NIST Standards Development for Optical Medical Imaging

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NIST
National Institute of Standards and Technology
U.S. Department of Commerce

NIST's Role in Phantoms

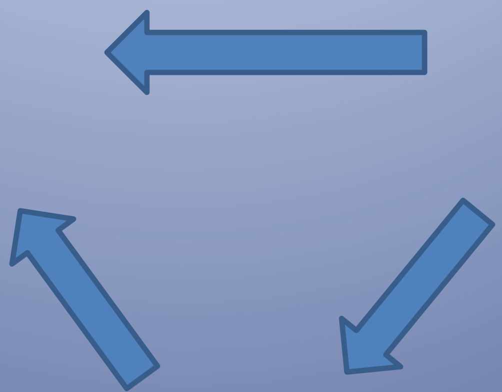
- *Facilitate development of phantoms and implementation of standards*

Optical Medical Imaging

- Ground-breaking
- Revolutionary
- Cutting edge
- Innovative

Standards

- Mundane
- Unremarkable
- Routine
- Expected



Phantoms

- Development
- Verification
- Validation

- *Net result; reliable, repeatable, and reproducible measurements*

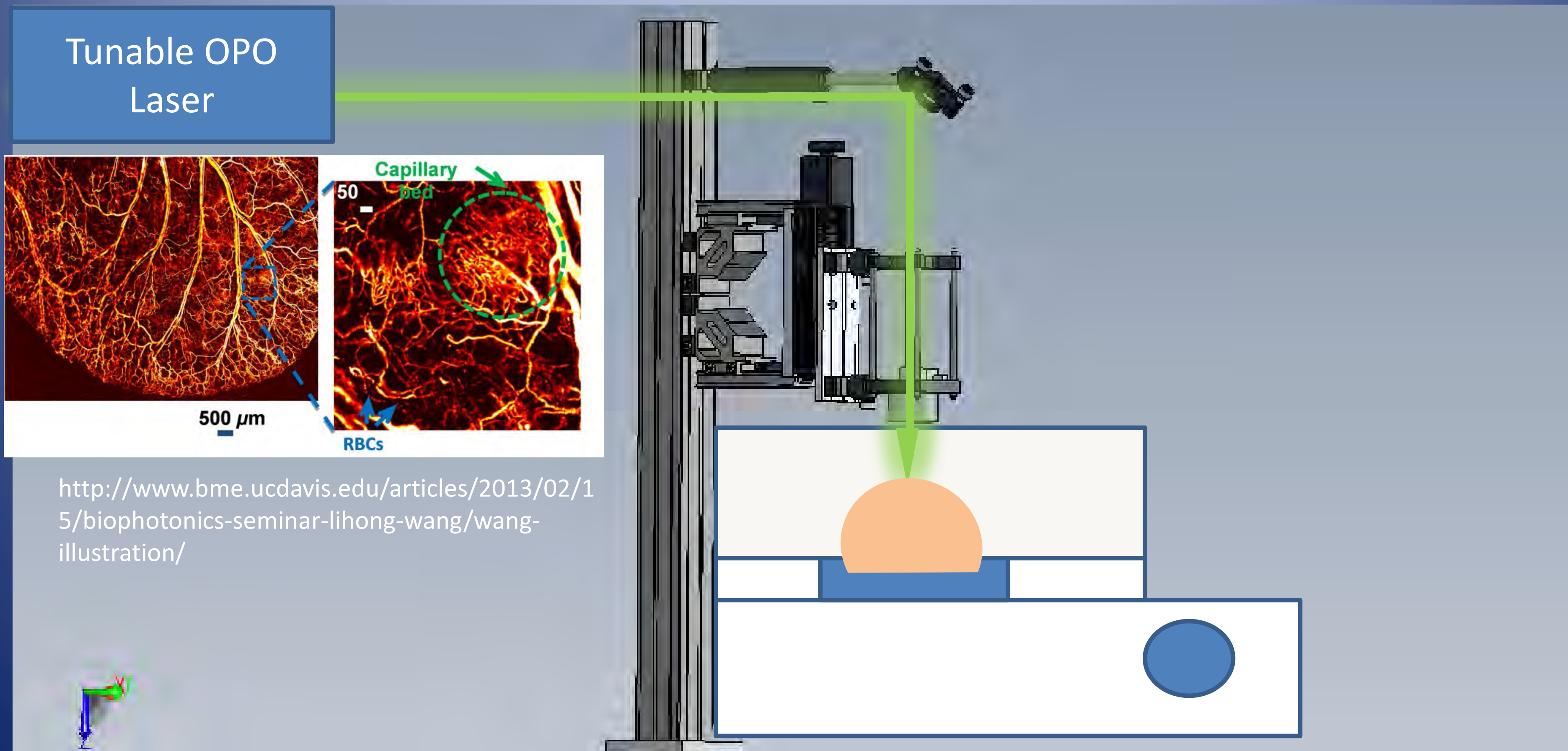
Standards

- **Traceability - NIST Policy and Supplementary Materials**

- NIST is responsible for developing, maintaining and disseminating national standards - realizations of the SI - for the basic measurement quantities, and for many derived measurement quantities. NIST is also responsible for assessing the measurement uncertainties associated with the values assigned to these measurement standards. As such, the concept of measurement traceability is central to NIST's mission. NIST's customers frequently ask questions about traceability and about NIST's role in traceability. It is not always obvious what NIST's role is in helping other organizations establish traceability of their measurement results to standards developed and maintained by NIST.
- The NIST Policy on Traceability is contained in the NIST Administrative Manual, Subchapter 5.16.

