Biomedical Optics: Multichannel Spectroscopy

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University of Rochester

Quantum-Limited Imaging Detectors Symposium
Rochester Institute of Technology
March 2, 2009

3 biomedical spectroscopy arenas

detectors used

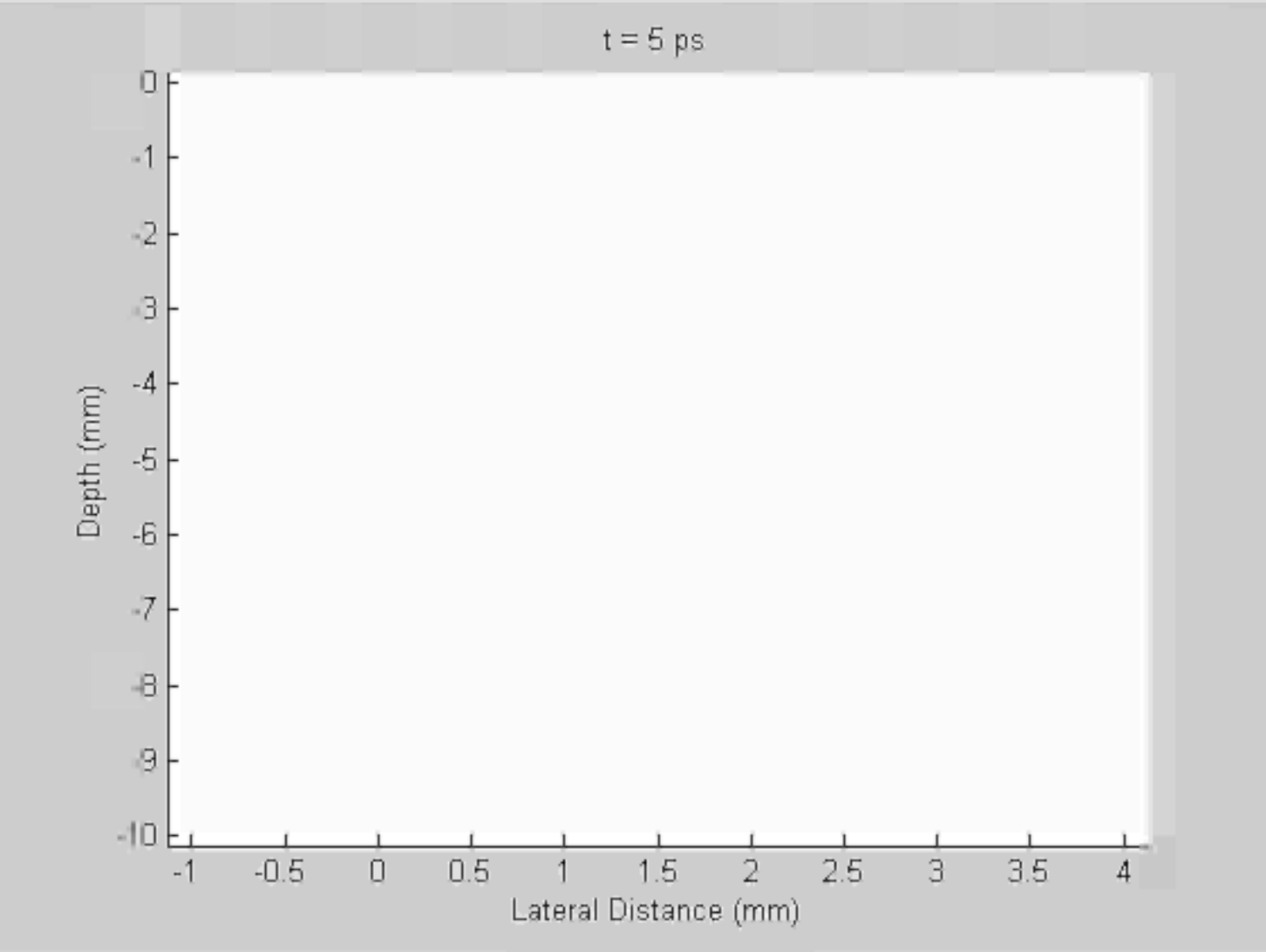
daring to dream

Biomedical Optics: Application Areas

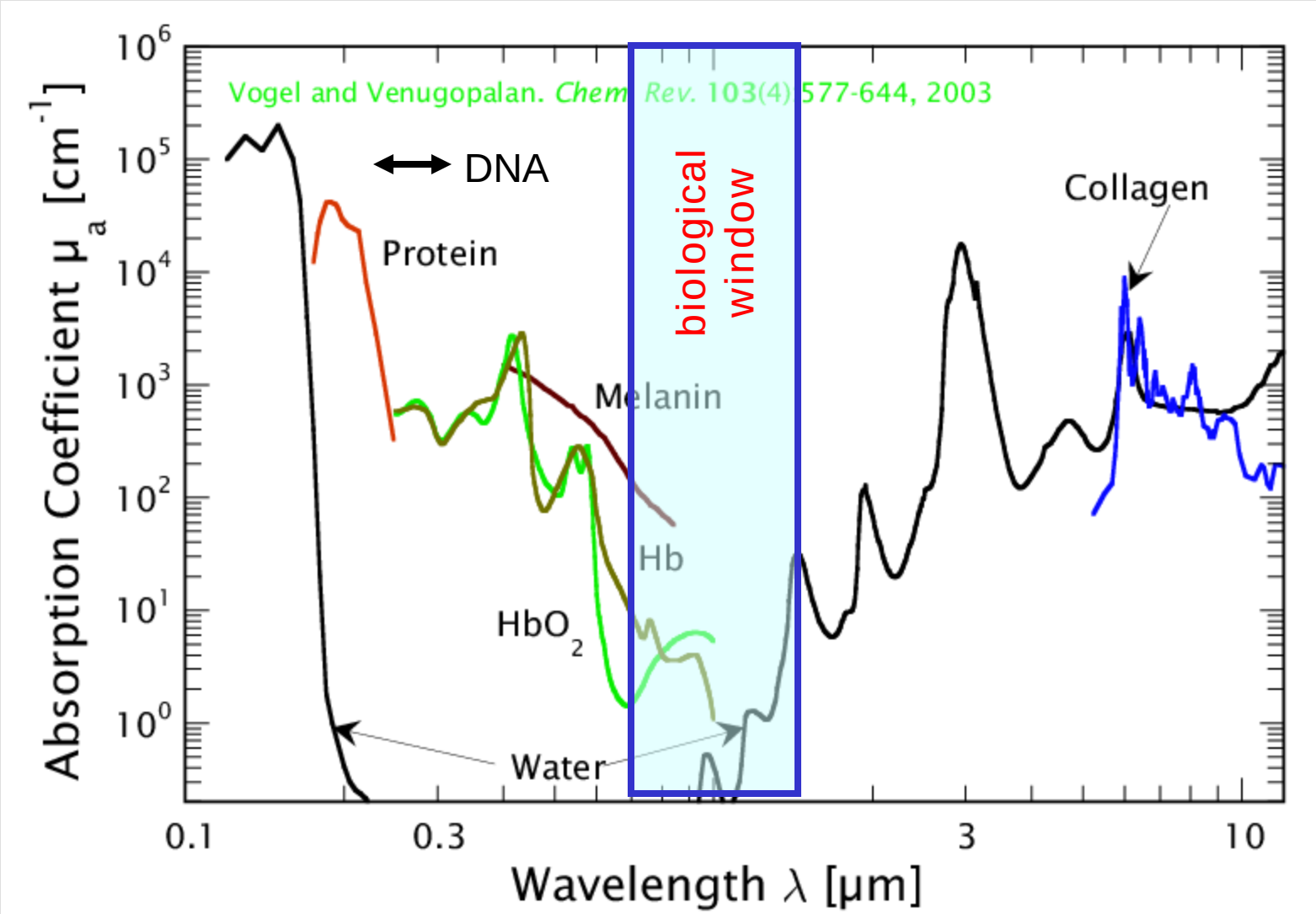
- diffuse photon propagation
- fluorescence lifetime spectroscopy
- Raman spectroscopy

