Opto-Acoustical Feedback System for Smart Laser Surgery

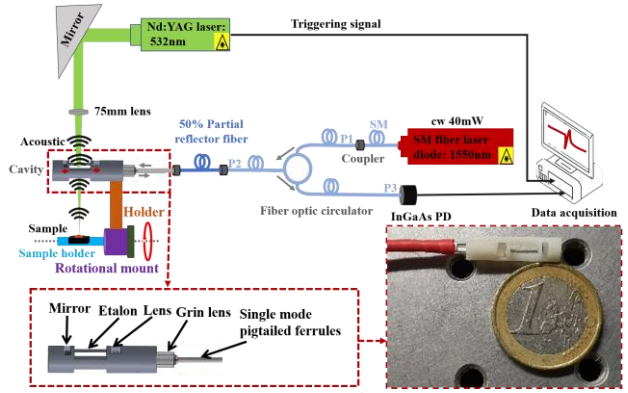

Figure 1: Illustration of the fiber-coupled Fabry-Pérot etalon system (Picture: H. Nguendon Kenhago).

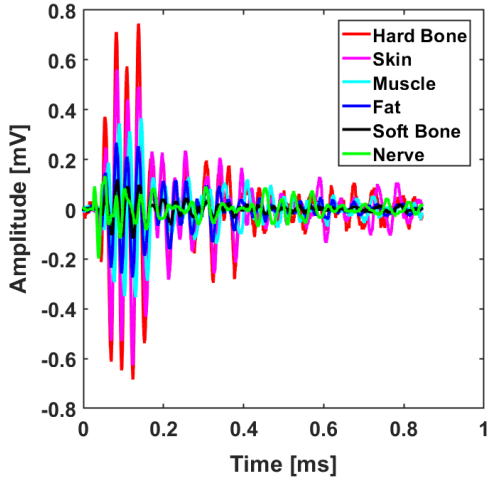

Figure 2: Acoustic shock waves in the time domain (Picture: H. Nguendon Kenhago).

PhD Thesis by Hervé Nguendon Kenhagho at BLOG.

Laser surgery requires efficient tissue classification to reduce the probability of undesirable or unwanted tissue damage. The aim of this study was to investigate acoustic shock wave spectroscopy as a means of classifying sciatic nerve tissue.

In this study, we classified sciatic nerve tissue against other tissue types — hard bone, soft bone, fat, muscle, and skin extracted from two proximal and distal fresh porcine femurs — using the acoustic shock waves (ASWs) generated by a laser. A nanosecond frequency-doubled Nd:YAG laser at 532nm was used to create ten craters on the surface of each tissue type. We used a fiber-coupled Fabry-Pérot sensor to measure the ASWs. The amplitude of the spectrum from each ASW frequency band measured was used as input for principal component analysis (PCA). PCA was combined with an artificial neural network to classify the tissue types. A confusion matrix and receiver operating characteristic (ROC) analysis was used to calculate the accuracy of the testing-data-based scores from sciatic nerve and the area under the ROC curve (AUC) with a 95% confidence-level interval. Based on the confusion matrix and ROC analysis of the model's tissue classification results (leave-one-out cross validation), nerve tissue could be classified with an average accuracy rate and AUC result of 95.78± 1.3% and 99.58± 0.6%, respectively. The results of this work demonstrate the opportunity acoustic shock wave spectroscopy presents for remote classification of nerve and other types of tissue. The technique can serve as the basis of a feedback control system to detect and preserve sciatic nerves in femur laser surgery.

Funding:

WSS
WERNER SIEMENS-STIFTUNG

Supervisors:
Prof. Dr. Azhar Zam
azhar.zam@unibas.ch

Prof. Dr. Raphael Guzman
Raphael.guzman@unibas.ch

Prof. Dr. Philippe C. Cattin
philippe.catting@unibas.ch

References:

1) H. N. Kenhagho, G. Rauter, R. Guzman, P. Cattin, and A. Zam, "Optoacoustic Tissue Differentiation using a Mach-Zehnder Interferometer," IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control, pp. 1-1, 2019.

2) H. N. Kenhagho, F. Canbaz, R. Guzman, P. Cattin, and A. Zam, "Miniaturized Optoacoustic Feedback Sensor for Smart Laser Osteotome: Fiber-Coupled Fabry-Pérot Etalon Sensor," *Sensors and Actuators A: Physical*, p. 112394, 2020.