Abstract

This thesis is on non-invasive elastic property measurement of tissue or tissue-mimicking materials through vibro-acoustography and ultrasound assisted diffusing wave spectroscopy (UA-DWS). Towards this, a known force is applied by focused ultrasound beams and the novel measurement is the set of natural frequencies of vibration of the object defined by the focal volume, also called the region-of-interest (ROI). In the first investigation, vibro-acoustic (VA) secondary waves from the ROI, carrying its resonant modes, reaching the surface of the object, are made use of. A new physical model which explains the transport of local shear waves by modulating the VA wave and using it as a carrier is suggested and demonstrated. Through an eigenvalue analysis of the vibrating ROI (VROI) connection is established between the material properties of the ROI, including Young's and shear modulus, and the measured resonant modes. The measured first natural frequencies from phantoms made of agar are inverted for their storage moduli, which are verified by simulation and independent measurement using a rheometer. The shift of the natural frequency with temperature is used to calibrate temperature at the ROI in tissue-mimicking objects. Through this, a remote temperature sensor for application in an ultrasound hyperthermia system is demonstrated. In the second investigation, ultrasound-assisted diffusing wave spectroscopy (UA-DWS) is adapted to measure many resonant modes of the ROI. The evolution of mean-squared displacement (MSD) obtained through DWS displays a plateau which becomes noisy with the introduction of ultrasound forcing. It is observed that the power spectrum of the fluctuations contains peaks at locations corresponding to many of the natural frequencies of the VROI. With this measurement of a number of resonant modes, recovery of the anisotropic elastic tensor of the material in the ROI is demonstrated in pork fat. This opens up the possibility of imaging progress of malignancy in soft-tissue organs through the components of this tensor. In the final part of the work, rotational diffusion micro-rheology is demonstrated by doing UA-DWS in agar phantoms using non-spherical scattering centres. The main findings of this study is the sharper rise in the transient part of the MSD curve and in the intensity of noise in its plateau leading to a scaling of the complex modulus of elasticity spectrum when compared those from spherical particles. The reason for these differences is owing to the ability of non-spherical particles to capture phase fluctuations arising of both translation and rotation. The modelling of the dynamics of the ROI was done through a generalized Langevin equation (GLE) for a single predominant translational degree of freedom (DOF) system particle representing the ROI. The fluctuations in the plateau are correctly recovered through a multiplicative, internal noise, constructed using micro-polar theory, in the stiffness term. Possibility of morphological characterization of biological cells and their internal constituents is demonstrated through laboratory experiments in phantoms.