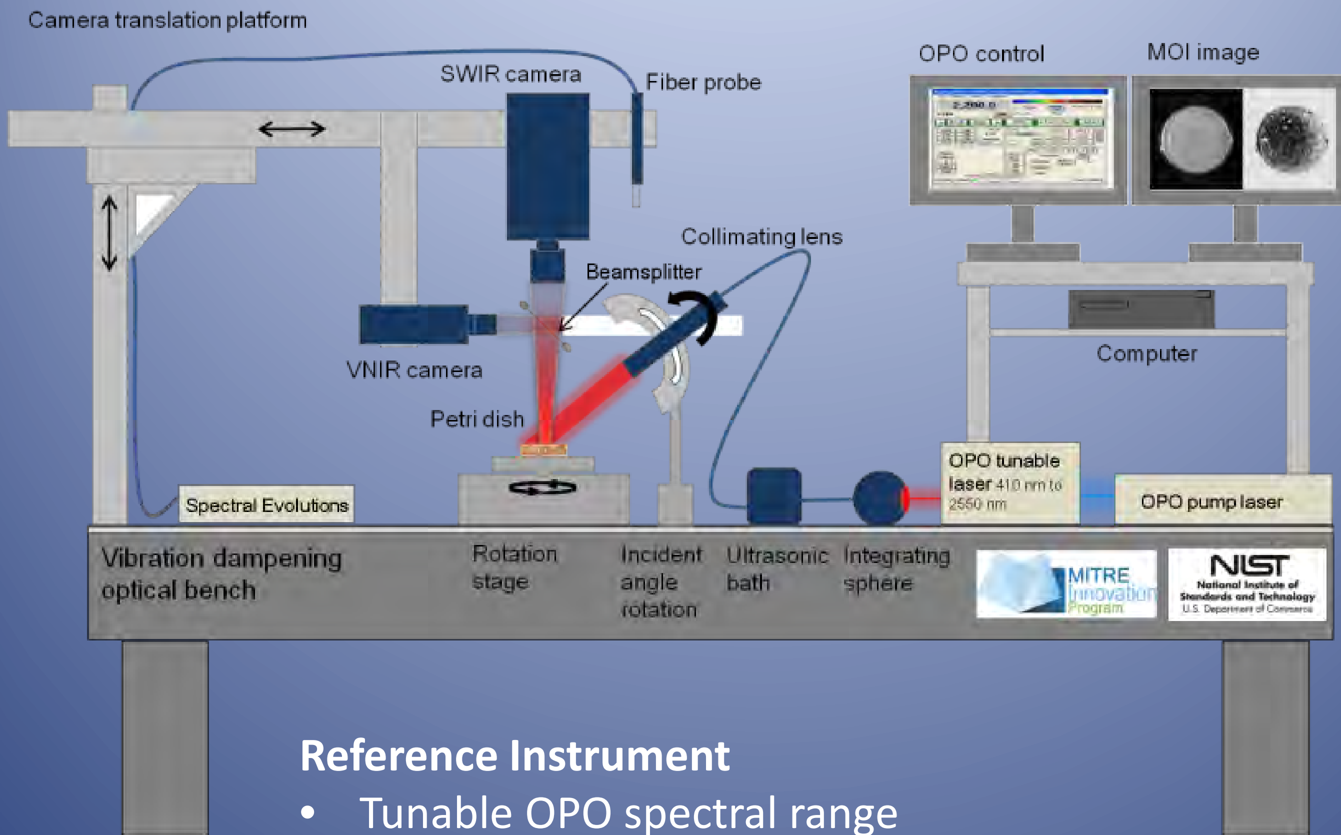
Photoacoustic Imaging

- In collaboration with Lihong Wang Washington U.



http://www.bme.ucdavis.edu/articles/2013/02/15/biophotonics-seminar-lihong-wang/wang-illustration/

Tunable Laser Based Ultraspectral Microscope



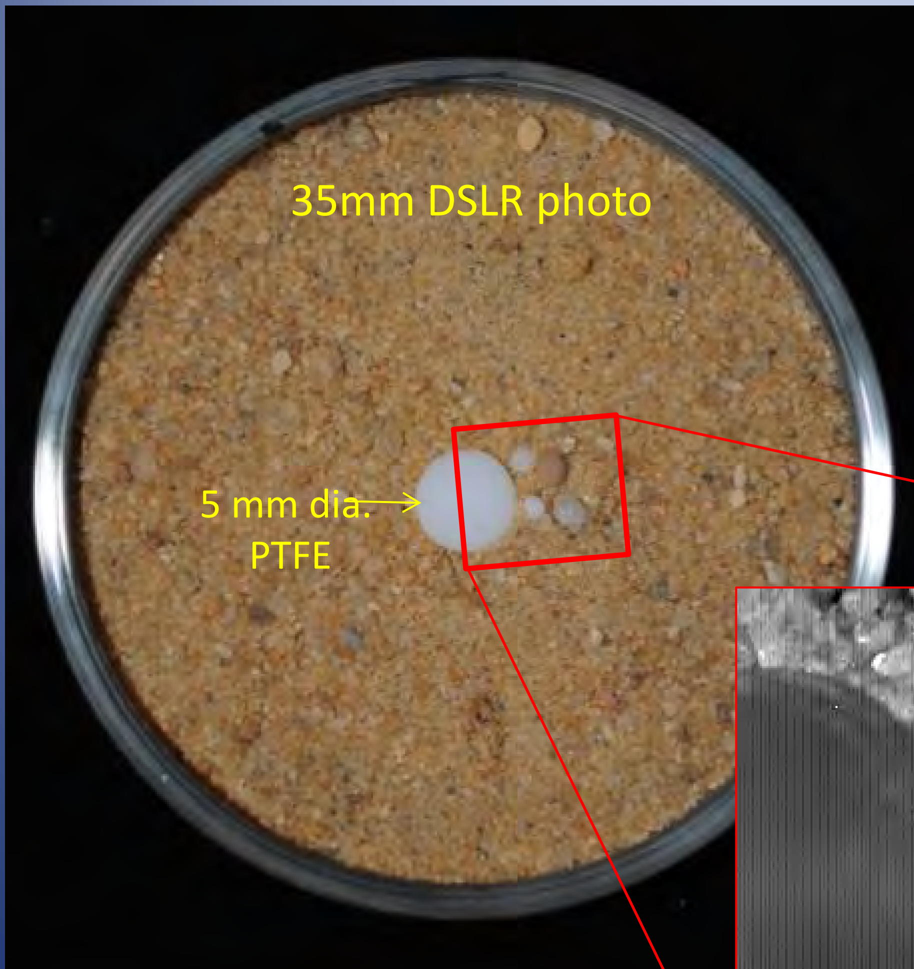
Reference Instrument

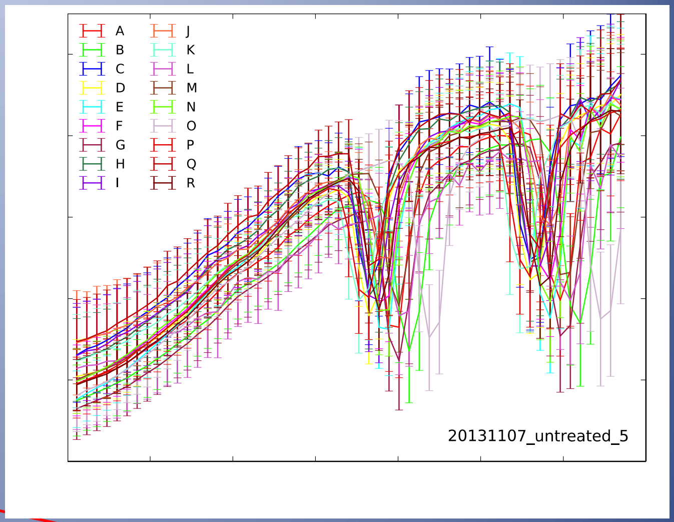
- Tunable OPO spectral range 405 nm to 2500 nm
- Spectral Band Width <1nm
- Spatial resolution <7µm
- Low Stray light
- High Wavelength accuracy
- 3D Laser scanning topography