- ***barely imaging!!!***

Area #1: Diffuse photon propagation

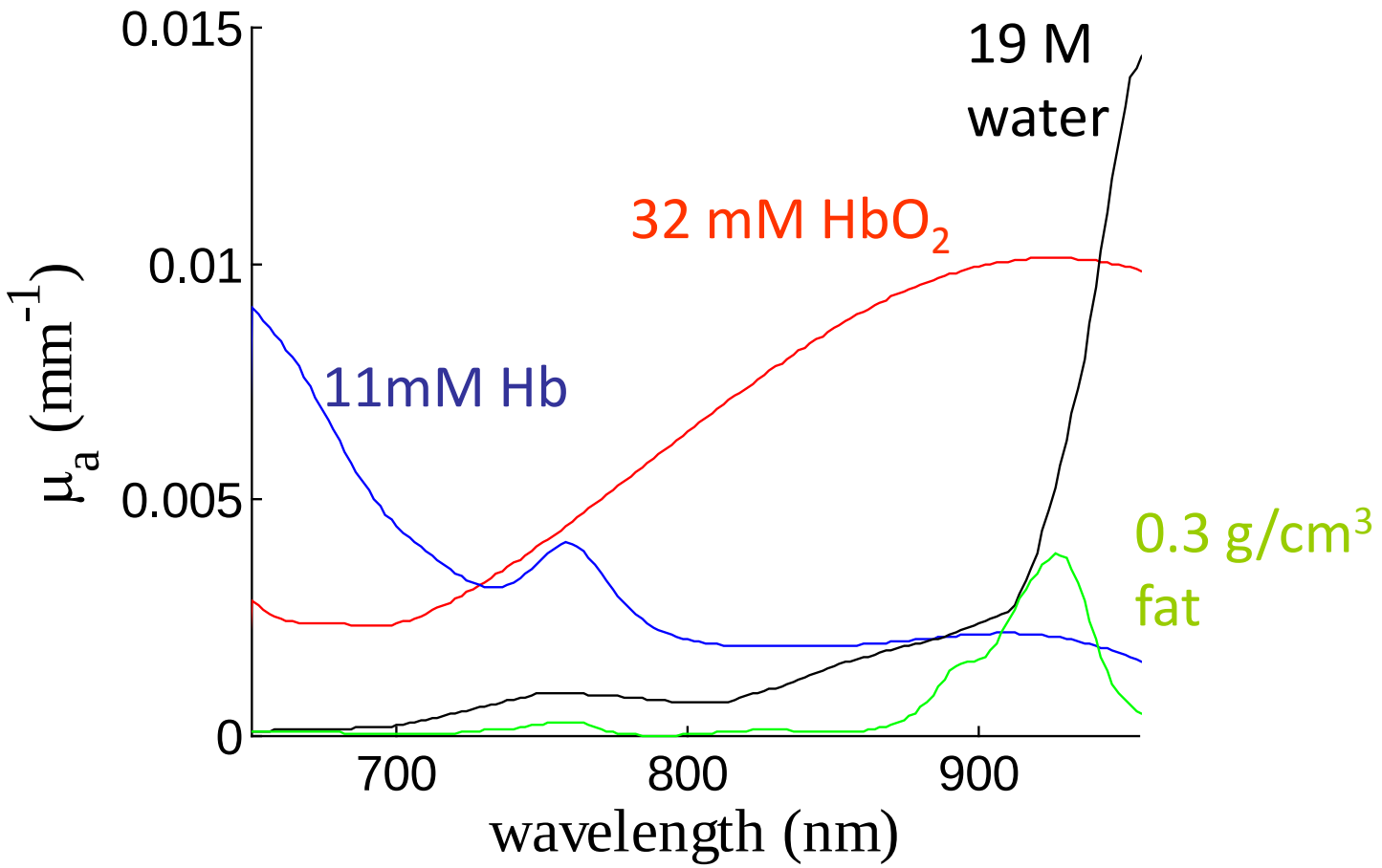


Where biomedical optics lives….

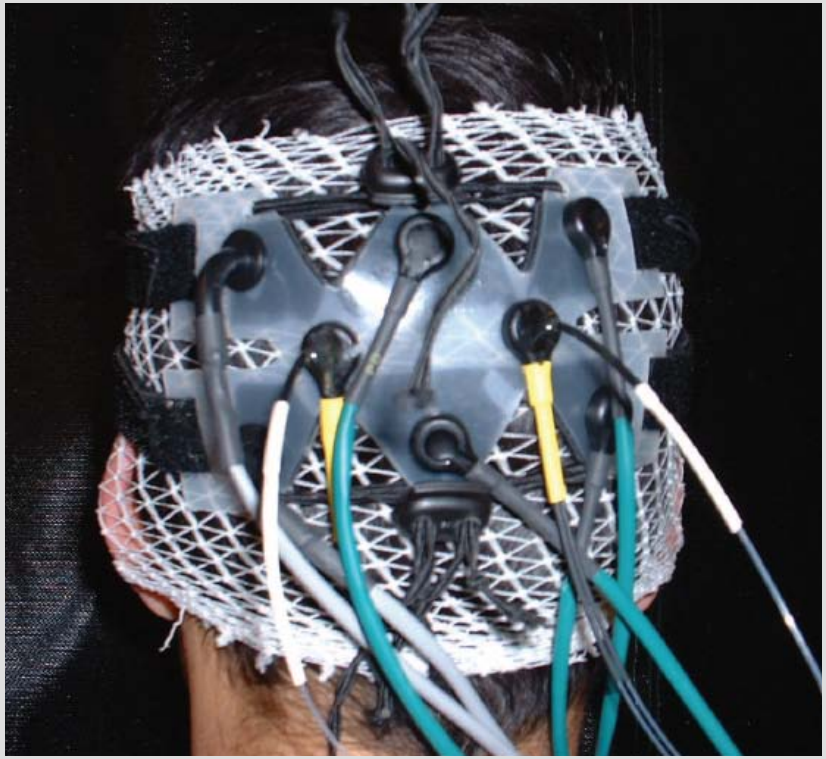


courtesy V. Venugopalan, http://www.osa.org/meetings/archives/2004/BIOMED/program/#educ

