Tissue diagnostics and classification using multimodal fiber-probe spectroscopy

Riccardo Cicchi,[1,2] Suresh Anand,[1] Alfonso Crisci,[3] Flavio Giordano,[4] Susanna Rossari,[5] Vincenzo De Giorgi,[5] Vincenza Maio,[6] Daniela Massi,[6] Gabriella Nesi,[6] Anna Maria Buccoliero,[6] Marco Carini,[3] Renzo Guerrini,[4] Nicola Pimpinelli,[5] and Francesco Saverio Pavone[2,7]

[1] National Institute of Optics, National Research Council (INO-CNR), Largo Enrico Fermi 6 - 50125, Florence, Italy;
[2] European Laboratory for Non-Linear Spectroscopy (LENS), University of Florence, Via Nello Carrara, 1 - 50019, Sesto Fiorentino, Italy;
[3] Division of Urology, Department of Critical Care Medicine and Surgery, University of Florence, Viale Giovanni Battista Morgagni 85 - 50134, Florence, Italy;
[4] Division of Neurosurgery, Department of Neuroscience I, "Anna Meyer" Pediatric Hospital, Viale Gaetano Pieraccini 24 – 50141, Florence, Italy;
[5] Division of Clinical, Preventive and Oncology Dermatology, Department of Critical Care Medicine and Surgery, University of Florence, Piazza Indipendenza 11 – 50129, Florence, Italy;
[6] Division of Pathology, Department of Critical Care Medicine and Surgery, University of Florence, Viale Giovanni Battista Morgagni 85 - 50134, Florence, Italy;
[7] Department of Physics, University of Florence, Via Giovanni Sansone 1 - 50019, Sesto Fiorentino, Italy;

The recent introduction of optical and spectroscopic techniques in the clinical settings contributed to the achievement of a more accurate tissue diagnostics. Most of these techniques are based on tissue auto-fluorescence [1] or on spontaneous Raman scattering [2]. With the technical improvements in optical fiber technology, new flexible fluorescence and Raman probes, employing optical fiber bundles, have been developed [3]. In this study, an optical fiber probe for combined Raman, reflectance and fluorescence with dual wavelength excitation was designed, developed and used for tissue diagnostics. The probe was engineered by using a custom geometry with optical fiber of various size, each of them properly filtered on the distal tip. All fluorescence, reflectance and Raman spectra were acquired using the same detection unit, based on a cooled CCD camera, connected to a spectrograph.

The probe was successfully employed for diagnostic purposes on various tissues in a good agreement with common routine histology. In particular, the developed device allowed classifying: malignant melanoma against melanocytic lesions and healthy skin [4]; urothelial carcinoma against healthy bladder mucosa; brain tumor against dysplastic brain tissue. The diagnostic capabilities were determined using a cross-validation method with a leave-one-out approach, finding very high sensitivity and specificity for all the examined tissues.

The obtained results demonstrated that the multimodal approach is crucial for improving diagnostic capabilities. The system presented here can improve diagnostic capabilities on a broad range of tissues and has the potential of being used for clinical inspections in the near future.

References

[1] G.A. Wagnieres, W.M. Star, and B.C. Wilson, Photochem. Photobiol. **68**(5), 603–632 (1998)
[2] U. Utzinger and R.R. Richards-Kortum, J. Biomed. Opt. 8(1), 121–147 (2003)
[3] N.D. Magee, J.S. Villaumie, E.T. Marple, M. Ennis, J.S. Elborn, and J.J. McGarvey, J. Phys. Chem. B **113**(23), 8137–8141 (2009)
[4] R. Cicchi, A. Cosci, S. Rossari, D. Kapsokalyvas, E. Baria, V. Maio, D. Massi, V. De Giorgi, N. Pimpinelli, and F.S. Pavone, J. Biophoton. **7**, 86-95 (2014)