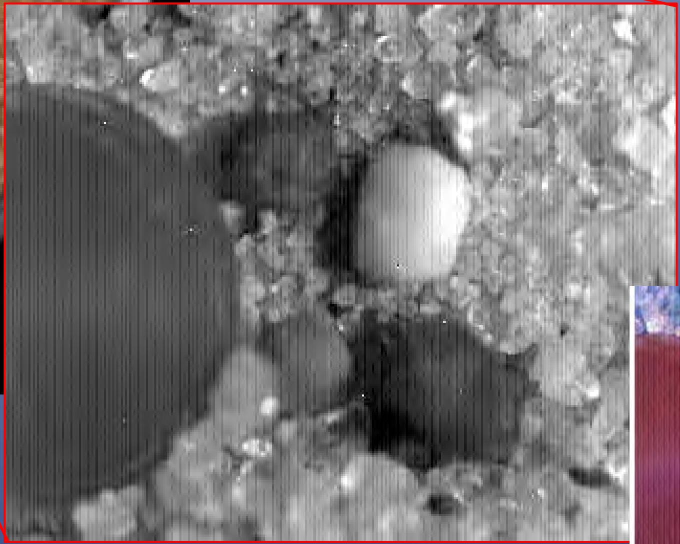
Subjects

- Live tissue
- Phantoms
- Slides
- Minerals
- Plants

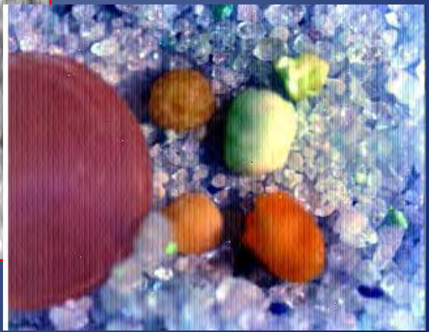
Hyperspectral Microscopy for Spectral Signature Variability







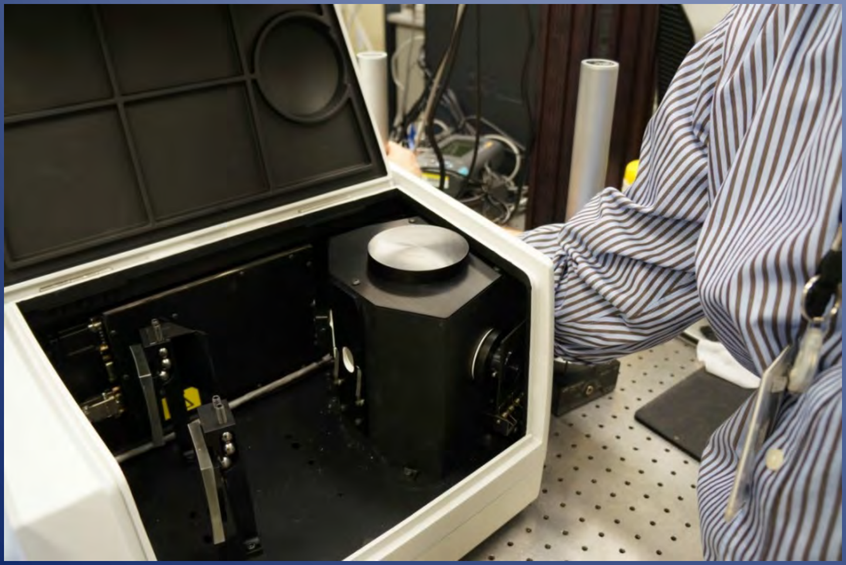
First PCA Grayscale Image



Spectral reflectance of skin

Reflectance measurements:

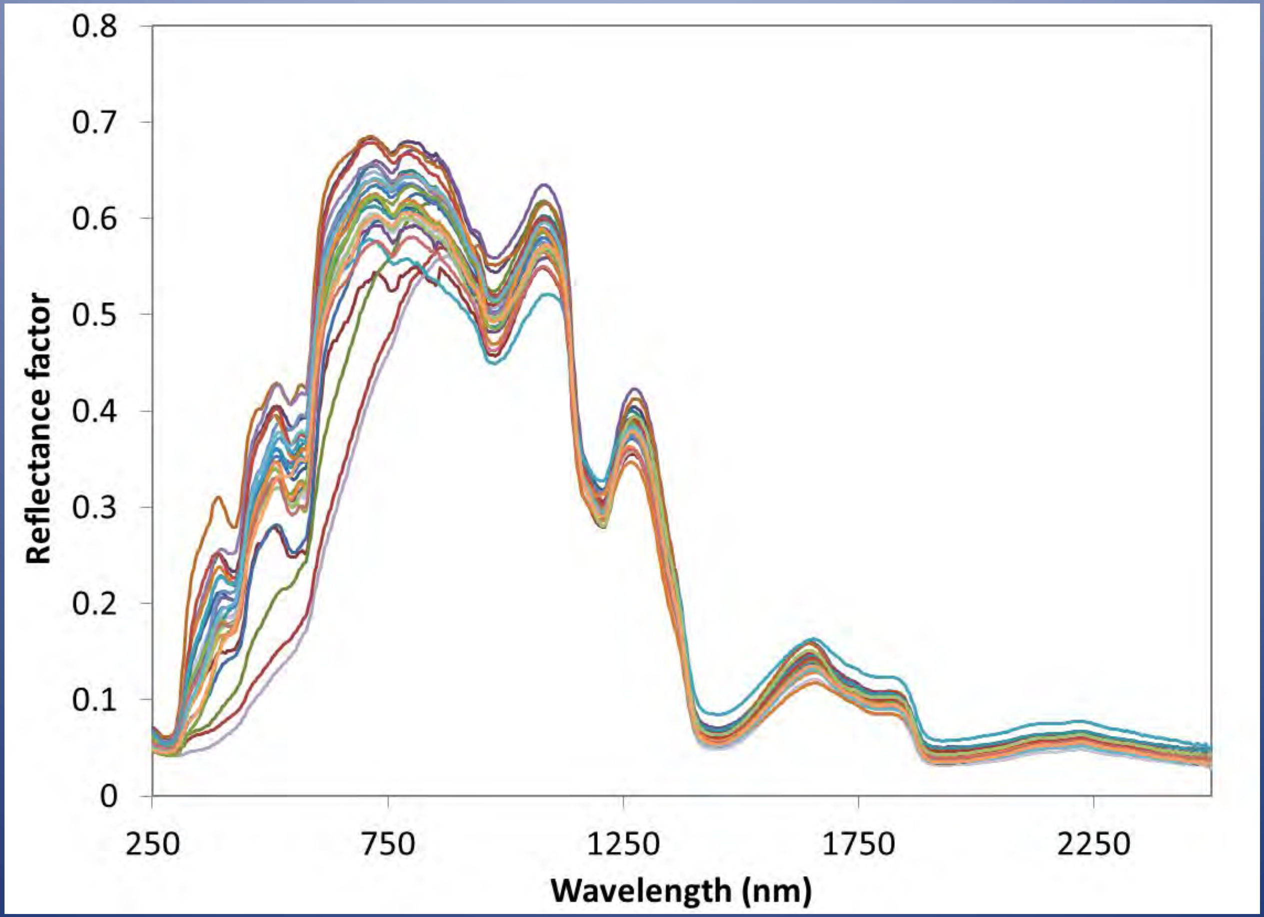
- 8°/h Directional Hemispherical measurement of forearm
- Simple measurement
- 250 nm to 2500 nm spectral range
- 3 nm spectral bandwidth
- Low noise, stated uncertainties
- NIST traceable



Reflectance of human skin

8°/h spectral reflectance factor *R* at each wavelength λ :

$$R(\lambda) = \frac{S(\lambda) - S_d(\lambda)}{S_s(\lambda) - S_d(\lambda)} \cdot R_s(\lambda)$$



Reflectance of human skin

Instrument uncertainty:

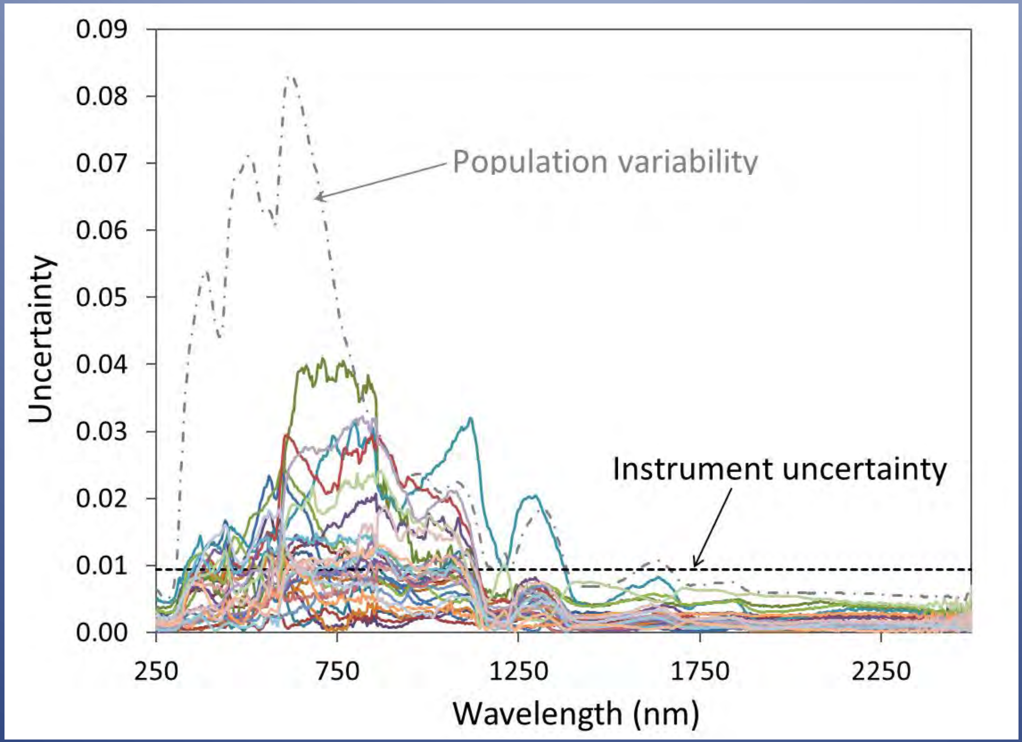
- Sintered PTFE standard
- Sphere geometry
- Wavelength
- Random effects

Subject variability:

