DISSIPATIVE AND NON-DISSIPATIVE SHEAR WAVE GENERATION IN MEDICAL ULTRASOUND

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The acoustic radiation force became one of the hottest subjects of research in biomedical ultrasonics during the last decade. Shear waves generated in tissue by focused ultrasound via the radiation force (RF) makes it possible to remotely assess viscoelastic properties of biological tissues for diagnostic purposes. Tissue mechanical properties are highly sensitive to development of disease. Investigation of the RF action in biological media is of great importance for many medical applications related to elasticity imaging, to cancer diagnostics and treatment monitoring.

In this talk, a brief review of physical basics of RF is presented starting from classical works of Lord Rayleigh and P. Langevin and up to a new mechanism for the use of RF in biological tissues. It is indicated that, in spite of century-old history, the physics of RF has not been studied exhaustively yet and there are still grey areas.

To get insight into the physical mechanisms of shear generation, it should be understood that a linear, potential ultrasound in a homogeneous, non-dissipative medium creates only a potential force that does not excite shear deformations. Thus, dissipation of an ultrasound beam is typically considered as a factor necessary for shear generation in water-like media with a small (but finite) shear modulus such as biological soft tissues. Along with examples of the corresponding role of dissipation, we also discuss possible non-dissipative mechanisms of shear generation, namely, the medium inhomogeneity and/or nonlinearity of the primary ultrasound. We propose a new theoretical model of RF generation, which is based on the five-constant theory for elastic solids that is extended to the media with the Poisson's ratio close to 0.5 such as that in soft biological tissues.

Estimates show that in inhomogeneous media at relatively low frequencies when attenuation of ultrasound is small, the non-dissipative RF can exceed the classical dissipative RF. Theoretical predictions are confirmed by published experimental results showing the possibility of the RF increase in soft tissue under the condition when the ultrasound attenuation decreases. Several medical applications of the proposed RF generation mechanism are discussed, such as monitoring of ultrasound hyperthermia therapy of cancer and elasticity imaging with the use of ultrasound contrast agents.

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