Manipulator-mounted optical/NMR dual-modality probe for multimodality scanning in MR guided and robot-assisted interventions

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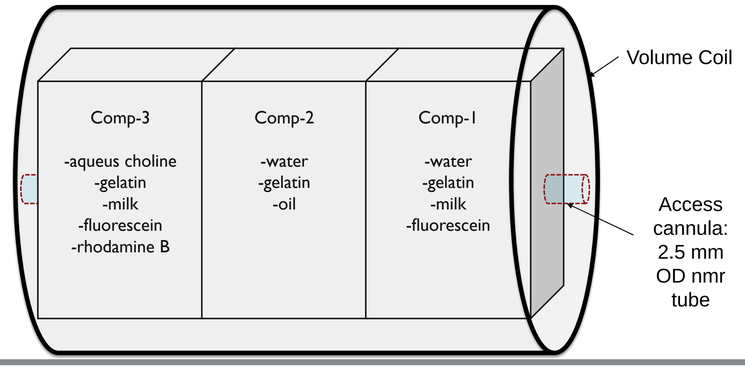
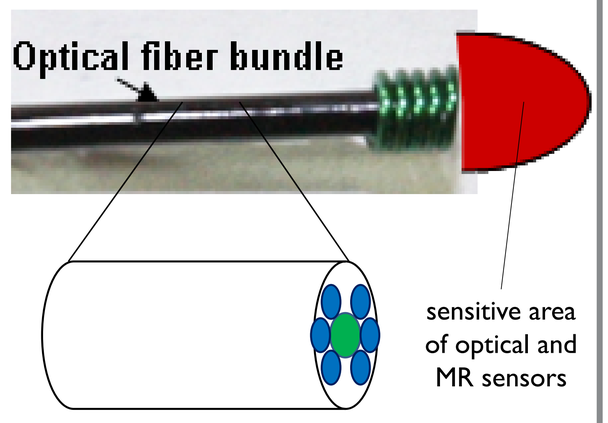
Abstract

Multimodality biosensing is emerging as a valuable approach for characterizing the pathophysiology of tissue. Optical fluorescence and MR spectroscopies (MRS) may offer complementary information about endogenous or exogenous fluorophores and metabolites, respectively. While depth penetration is an issue for optical tomography, endoscopic approaches position the probe near the region of interest, therefore reducing this limitation. Recently the combination of light-induced fluorescence (LIF) and MRS was demonstrated [1]. We describe a forward looking optical/NMR probe for loco-regional in situ biosensing for collecting LIF and 1H MRS from the same region. This dual modality probe was mounted on an MR compatible manipulator to (I) co-register MR image, LIF and MR 1H spectra, and (II) mechanically scan to assess the spatial distribution of fluorophores (from LIF) and metabolite (from MRS).

