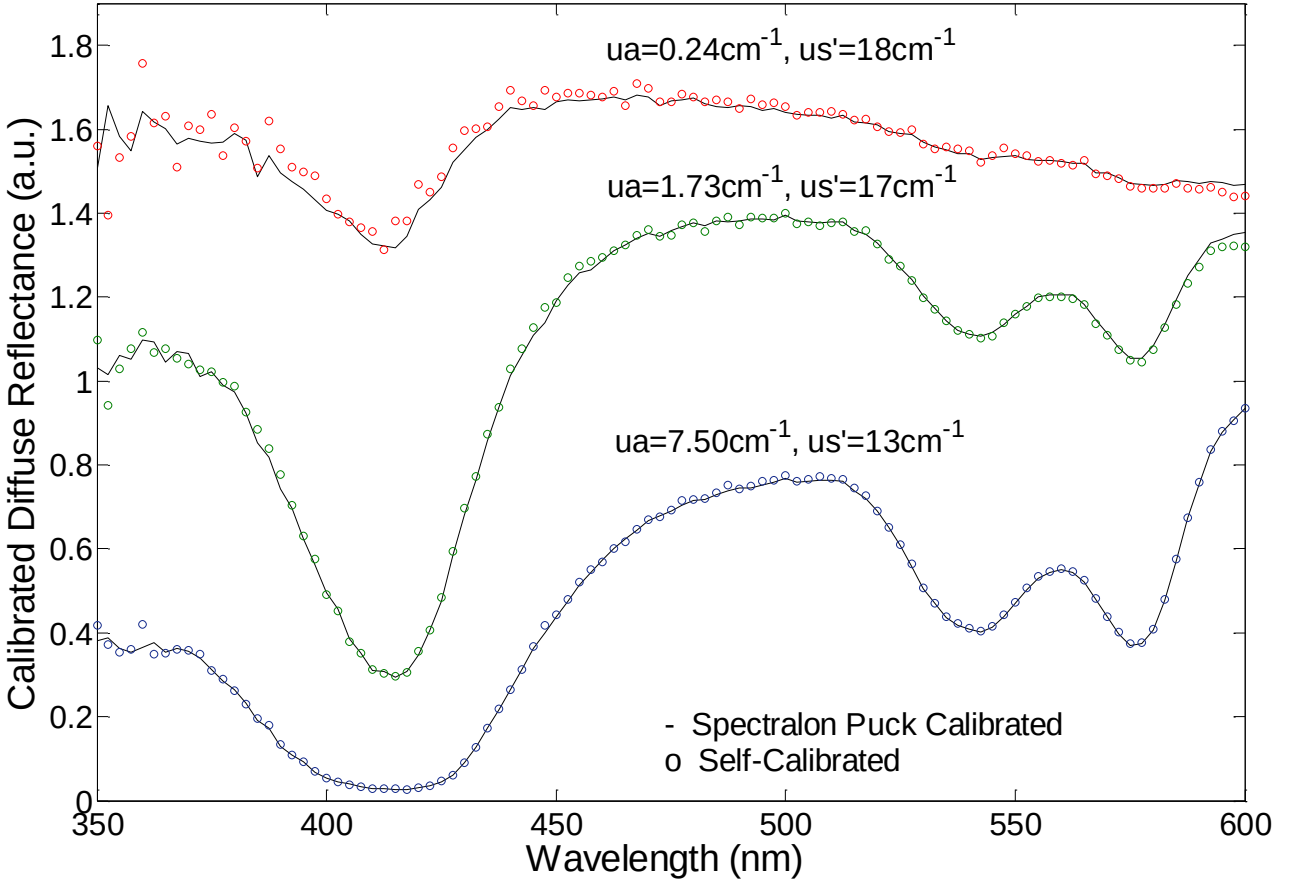

Liquid Phantom

**Tissue-mimicking phantoms:**

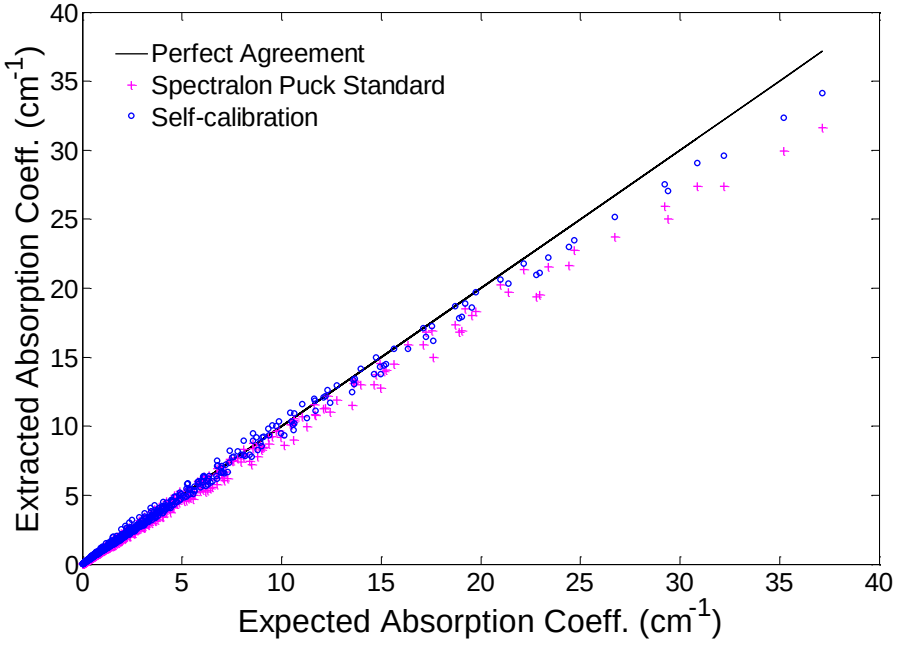
- **Absorber: hemoglobin**
- **Scatterer: 1 μm polystyrene microspheres**
- **[Hb]: 1 – 32 μM**
- **$\mu_a$ = 0.006 – 37 $cm^{-1}$**
- **$\mu_s$' = 11.2 – 22.3 $cm^{-1}$**
- **Reference phantom: [Hb]=8.42 μM, $\mu_s$'=16.8 $cm^{-1}$**

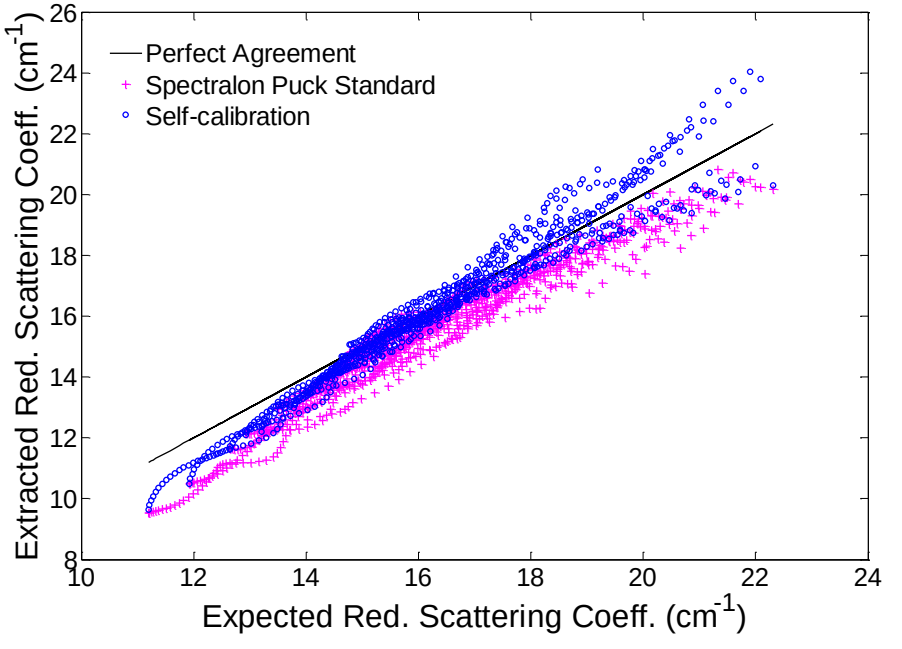
# Calibrated Phantom Spectra

$$R_{puck\_calibrated} = \frac{R_{tissue}}{R_{puck}} \quad v.s. \quad R_{sc\_calibrated} = \frac{R_{tissue}}{R_{sc} \cdot F_{corr}(\lambda)}$$



# Extracted vs Expected Phantom Optical Properties




| | Spectralon Standard | Self-Calibration |
|---|---|---|
| **Error in $\mu_a$** | 6.9±7.2% | 6.8±5.1% |
| **Error in $\mu_s$'** | 3.5±1.5% | 5.6±2.9% |

# Conclusions

| | Tissue Type | Calibration Method | Corrected for | | | | Warm-up NOT Required | Cal. Meas. NOT Required in Clinic |
|---|---|---|---|---|---|---|---|---|
| | | | Through-put | Day-to-Day | Real-time | | | |
| | | | | | Lamp Drift | Fiber Bend | | |
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| Our Group (Old)[6] | Breast, Cervix | Diffuse refl. Standard & Phantom | Y | Y | N | N | N | N |
| **Our Group (New)** | **Phantoms** | **Self-cal. & Phantom** | **Y** | **Y** | **Y** | **Y** | **Y** | **Y** |

**Accuracy** **Efficiency**

**Combined with a one time, single-reference phantom measurement, the self-calibrating probe can provide instrument-independent optical properties.**

# Acknowledgements


**Tissue Optical Spectroscopy Lab**

**Dept. of Biomedical Eng.**

**Duke University**

**Funding**

- **National Institute of Health RO1-CA-100559-05**
- **Department of Defense Era of Hope Scholar Award**