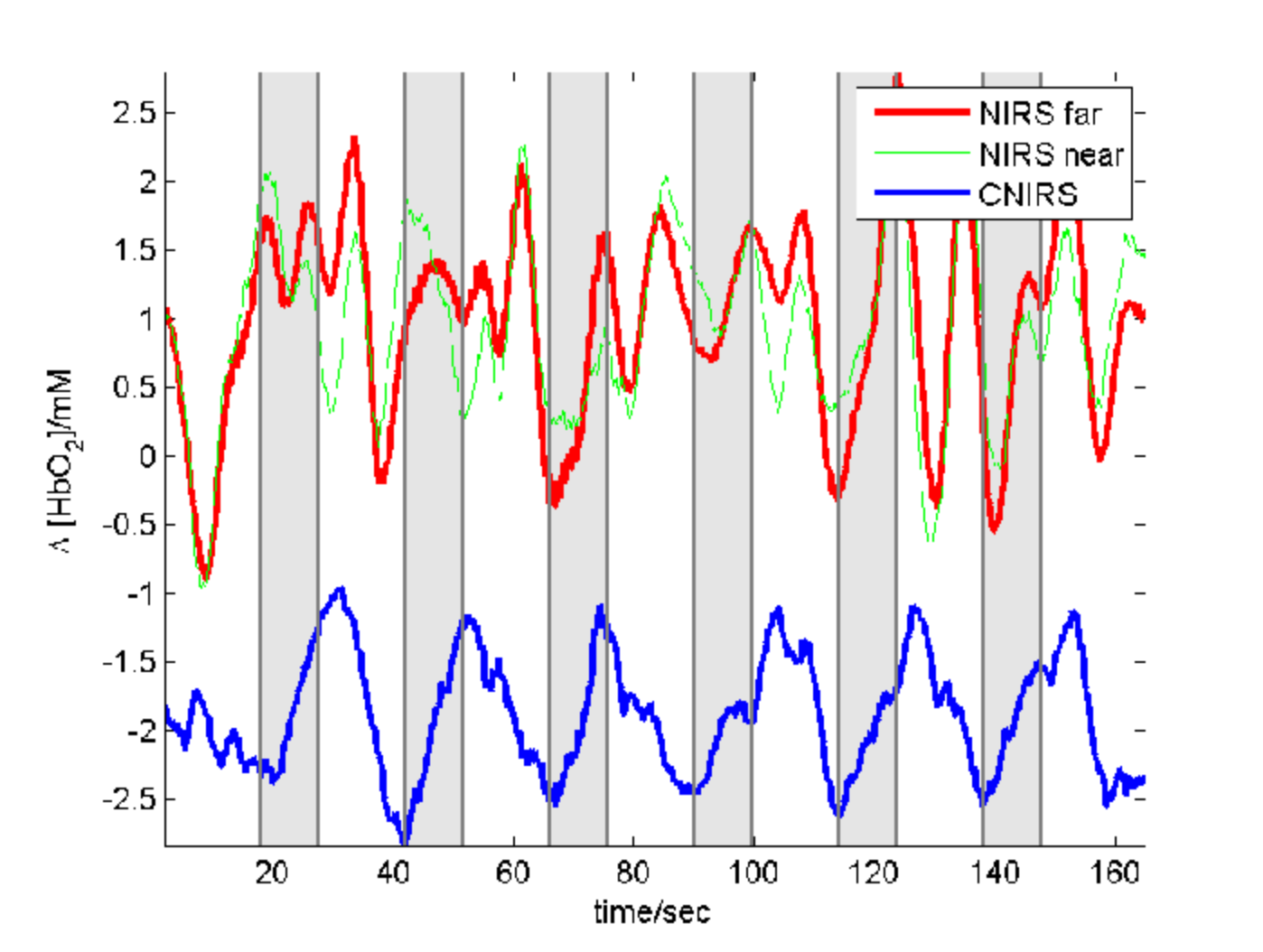
Important near-IR absorbers



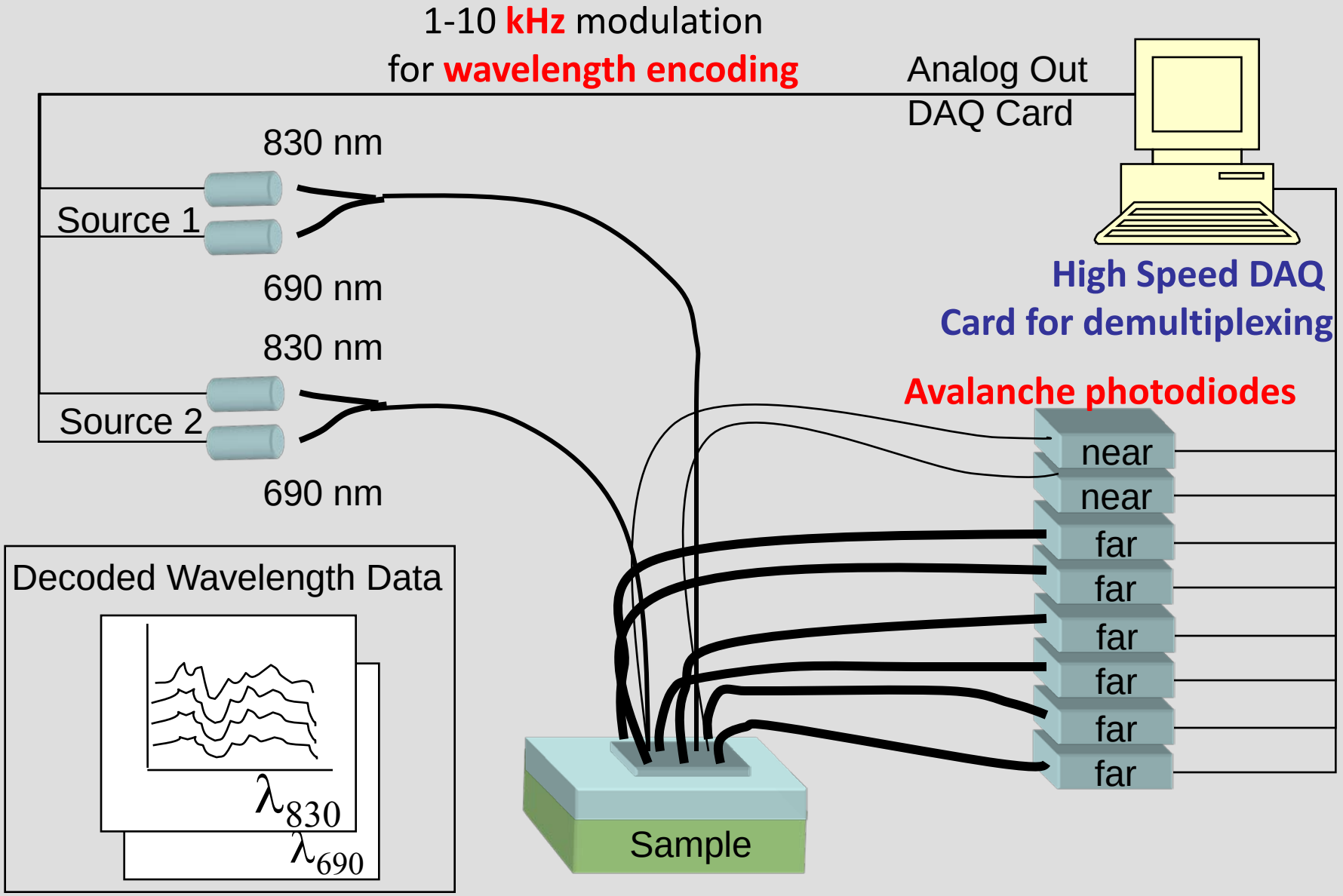
Near-infrared cerebral blood monitoring



Seeing functional responses: visual stimulation

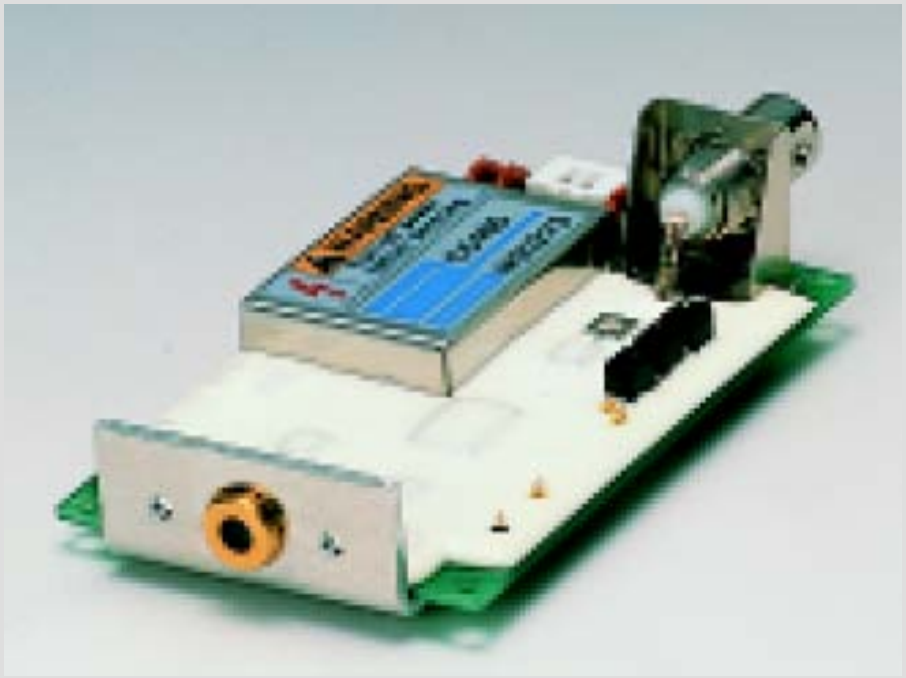


Brain monitoring system layout

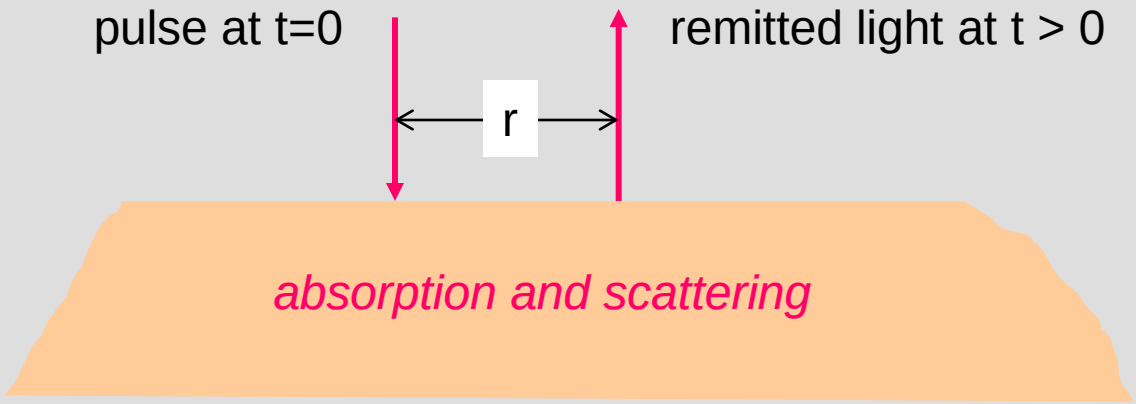


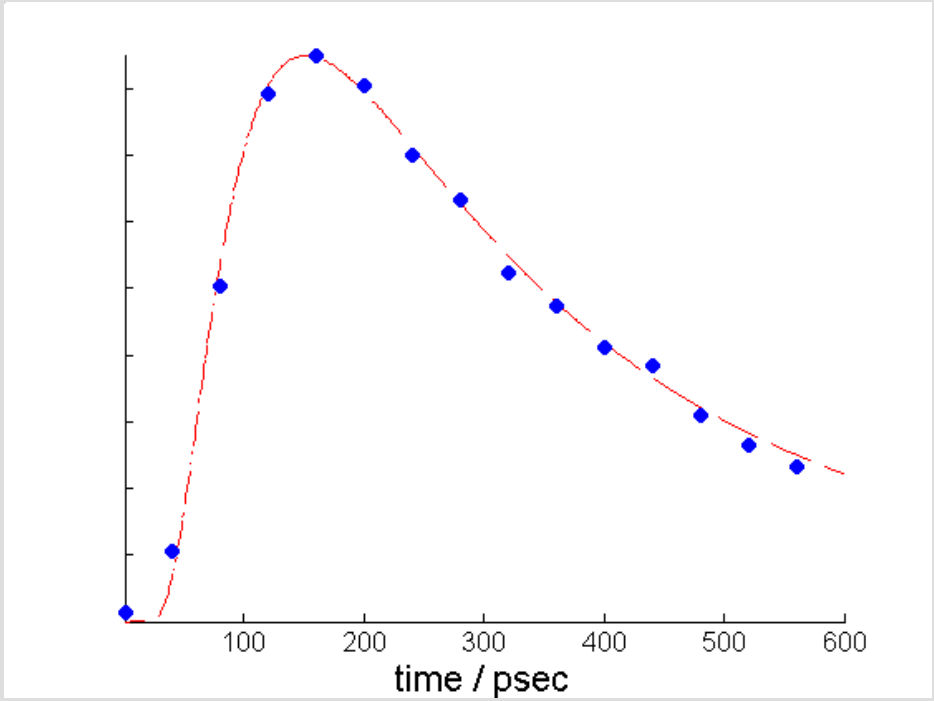
Typical detector for NIRS work

- Hamamatsu silicon avalanche photodiode modules
- Frequency rolloff in low MHz to GHz