Standard deviation of subject's 3 scans

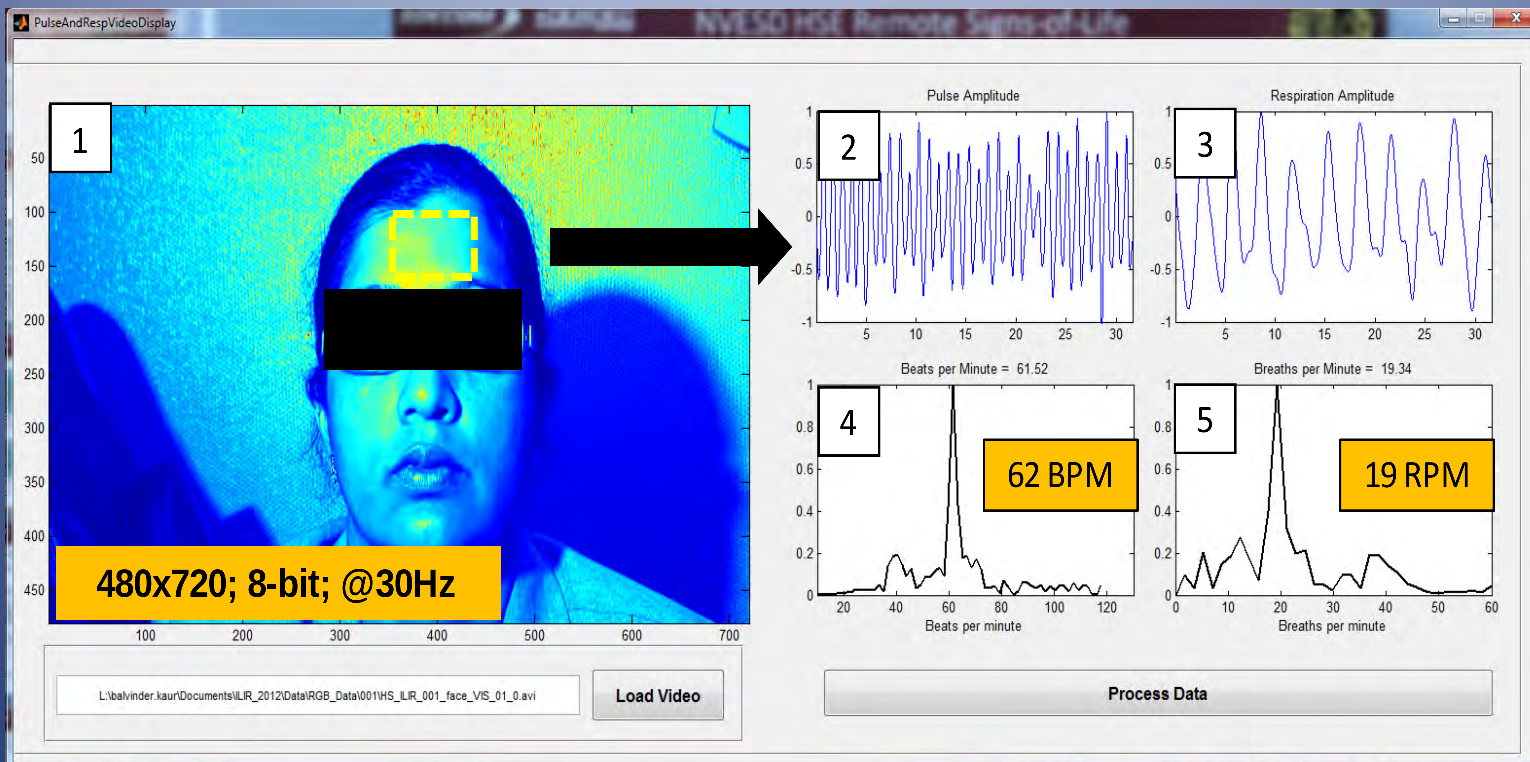
Population variability:

Standard deviation of full set of scans



SPIE Defense + Security
A collection and statistical analysis of skin reflectance signatures for inherent variability over the 250 nm to 2500 nm spectral range
Catherine C. Cooksey, Benjamin K. Tsai, David W. Allen

