CThP4 Fig. 1. Wavelength dependence of the modal gain of quantum-dash lasers with dashes oriented parallel and perpendicular to the cavity axis. Solid lines and solid symbols correspond to the modal gain of the laser with dashes oriented perpendicular to the cavity axis. Dotted lines and open symbols represent the modal gain for the laser with dashes oriented parallel to the cavity axis.

CThP4 Fig. 2. Wavelength dependence of the linewidth enhancement factor for quantum-dash lasers with dashes oriented parallel and perpendicular to the cavity axis.

the cavity axis for the whole wavelength range from 1555 nm to 1640 nm.

While the modal gain results clearly illustrate the polarization dependence expected for this quantum wire-like active media, the difference in the linewidth enhancement factor with orientation also suggests a strong wavelength dependence of the transition matrix element.

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CThQ

2:30 pm-4:15 pm

Room: 101B

Fluorescence Methods for Tissue Characterization

TBA, Presider

CThQ1

2:30 pm

Imaging of Fluorescence, Absorption, and Scattering Properties in Diffuse Media Using Pump and Emission Wavelength Measurements

A.B. Milstein, S. Oh, K.J. Webb, and C.A. Bouman, School of Electrical and Computer Engineering, Purdue University, West Lafayette, IN 47907-1285

R.P. Millane, Department of Electrical and Electronic Engineering, University of Canterbury, Private Bag 4800, Christchurch, New Zealand, Email: webb@ecn.purdue.edu

Optical diffusion imaging, where the scattering and absorption properties of tissue are reconstructed from noninvasive measurements, offers potential advantages of safety and diagnostic specificity over other imaging modalities.¹ In addition, fluorescent contrast agents may provide enhanced chemical specificity, with greater potential to distinguish between diseased and healthy tissue.² Imaging simulations of fluorescence lifetime and yield^{2,3,4} have assumed known scattering and partially known absorption properties. In this work we demonstrate a Bayesian reconstruction in which absorption and scattering parameters at the excitation and emission wavelengths are imaged, in addition to the fluorescent yield and lifetime.

The transport of modulated light (at ω , with $e^{j\omega t}$ variation) in a fluorescent, highly scattering medium can be modeled using coupled diffusion equations:³

$$\nabla \cdot [D_x(r) \nabla \phi_x(r, \omega)] - [\mu_a x(r) + j\omega/c] \phi_x(r, \omega) = -S_x(r, \omega) \quad (1)$$

$$\nabla \cdot [D_m(r) \nabla \phi_m(r, \omega)] - [\mu_a m(r) + j\omega/c] \phi_m(r, \omega) = -\phi_x(r, \omega) [\gamma(r, \omega) + j\beta(r, \omega)] \quad (2)$$

$$\gamma(r, \omega) + j\beta(r, \omega) = \eta \mu_{ax \rightarrow m}(r) \frac{1 - j\omega\tau(r)}{1 + [j\omega\tau(r)]^2} \quad (3)$$

where x and m denote excitation and emission wavelengths, $\phi(r, \omega)$ is the photon fluence, and $S(r, \omega)$ is the source. The optical parameters are the diffusion coefficient $D(r)$ and the absorption coefficient $\mu_a(r)$. The fluorescence parameters are the lifetime $\tau(r)$ and the fluorescent yield $\eta \mu_{ax \rightarrow m}(r)$.²

To image the excitation and emission optical parameters, measurements may be made with a set of sources and detectors at each wavelength. Our proposed reconstruction algorithm⁵ iteratively minimizes a Bayesian cost function to determine the maximum *a posteriori* estimate of the optical parameter image, given a measurement vector. Once reconstructions for $\mu_{ax, m}$ and $D_{x, m}$ are obtained, additional measurements with

sources at the excitation wavelength and detectors at the emission wavelength may be used to reconstruct γ and β (and hence τ and $\eta\mu_{ax \rightarrow m}$) by minimizing a similar objective function.

Figure 1 shows a tissue phantom having background values $\mu_{ax,m} = 0.01 \text{ cm}^{-1}$, $D_{x,m} = 0.05 \text{ cm}$, $\tau = 0.8 \text{ ns}$ and $\eta\mu_{ax \rightarrow m} = 0.002 \text{ cm}^{-1}$. Smoothly tapered spherical heterogeneities are considered,

with μ_{ax} ranging from 0.01 cm^{-1} to 0.07 cm^{-1} , D_x and D_m ranging from 0.024 cm to 0.05 cm , τ ranging from 0.8 ns to 8.0 ns , and $\eta\mu_{ax \rightarrow m}$ ranging from 0.002 cm^{-1} to 0.024 cm^{-1} . The locations of 30 sources (modulated at 100 MHz) and 24 detectors are also illustrated. Simulated measurements with shot noise have a signal/noise ratio of approximately 33 dB for sources and detectors on

opposite faces. Reconstructions of $\mu_{ax,m}$, $D_{x,m}$, τ , and $\eta\mu_{ax \rightarrow m}$ are shown in Figure 2. Despite reduced contrast resulting from the noise, all heterogeneities are clearly present, with accurate shapes and locations. The ability to reconstruct all scattering, absorption, and fluorescent parameters, with none known *a priori*, is important for practical imaging.

References

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CThQ1 Fig. 1. Tissue phantom of dimension 5.8 cm . At the pump wavelength, dark circles represent sources, and white circles represent detectors. At the emission wavelength, crosses represent sources, and white boxes represent detectors. The isosurfaces correspond to: (a) $\mu_{ax} = 0.016 \text{ cm}^{-1}$ and $D_x = 0.043 \text{ cm}$, where the darker tone denotes the absorber, (b) $D_m = 0.043 \text{ cm}$, (c) $\tau = 2.0 \text{ ns}$, and (d) $\eta\mu_{ax \rightarrow m} = 0.007 \text{ cm}^{-1}$.

CThQ1 Fig. 2. Reconstructed phantom, where the isosurface contours are the same as in Fig. 1: (a) μ_{ax} and D_x , with the darker tone denoting the absorber, (b) μ_{ax} and D_m , (c) τ , and (d) $\eta\mu_{ax \rightarrow m}$.

CThQ2

2:45 pm

Spectroscopy of Upconverting Chelates

Gregory W. Faris, Konstantinos S. Kalogerakis, and Megan Hryndza, *Molecular Physics Laboratory, SRI International, 333 Ravenswood Avenue, Menlo Park, CA 94025-3493, Email: gregory.faris@sri.com*

Optical reporter technologies are used in a wide variety of applications, including in vitro biomedical assays and in vivo labeling. With the increasing requirements for molecular understanding of disease and other applications such as high throughput screening, new reporter technologies are needed. We are developing a new class of optical reporter for these applications called upconverting chelates.

Upconversion refers to emission of light at wavelengths shorter than the excitation wavelength. Because only a few very specific compounds exhibit upconversion, measurements using upconverting chelates have essentially no autofluorescent background. The upconverting chelates comprise a lanthanide ion in an organic ligand. Unlike upconverting phosphors,^{1,3} which typically rely on energy transfer for upconversion, the upconverting chelates rely on stepwise excitation, as shown in Fig. 1. Two photons are absorbed followed by emission of a single photon at higher energy. The process can include an intermediate relaxation step as shown in Fig. 1(b). The materials are photostable because the lanthanide ion cannot photobleach. The upconverting chelates possess narrow emission profiles, which is beneficial for multiplexed assays.

We have previously demonstrated upconversion in chelates using a single excitation wavelength in neodymium and other lanthanide ions.