- Spectral response out to 1000 nm



Time-resolved measurements





Hand-Held Optical Breast Scanner

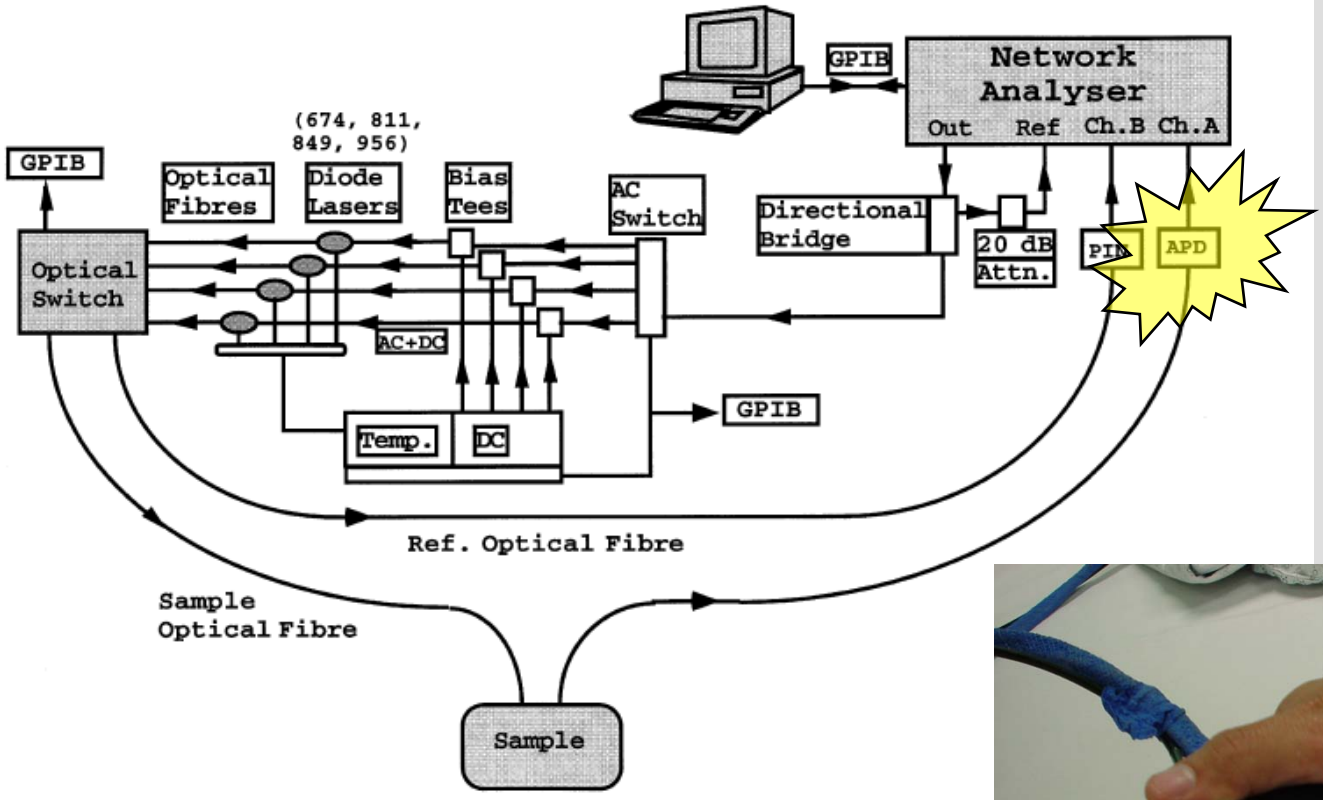


Figure 1. Multiwavelength, multifrequency FDPM instrument.

Hand-Held Optical Breast Scanner

Pham, TH., et al. Review of Scientific Instruments, 71 , 1 – 14, (2000).
Bevilacqua, F., et al. Applied Optics, 39, 6498-6507, (2000).
Jakobowski et al., J. Biomed. Opt., 9(1), 230-238 (2004).

(courtesy F. Bevilacqua)

Heavily multiplexed systems!