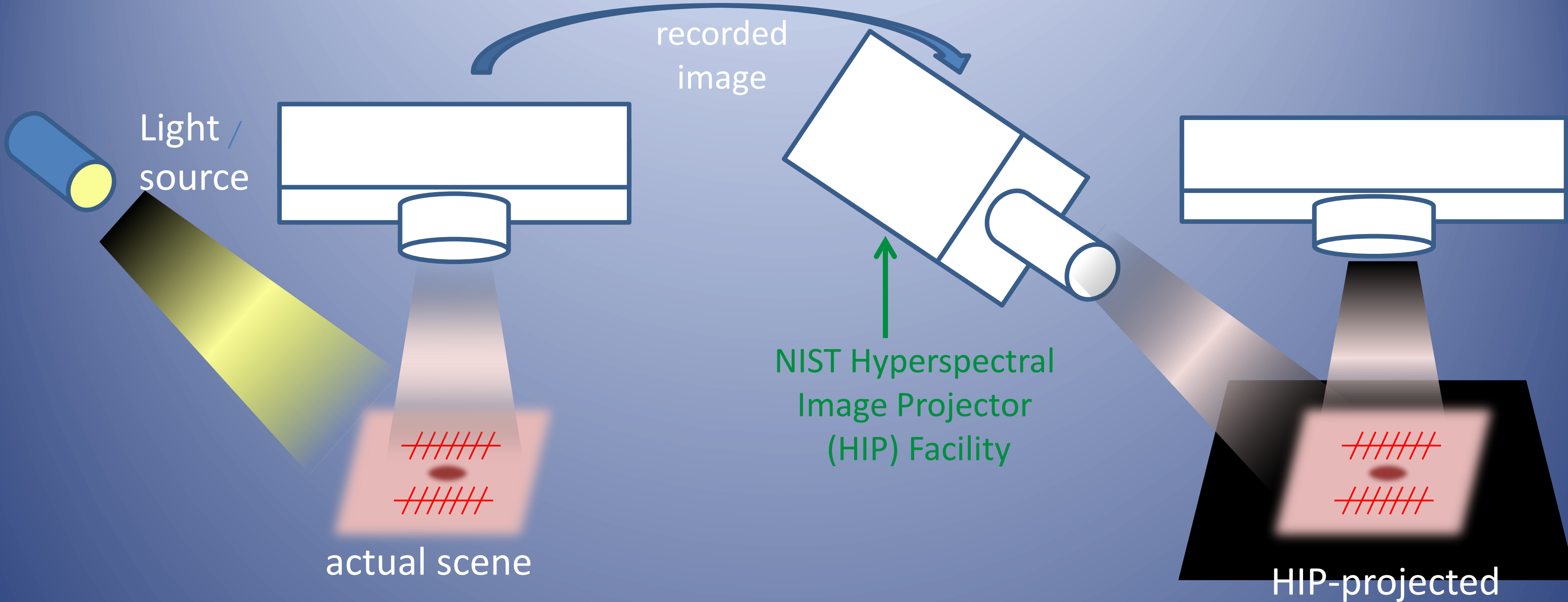
Non-contact vital sign imaging



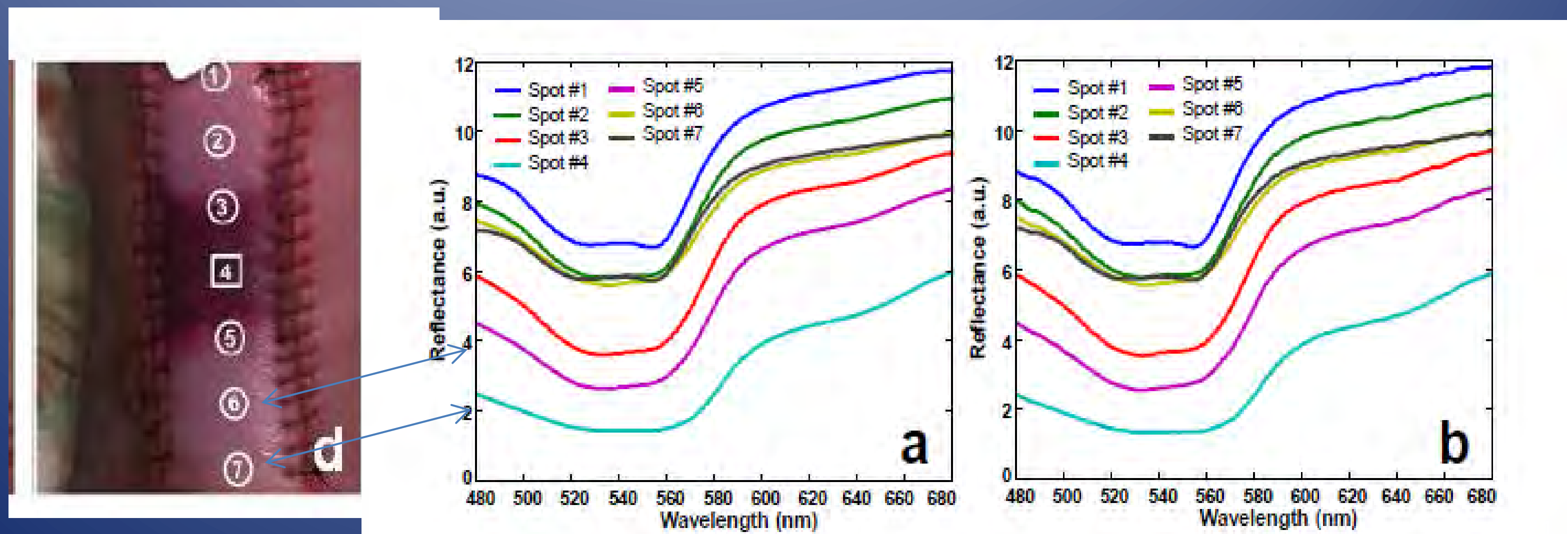
Kaur, B., Hodgkin, V. A., Hutchinson, A.J., Nelson, J.K., and Ikonomidou, V.N. "Hyperspectral Waveband Group Optimization for Time-resolved Human Sensing." SPIE Conference- DSS, Baltimore, MD, Apr. 2013.

Digital tissue phantom

Allen, et al



Pig Skin flap



Original spectra

HIP-projected

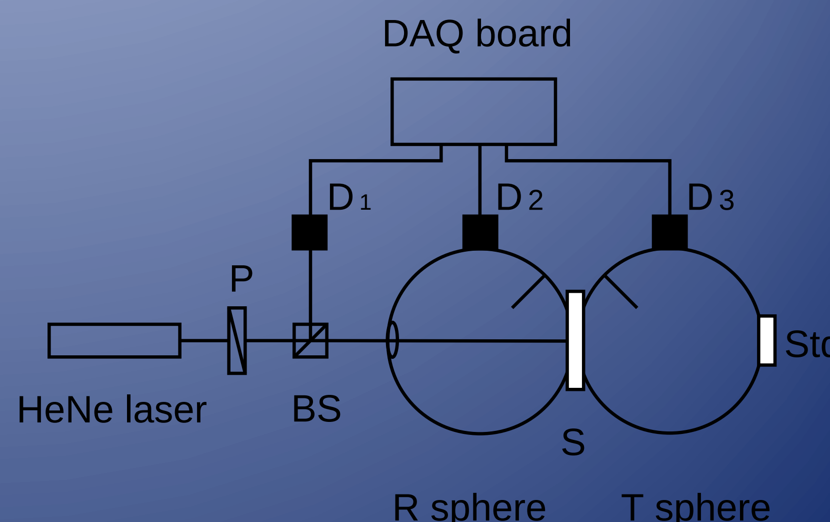
Solid tissue-simulating phantoms

- Recommended Direction from participants at workshop at Catholic University, Nov. 2011
  - Develop measurement service for diffuse optical properties
  - Stated uncertainties
  - Traceability to NIST
  - Validated by model and intercomparisons
- Solid phantoms
  - Easy to use
  - Long term stability of the optical properties
  - Can be disseminated
- Optical properties measured by
  - Steady state domain: Inverse Adding Doubling
  - Time domain: time resolved transmittance
- Made possible by Dr. Paul Lemaillet, NIST Guest Researcher

S. A. Prahl, M. J. C. van Gemert and A. J. Welch, "Determining the optical properties of turbid media by using the adding--doubling method," Appl. Opt., vol. 32, no. 4, pp. 559-568, Feb 1993

Steady state domain

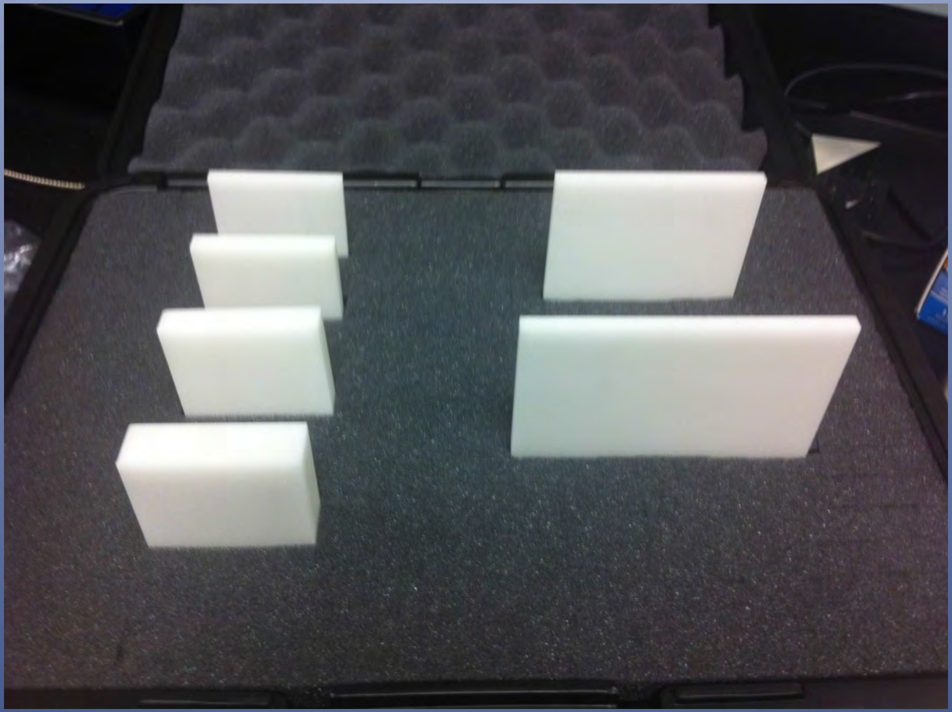
- **Double sphere setup**
  - Reflectance sphere: total reflectance
  - Transmittance sphere: total transmittance
  - Input quantities for Inverse Adding Doubling
  - Planned spectral range: 400 to 1000 nm
- **Sample thickness:** ~1mm to 1cm