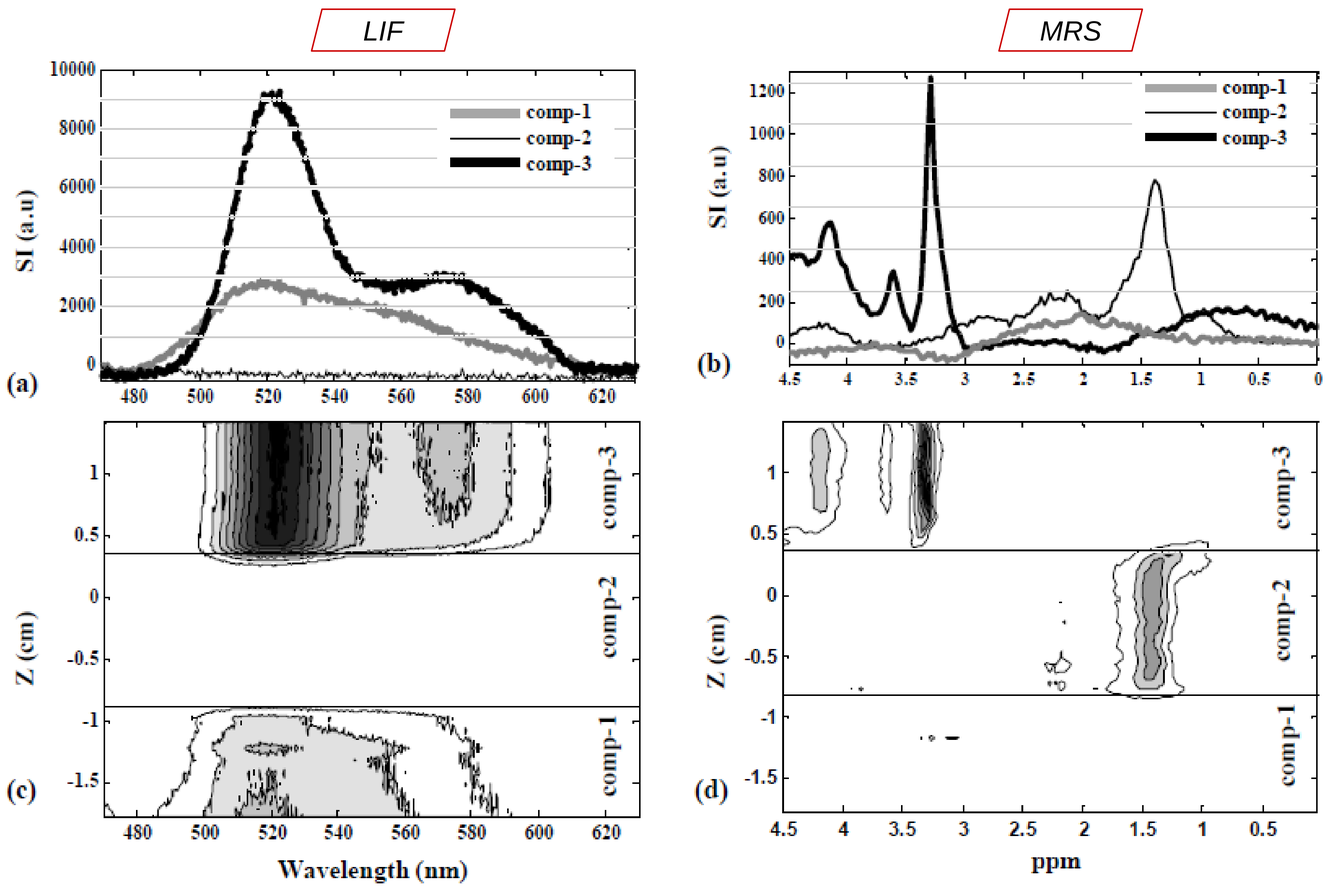
METHODS

- Light Induced Fluorescence (LIF)
  - A 1.25mm OD 7-fiber optical sensor
- Magnetic Resonance Spectroscopy (MRS)
  - An RF coil (OD 2.3mm, length 2.2mm, five turns 26 AWG) for 1.5T, 3.0T or 4.7T





EXPERIMENTAL RESULTS



Motor Status	*Encoder Status*	*Spectra*	*Images*
unpowered	unpowered	12023±487	72.96±2.79
unpowered	powered	11956±570	77.68±3.80
powered (idle)	powered	12294±530	73.34±2.80
powered (running)	powered	12188±648	73.00±2.81

DISCUSSION AND CONCLUSION

The use of MR and optical sensors may have impact in improving diagnosis in situ, as well as in performing basic research in vivo. For instance, it may enhance the detection of tumor margins and even used to guide biopsies [2]. Compared to a prior work that reports LIF/MRS (A) our probe has spatially matched optical and MR profiles (without post-processing) and (B) the side-firing probe scans via an NMR tube that is inappropriate for in vivo and clinical studies [1]. Clinically, the herein described probe can be operated the same way as a standard clinical confocal endoscope (i.e. placed in the scanned area and pulled back [3] or it can be directly mounted on the end-effector distal end). Currently, we investigate other microcoil shapes. In addition, we study the 3D spatial matching of the LIF and MR sensors with simulations (LIF profile with Monte Carlo and coil with Biot-Savart). This type of sensor can be modified, e.g. for optical conference tomography (OCT) and with coils for phosphorous (31P) or sodium (23Na) MRS. We describe a forward looking MR compatible optical/MR probe for assessing the spatial distribution of co-registered optical and 1H signal sources using a mechanical scan.

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This work was supported by the National Science Foundation grant CNS-0932272. All opinions, findings, recommendations conclusions or in this work are those of the authors and do not necessarily reflect the views of our sponsors.