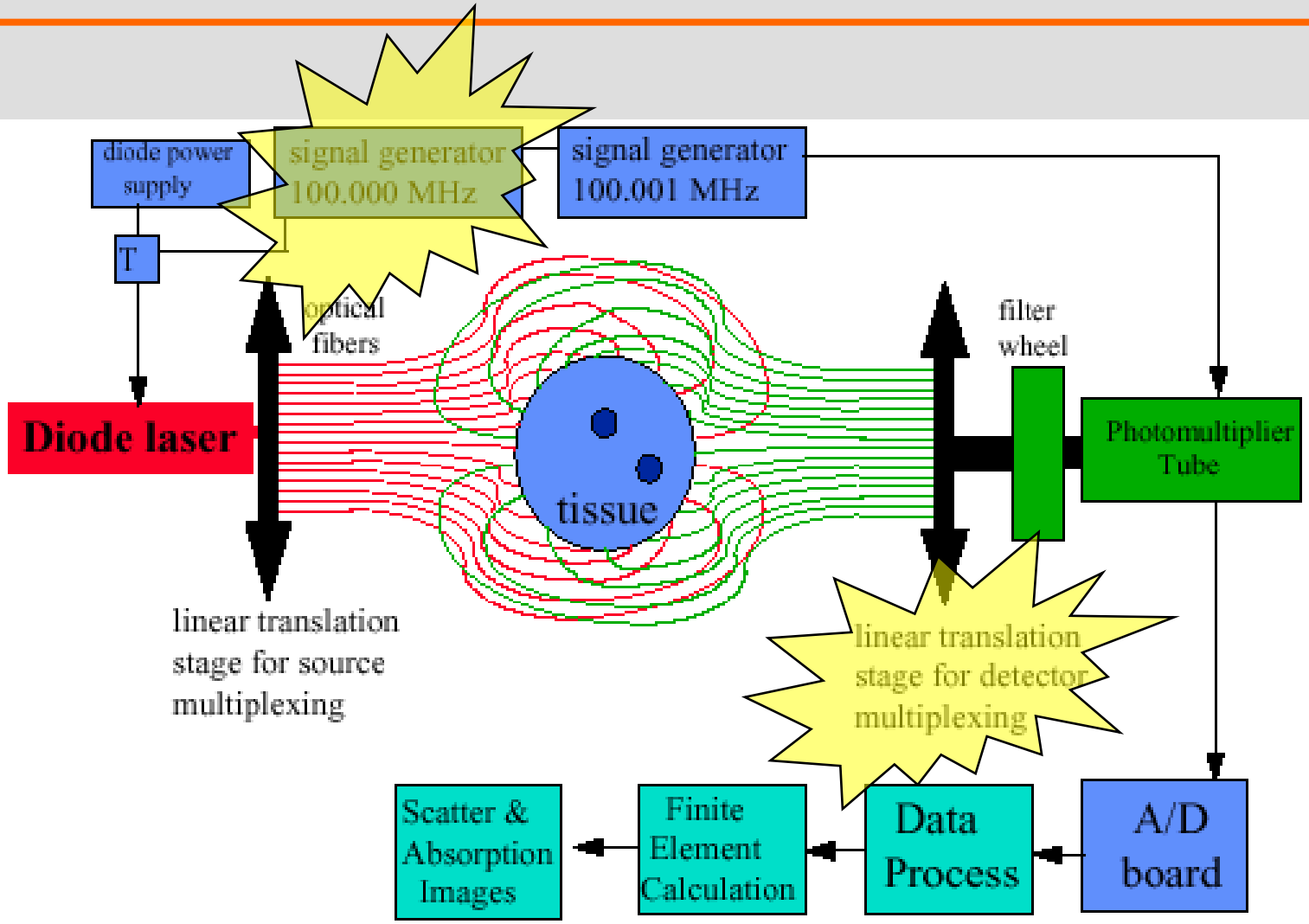


Fig. 1. Schematic of the automated imaging instrument including hardware and software processing. Source optical fibers are indicated in red and detector optical fibers in green.

B. W. Pogueet al, Opt. Express **1,** 391-403 (1997), http://www.opticsexpress.org/abstract.cfm?URI=OPEX-1-13-391

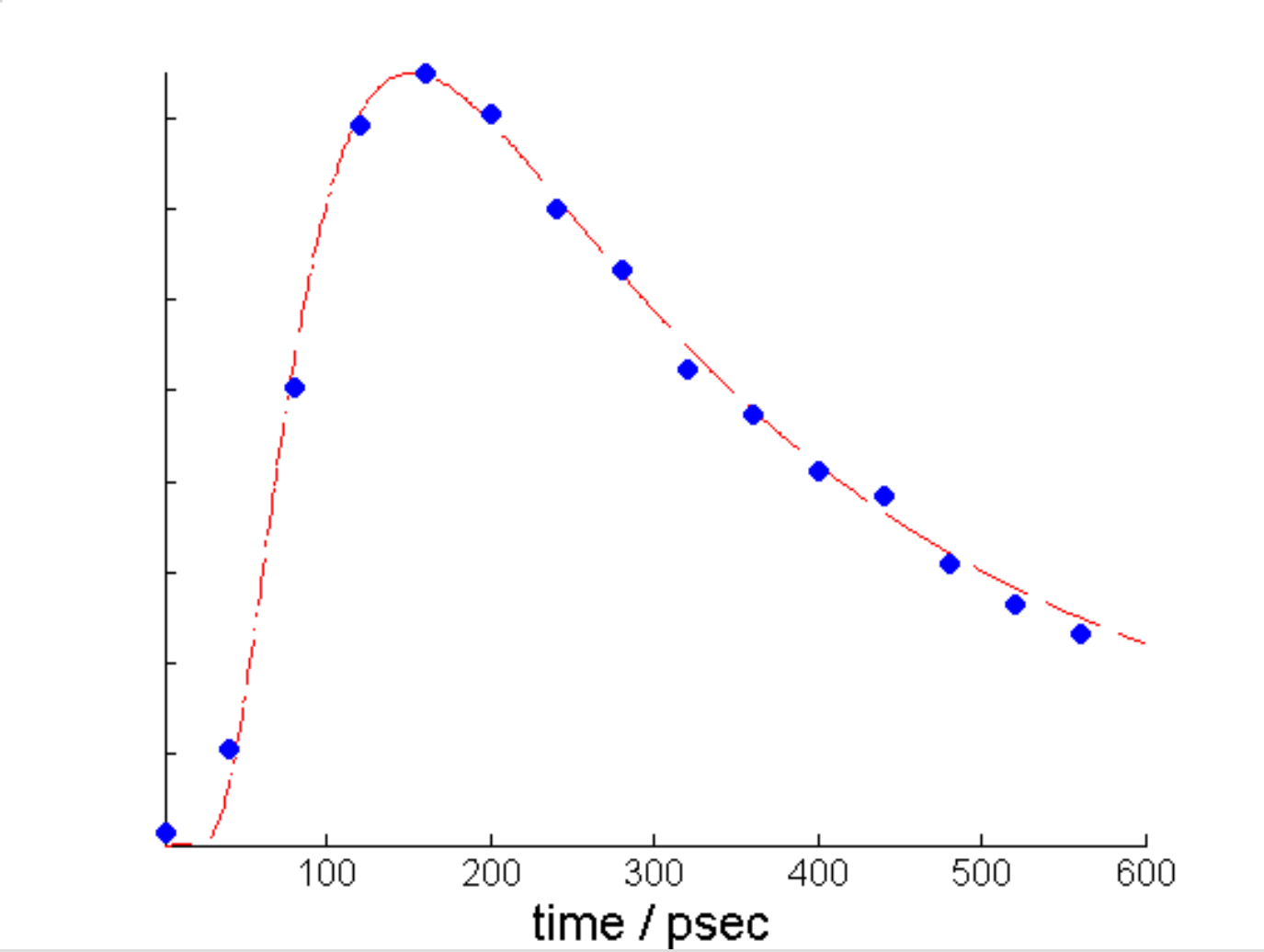
Diffuse propagation: goals, requirements

- Distinguish benign from malignant tumor tissue
- Map blood activity (hemodynamics) within brain

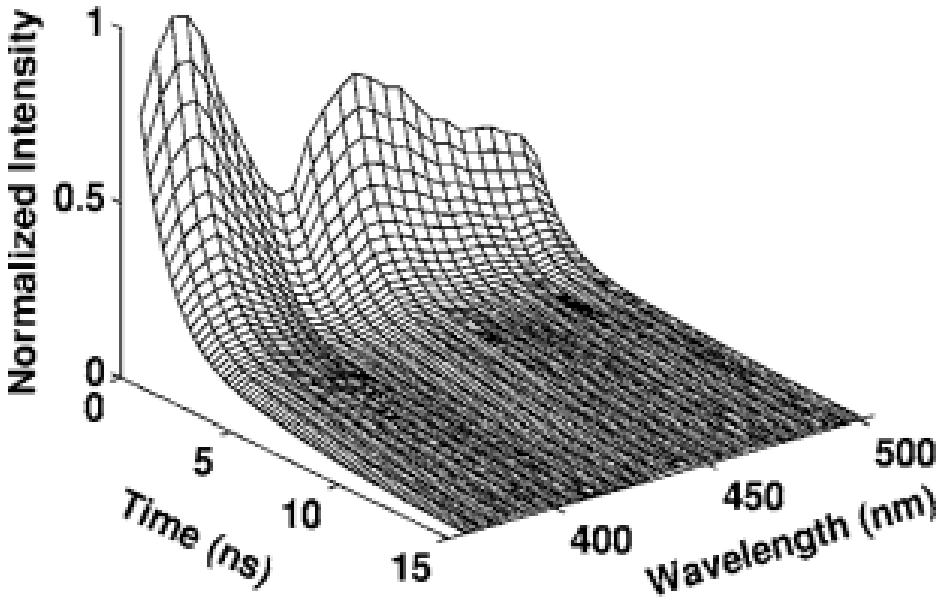
- Sense deep within tissue (cm)
- Record at many locations
- Record at many wavelengths
- Time resolution to few psec

Area #2: Fluorescence lifetime spectroscopy

Once again, psec-nsec timescale!