In collaboration with Jean-Pierre Bouchard

INO BIOMIMICTM Phantom: $\mu_a = 0.0829\ \mathrm{mm}^{-1}$ and $\mu_s{}' = 0.952\mathrm{mm}^{-1}$

at $\lambda = 805\ nm$, measured by time domain transmittance



J.-P. Bouchard, I. Veilleux, R. Jedidi, I. Noiseux, M. Fortin and O. Mermut, "Reference optical phantoms for diffuse optical spectroscopy. Part 1- Error analysis of a time resolved transmittance characterization method," Opt. Express, vol. 18, no. 11, pp. 11495-11507, May 2010.

Modified Inverse Adding Doubling

- Integration of Prahl's Adding-Doubling routine in a C++ code
- Versatility on the integrating sphere model and sphere correction model
- Ability to propagate the measurements and parameters uncertainty to the sample optical properties following the GUM

United States Department of Commerce
Technology Administration
National Institute of Standards and Technology

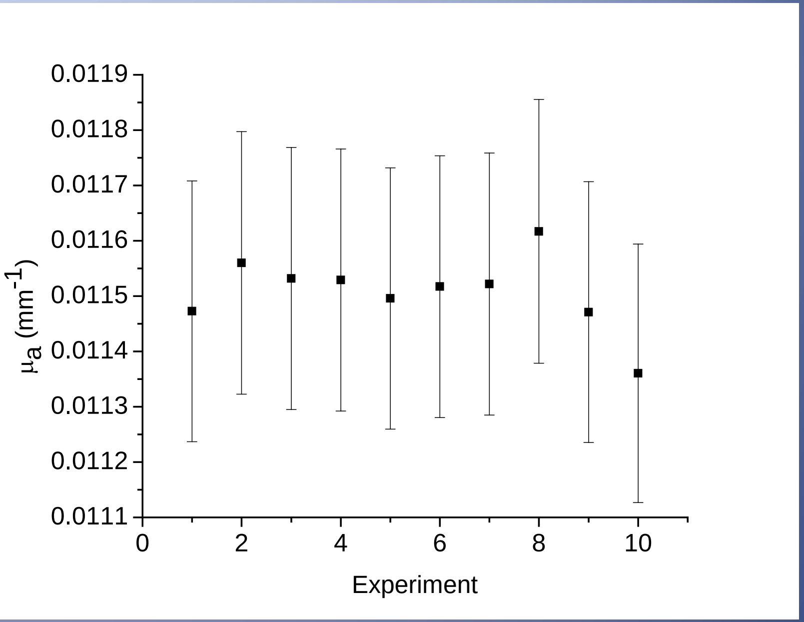
NIST Technical Note 1297
1994 Edition

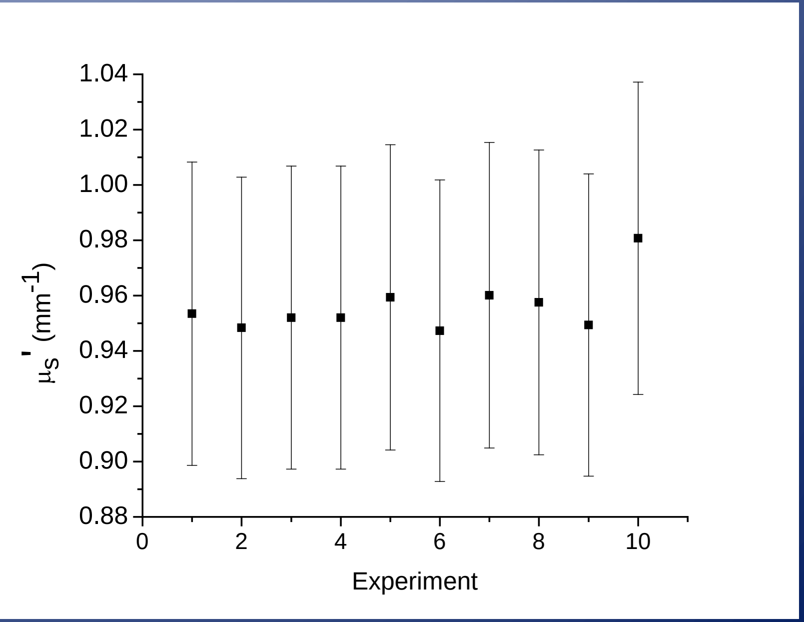
Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results

http://physics.nist.gov/Pubs/guidelines/TN1297/tn1297s.pdf

INO sample 100x100x5 mm at 543.5 nm

	Value	Absolute uncertainty (k=1)	Relative uncertainty (k=1)
μ_a	$0.0115\ mm^{-1}$	$2.45\ 10^{-4} mm^{-1}$	2.14%
$\mu_s{}'$	$0.959\ mm^{-1}$	$0.0561\ mm^{-1}$	5.84%





INO phantom: $\mu_a = 0.0115\ \mathrm{mm}^{-1}$ and $\mu_s{}' = 0.959\mathrm{mm}^{-1}$ at $\lambda = 543.5\ nm$.

