Hyperthermia is a new type of cancer treatment in which the tumor target is exposed to elevated temperatures (42–45°C). When the rate of body temperature increment exceeds the ability of the regulation system to dissipate the heat, the cells die. The cells of a solid cancerous tumor are even more sensitive to heat than normal cells. Hyperthermia is usually used in combination with other forms of cancer therapy, such as radiation therapy and chemotherapy. Prolonged exposition to elevated temperature essentially weakens the cancer cells which better react to irradiation or chemotherapy.

Localization is an important factor to consider when applying hyperthermia in medicine. When treating the tumors with the so-called whole-body hyperthermia there is a risk that achieving a therapeutic temperature at the cell level will cause the excessive surface heating. Consequently, producing localized deep heating is of main interest.

The heating of cancerous tissues can be accomplished by several means, like microwave irradiation applied via radiofrequency antennas (dielectric heating), Ohmic heating via electrode-applied high frequency currents, optical laser irradiation via fibres, water bath heating or ultrasonic heating. Ultrasonics in the field of medicine was oriented to applications in therapy and its heating and dissociation effects were used on biological tissues. Ultrasonic therapy uses of high-intensity ultrasounds in order to induce changes in the state of the tissue by means of their thermal and other effects. It has been known for some time that ultrasonic irradiation interacts with biological tissue and can serve as a mean for the treatment of different diseases. The main problem is the accuracy in the method of directing controlling the heat. Therapeutic ultrasound can be divided into two classes: at low intensities, and at higher intensities. High intensity, focused ultrasounds are much more effective but they can result in negative impact on healthy tissue so in hyperthermia application low intensity ultrasounds are usually used. Vibration due to passage of ultrasound waves through tissues causes the displacement of tissue molecules. Heating is produced as a result of the absorption of this ultrasound vibration in the tissue. Thus the effectiveness of ultrasounds for medical purposes can be significantly improved by using the so-called sonosensitizers that can enhance the thermal effect of ultrasound on tissue by increasing US absorption. One possible candidate for such sonosensitiser are nanoparticles with mean sizes of 10-300 nm that can be efficiently heated in aqueous suspensions due to additional attenuation and scattering of ultrasounds.

In our proposal we would like to test another good candidate for sonosensitizer that is magnetic nanoparticles. Solid ferromagnet or ferrimagnet particles that have a characteristic dimension of d ~ 10 nm are single domain and possess a magnetic moment proportional to the volume of the particle. Dispersed in the carrier liquid they form so-called magnetic fluid. Magnetic fluid, being a suspension of solid nanoparticles in a carrier liquid, exhibit the additional attenuation of ultrasound wave caused by ultrasound scattering and extra absorption arising from viscous relative motion losses and heat exchanges losses at the interfacial boundary.

On the other hand, magnetic nanoparticles are able to produce heat – magnetic hyperthermia. Magnetic particle hyperthermia improves the precision of heating by embedding the heating source (magnetic particles) into the tumour tissue and heating it using an external alternating magnetic field. The heating effect of magnetic nanoparticles is a result of an absorbing energy from the alternating magnetic field and conversion of it into a heat. This phenomenon can set two ways mainly: (1) hysteresis losses during reversal of magnetization and (2) relaxation losses accompanying demagnetization. Thermal energy from a hysteresis loss depends on the type of the remagnetization process over certain portions the magnetization curve is irreversible and the energy of the magnetic field is dissipated into the medium with each flux-reversal cycle in the form of heat. Another mechanism of the heating effect is associated with a lag between the field and magnetization due to the relaxation nature of the magnetization process in nanoparticles. There are two mechanisms by which the magnetization may relax after removing the applied magnetic field: the Brown and the Neel one. The Brown mechanism involves rotations of the entire nanoparticle relative to the surrounding medium, with its magnetic moment locked in an axis of easy magnetization. In the case of the Néel mechanism, the magnetic moment may reverse direction within the particle by overcoming the energy barier.

Now, it is obvious that both methods of hyperthermia are characterized by a limited effectiveness if the undesired side effects need to be avoided. The synergetic application of ultrasonic and magnetic hyperthermia can lead to the new treatment modality with shorter time regimes, lower intensities of ultrasound and minimal use of magnetic material delivered to the body. Magnetic nanoparticles that have been inserted into tissue not only enhance the effectiveness of ultrasonic hyperthermia due to the increase of the coefficient of ultrasound absorption but also become the source of additional heating, the amount of which can be controlled by the magnetic field. This new therapy would be safer for healthy tissues due to better controlled temperature by means of alternating magnetic field.