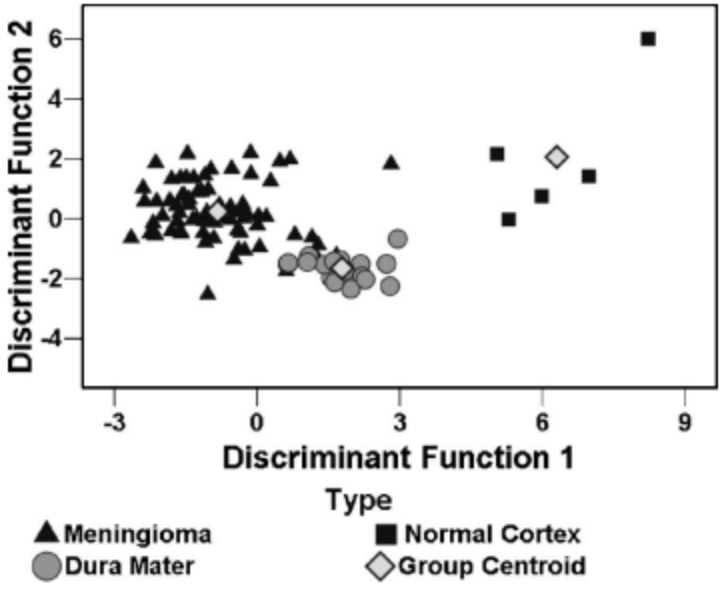


Fluorescence lifetime spectroscopy

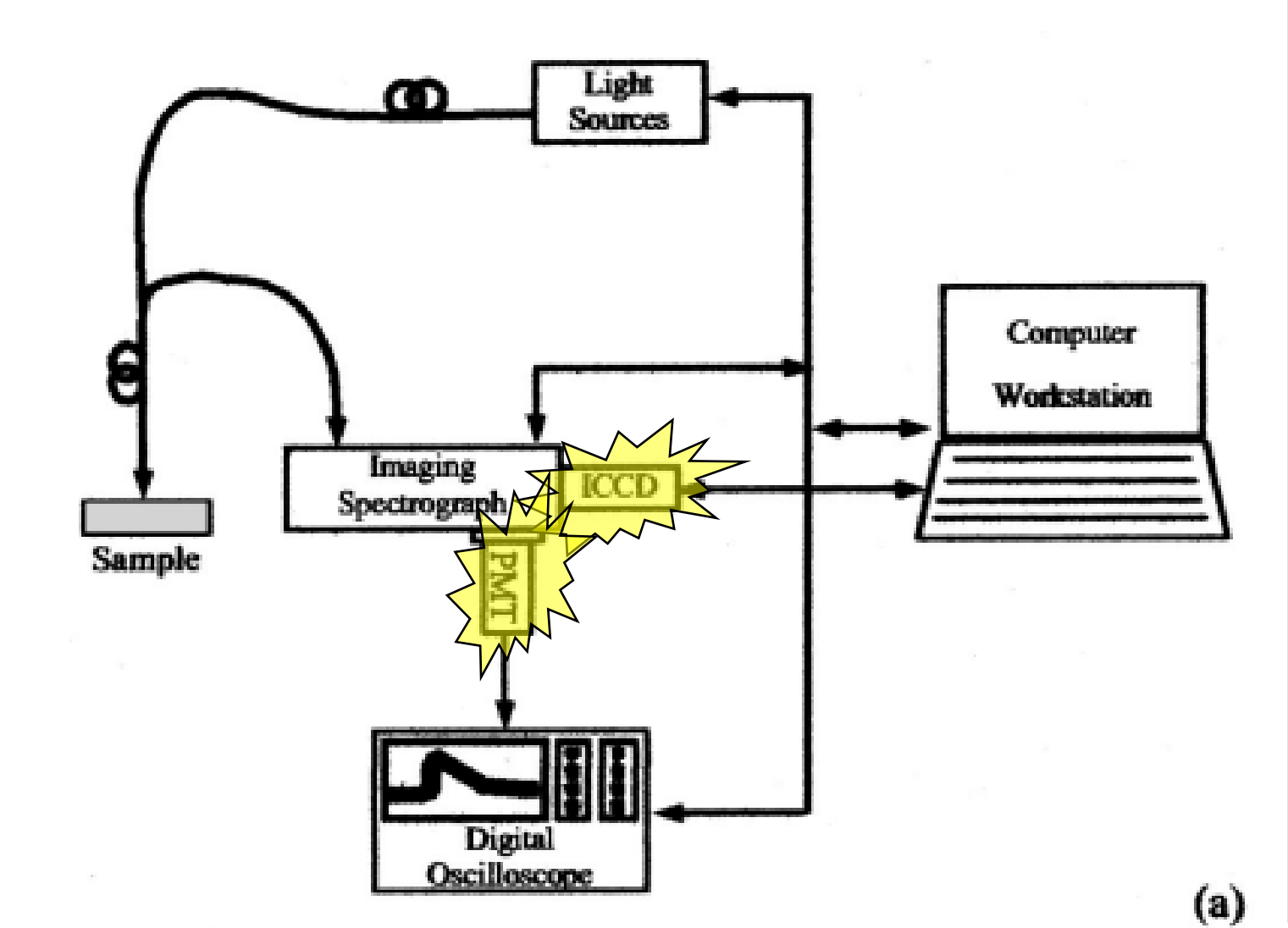


brain tissue

Butte et al., “Diagnosis of meningioma by time-resolved fluorescence spectroscopy,” Journal of Biomedical Optics 10(6), 064026 (November/December 2005).



Instrumentation for temporal fluorescence

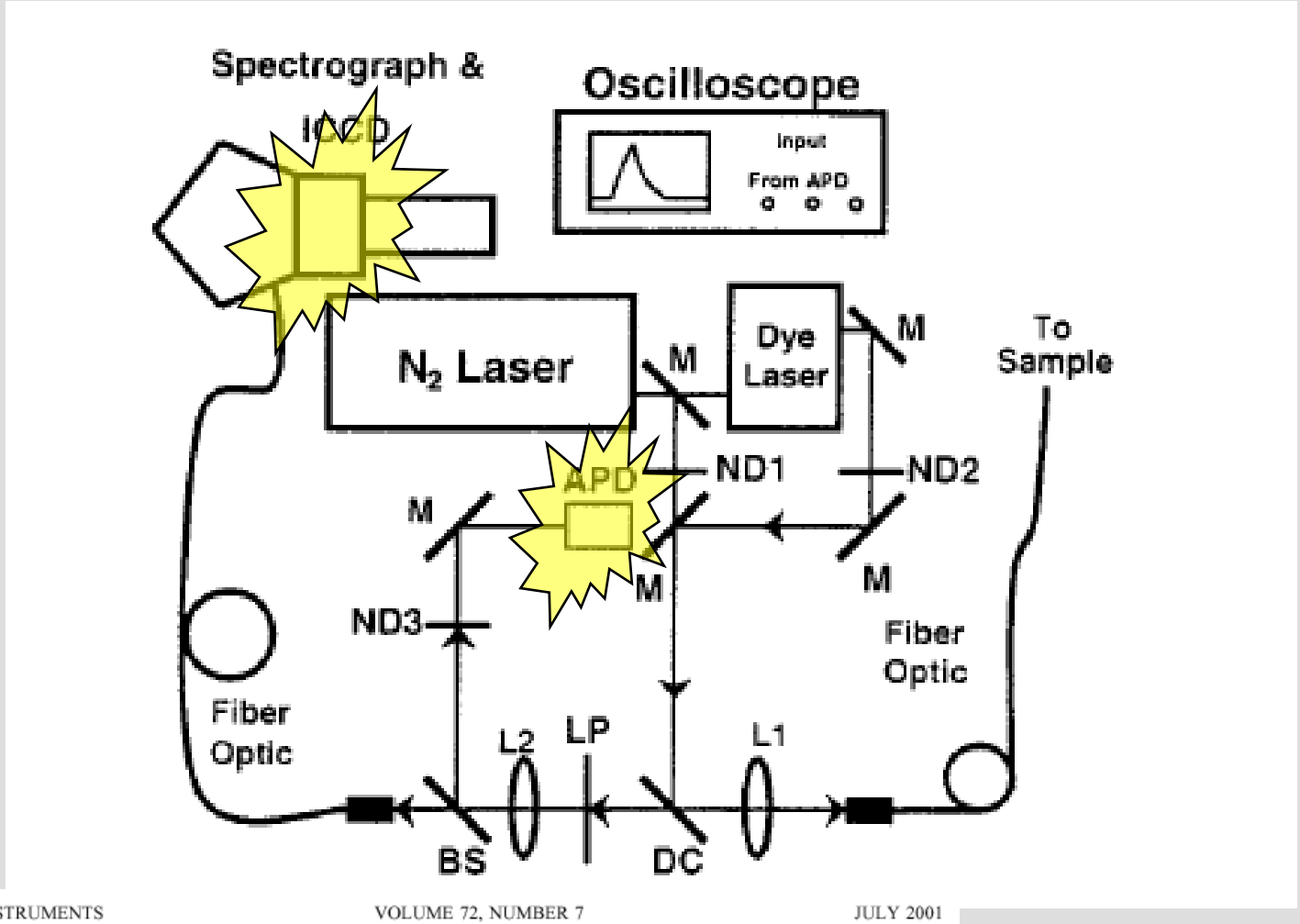


REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 75, NUMBER 1 JANUARY 2004

Time-domain laser-induced fluorescence spectroscopy apparatus for clinical diagnostics

Fang et al.