			Absolute uncertainties (mm^{-1})		Relative uncertainties (%)	
		Input σ	$\boldsymbol{\mu_a}$	$\boldsymbol{\mu_s{}'}$	$\boldsymbol{\mu_a}$	$\boldsymbol{\mu_s{}'}$
				Type A uncertainties		
	Measurements		1.24e-06	9.67e-05	0.0108	0.0101
				Type B uncertainties		
Reflectance sphere	$D^{R\ sphere}$	0.577	0	0	0	0
	$d^{R\ sphere}_{Sample\ port}$	0.0577	0	0	0	0
	$d^{R\ sphere}_{Entrance\ port}$	0.0577	0	0	0	0
	$d^{R\ sphere}_{Detector\ port}$	0.0577	0	0	0	0
	$R^{R\ sphere}_{StdCal}$	0.002	$1.45\ 10^{-5}$	$1.30\ 10^{-3}$	0.126	0.135
	$r^{R\ sphere}_{d}$	0.02	0	0	0	0
	$R^{R\ sphere}_{Std}$	0.002	$7.59\ 10^{-5}$	$5.72\ 10^{-3}$	0.660	0.596
Transmittance sphere	$D^{T\ sphere}$	0.577	$1.28\ 10^{-7}$	$8.19\ 10^{-7}$	$1.12\ 10^{-3}$	$8.54\ 10^{-5}$
	$d^{T\ sphere}_{Sample\ port}$	0.0577	$2.78\ 10^{-6}$	$1.62\ 10^{-5}$	0.0241	$1.69\ 10^{-3}$
	$d^{T\ sphere}_{Entrance\ port}$	0.0577	$4.31\ 10^{-6}$	$2.52\ 10^{-5}$	0.0375	$2.62\ 10^{-3}$
	$d^{T\ sphere}_{Detector\ port}$	0.0577	$4.37\ 10^{-10}$	$1.71\ 10^{-8}$	$3.80\ 10^{-6}$	$1.78\ 10^{-6}$
	$R^{T\ sphere}_{StdCal}$	0.002	$1.09\ 10^{-5}$	$6.38\ 10^{-5}$	0.0950	$6.65\ 10^{-3}$
	$r^{T\ sphere}_{d}$	0.02	$1.90\ 10^{-8}$	$1.11\ 10^{-7}$	$1.65\ 10^{-4}$	$1.16\ 10^{-5}$
	$R^{T\ sphere}_{Std}$	0.002	$1.85\ 10^{-6}$	$1.08\ 10^{-5}$	0.0161	$1.13\ 10^{-3}$
Adding Doubling	d	0.00577	$1.33\ 10^{-5}$	$1.11\ 10^{-3}$	0.115	0.115
	n	0.006	$8.57\ 10^{-5}$	$2.87\ 10^{-5}$	0.745	0.300
	g	0.015	$2.04\ 10^{-6}$	0.0535	0.0178	5.58
	θ	0.0005	$2.05\ 10^{-4}$	0.0118	1.79	1.23
	Type B uncertainty, u_B		$2.36\ 10^{-4}$	0.0552	2.05	5.75
	Reproducibility		$6.70\ 10^{-5}$	0.00976	0.0583	1.02
	Total type A uncertainty, u_A		$6.70\ 10^{-5}$	0.00976	0.0583	1.02
	Combined, u_C		$2.45\ 10^{-4}$	0.0561	2.14	5.84
	Expanded, U (k=2)		$4.91\ 10^{-4}$	0.112	4.271	11.7

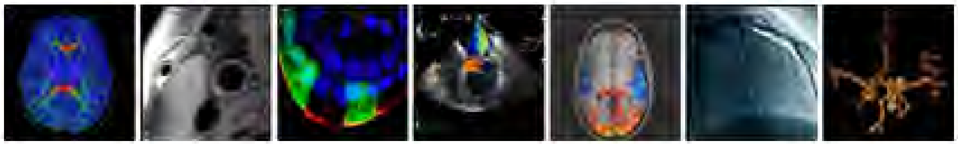
3D Printed Samples

- Customer or NIST printed sample for optical properties
- Disseminate NIST Scale
- Provide basis for phantom design

MakerBot Replicator 2
Consumer-level 3D Printer
Prints in PLA filament
Build size: 285 x 153 x 155 mm (11.2 x 6 x 6.1 in)
Layer Resolution: 100-340 microns (0.0039-0.0133 in)
Positioning Precision: XY: 11 microns (0.0004 in) Z: 2.5 microns (0.0001 in)
Manufacturer's details: http://store.makerbot.com/replicator2
MakerWare software (Optional - for orienting object at your desk before printing): http://www.makerbot.com/makerware/

Afinia H-Series
Consumer-level 3D Printer
Prints with any filament, including both ABS and PLA
Heated build platform (105°C)
Adjustable nozzle temperature, from 209°C to 266°C
Build size: 140 x 140 x 135 mm (5.5 x 5.5 x 5.3 in)
Layer Resolution: 150-400 microns (0.0059-0.0157 in)
Manufacturer's details: http://www.afinia.com/
Afinia software (Optional - for orienting object at your desk before printing): http://www.afinia.com/support/downloads

Save the date!



NIST

National Institute of Standards and Technology

NIST Workshop on Standards for the Advancement of Optical Medical Imaging

August 26 (Tue) -27 (Wed), 2014
8:30 am - 5:00 pm
Portrait Room, NIST Gaithersburg campus
100 Bureau Drive, Gaithersburg, MD 20899

Optical medical imaging promises to change the way medicine is practiced by providing rapid, low-cost, non-invasive diagnostics and treatment monitoring. This field has made steady progress over the last two decades at the research bench and is now beginning to benefit patients. The development of optical medical devices depends on the use of standards for verification and validation. In many cases existing standards are insufficient for the needs of newly developed medical imaging devices. This workshop will highlight recent advances in optical medical imaging. A special focus on the need for standards and proposed solutions to those needs will be illustrated with case studies. This workshop is intended to provide a forum for a broad cross-section of the optical medical imaging community. Participation from academic, clinical, and industrial interests will help in developing a roadmap to expedite progress towards a common goal.

SPIE. PHOTONICS WEST BIOS

Design and Performance Validation of Phantoms Used in Conjunction with Optical Measurement of Tissue VII (BO304)

Conference Chairs: **Jean-Pierre Bouchard,** INO (Canada); **David W. Allen,** National Institute of Standards and Technology (USA)

LOCATION

The Moscone Center
San Francisco, California, USA

DATES

Conferences & Courses:
7–12 February 2015

IMPORTANT DATES

Abstracts Due:
28 JULY 2014

BiOS Manuscript Due Date:
12 JANUARY 2015