Same idea, different group!



REVIEW OF SCIENTIFIC INSTRUMENTS VOLUME 72, NUMBER 7 JULY 2001

Design and development of a rapid acquisition laser-based fluorometer with simultaneous spectral and temporal resolution

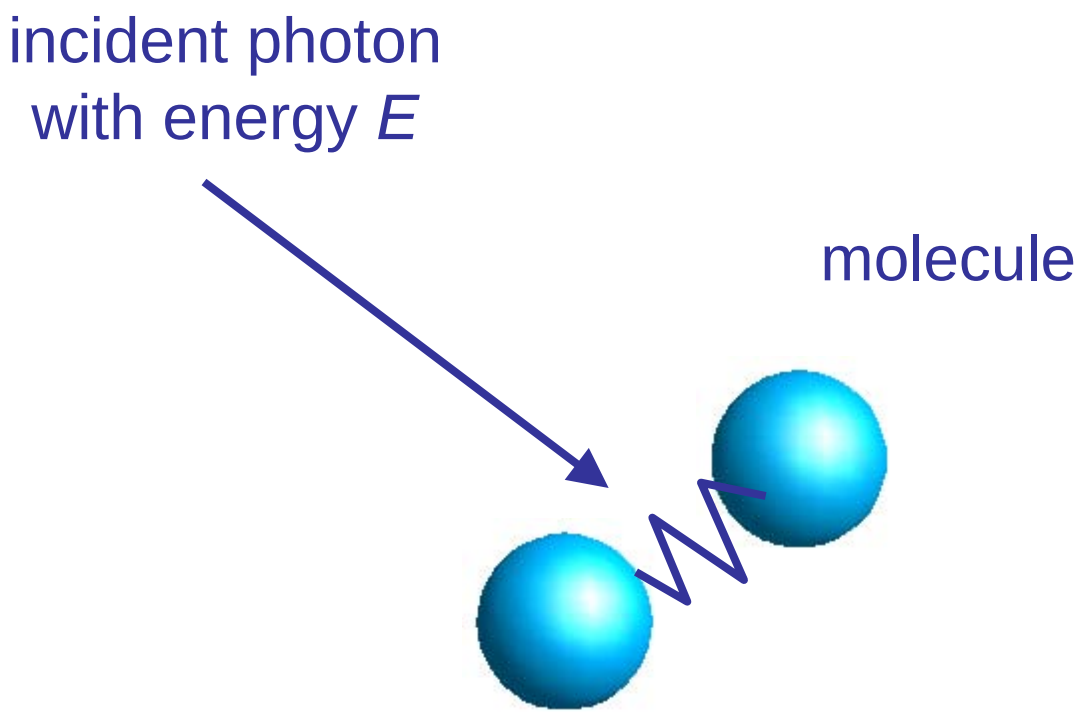
Jonathan D. Pitts and Mary-Ann Mycek[a)]
Department of Physics and Astronomy, Dartmouth College, 6127 Wilder Laboratory, Hanover, New Hampshire 03755

Fluorescence lifetime: goals, requirements

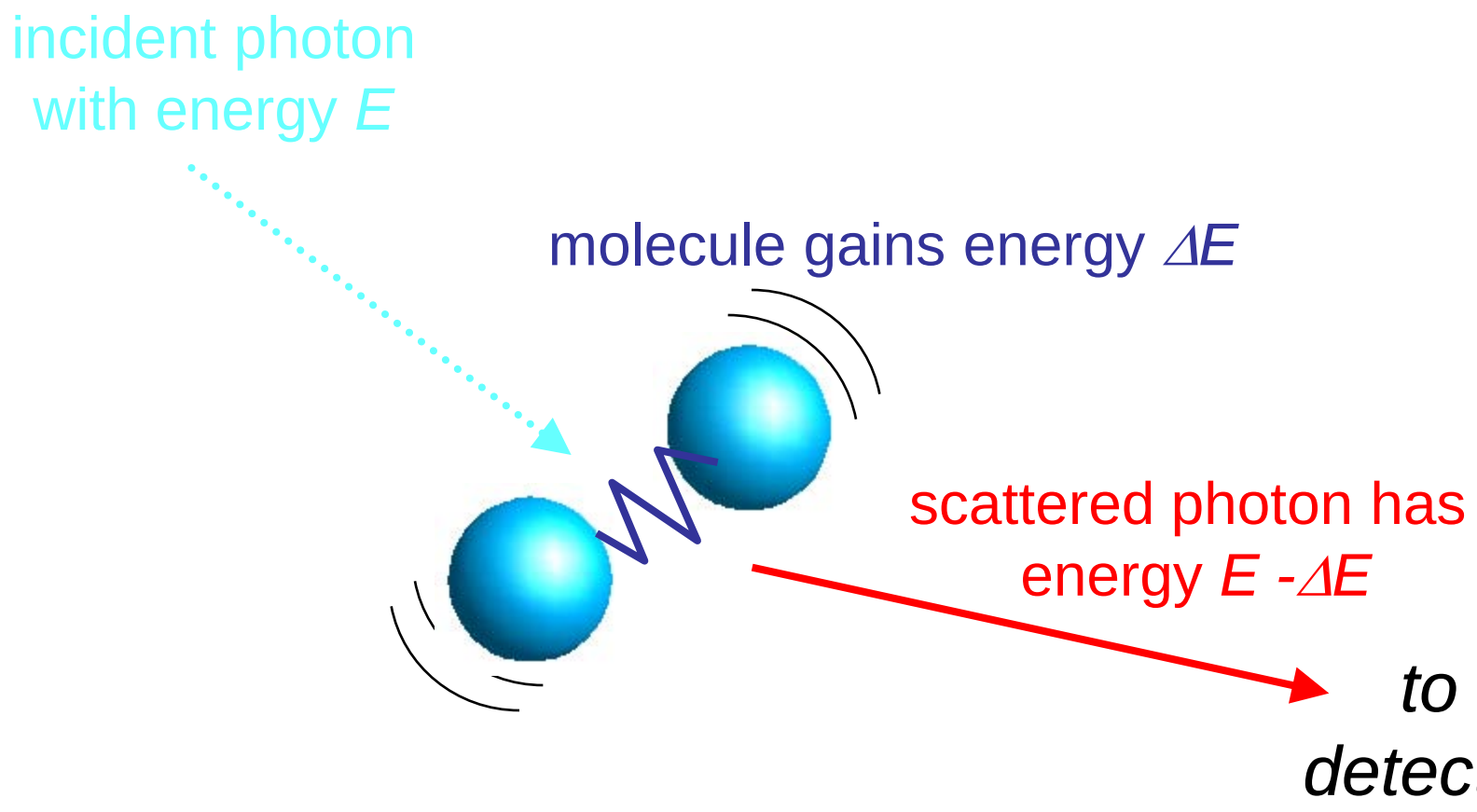
- Distinguish benign from malignant tumor tissue

- Record at many wavelengths
- Time resolution ***required*** to few psec
- ***Desirable*** to record at many locations (imaging)

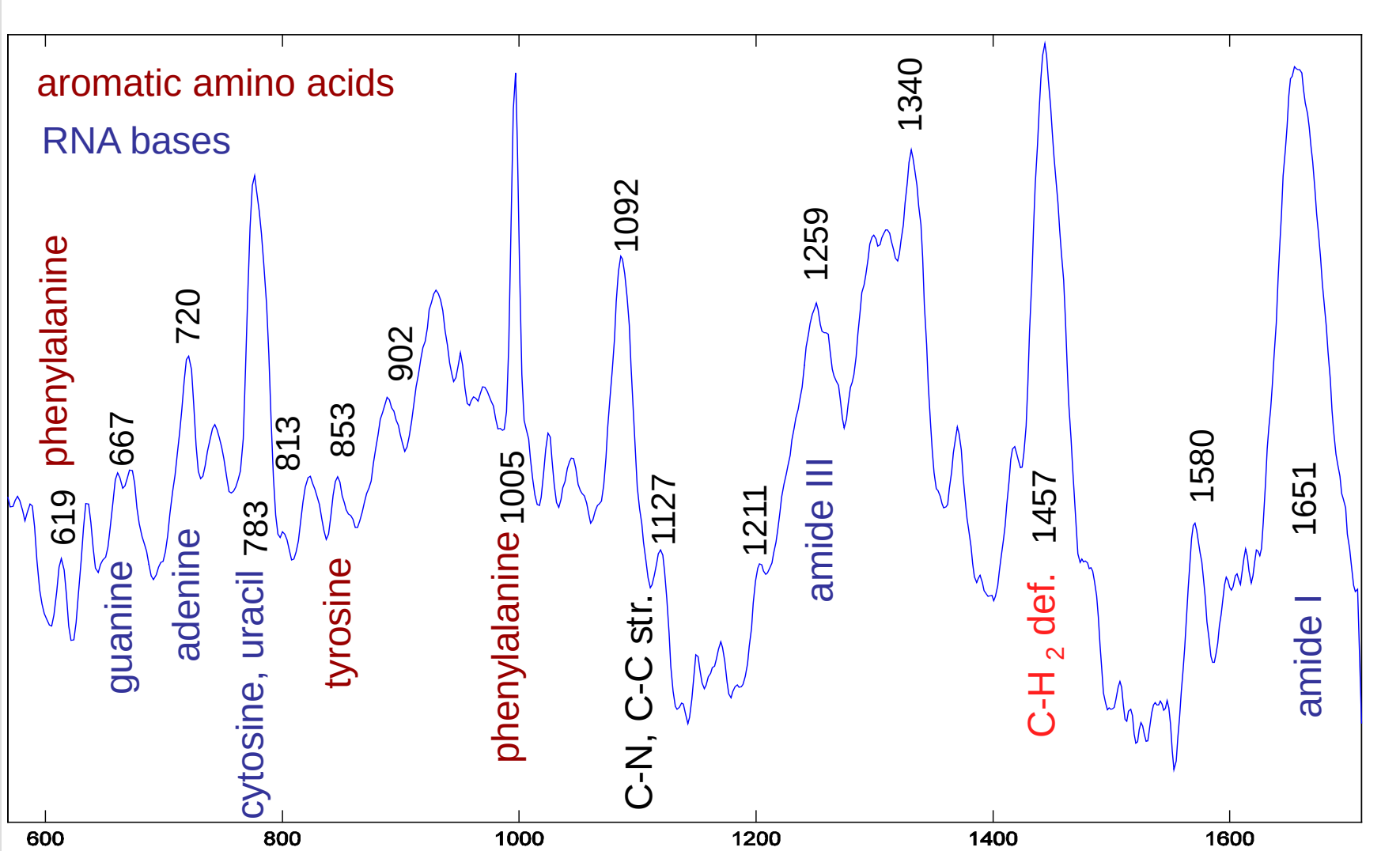
Area #3: Raman spectroscopy



Raman spectroscopy



Raman spectrum of immune cell



Detectors for Raman spectroscopy

- Thermoelectrically-cooled CCD array detectors
- Sensitive out to ~1150 nm, limited by **Si bandgap**
- 25 micron square pixels
- typical dimensions, 256 x 1024 pixels

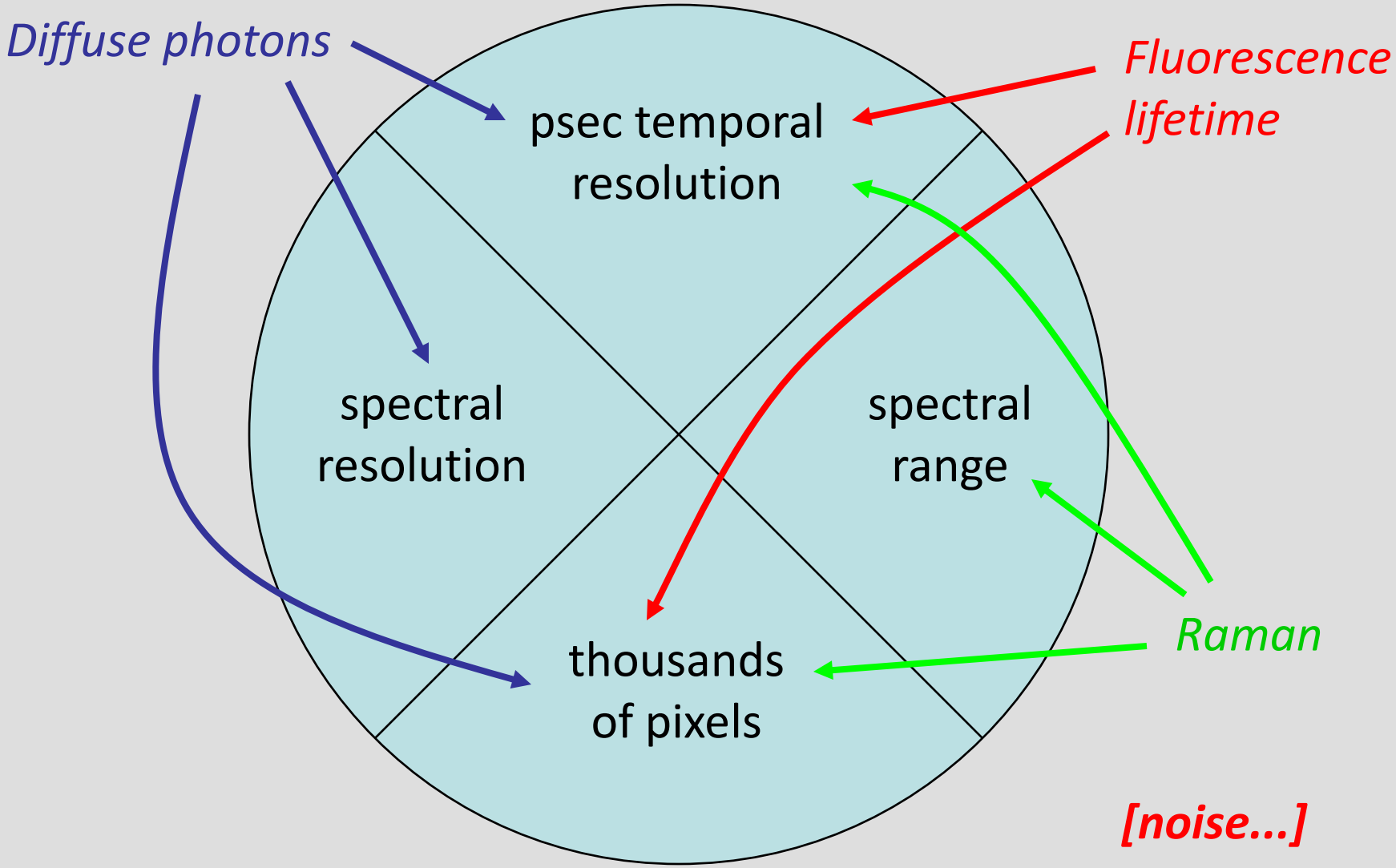
Princeton Instruments PIXIS CCD

Raman spectroscopy: goals, requirements

- Distinguish one cell type/state from another
- Quantify chemical levels in biofluids (e.g. blood)
- Yes, distinguish cancer from non-cancer

- Record at many wavelengths
- Long acquisition times (sec-minutes)
- ***Necessary*** to wavelength-tune down the fluorescence
- ***Desirable*** to time-gate away the fluorescence (intensified CCD or more exotic gating)

Benefits of QLIDs for biomedical optics



Summary

- biomedical spectroscopy: characterize tissue, biofluids, cells
- frequently in near-IR
- multiple factors driving sub-nsec time resolution
- many-many-channel sensing: a game-changer
- get past the Si bandgap cutoff
- spectral resolution at each pixel: good for diffuse spectroscopy

Questions?