Experimental Setup for Estimation of the Parameters for Magnetic Permeabilization of Biological Objects

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Abstract. *The computerized experimental setup for investigation of the cuvette parameters for further application in the field of contactless permeabilization of the biological objects such as cells, fungi or bacteria by subjection to the high pulsed magnetic fields has been developed. The experimental facility was automated using LabVIEW software package. The setup allows investigation of the high current pulse form, estimation of the resultant magnetic and induced electric fields and evaluation of the heat generated due to Joule heating based on the cuvette size, inductive coil structure and current pulse parameters. Application of the proposed facility creates opportunity to define critical parameters of the cuvettes for magnetic permeabilization in order to prevent other factors such as temperature influencing the outcome of the experiment. Also the setup provides possibilities for the calibration of the magnetic field generators for use in the field of magnetoporation.*

Keywords: Magnetoporation, Pulsed Magnetic Field, Joule Heating, Cuvette, Biological Cells

1. Introduction

Magnetic permeabilization or magnetoporation of the biological objects by application of pulsed high magnetic fields in the range of 4 – 15 T is gaining value in the field of biotechnology, environmental sciences and biomedicine as a contactless technique causing effects similar to electroporation such as reversible or irreversible permeabilization of the thin bilayer lipid membrane of the biological samples [1]. However, even though the technique has some superior features compared to electroporation, the generation of high pulsed magnetic fields requires peak currents in the range of 0.5 – 2 kA, the structure of the cuvette for magnetoporation is more complex, and the estimation of the generated magnetic and induced electric field the biological objects are subjected to is not as straightforward as in the electroporation case [2]. Other factors influencing the treatment such as the heat generated due to Joule heating should be also eliminated, therefore, certain limitations of the allowed treatment intensities or the number of pulses for each cuvette is specific. All these problems created a requirement to develop a computerized measurement system, which could allow efficient estimation of the cuvette output parameters, limitation of the maximum allowed pulse parameter values and also accurate calibration of the magnetic field facilities for application in the field of magnetoporation.

2. Subject and Methods

The structure of the cuvette that is applied for magnetoporation consists of an inductive coil having a form of a solenoid and a plastic container inside the coil where the cells are put. When the high current is flowing through the coil high magnetic field and induced electric field are generated inside the plastic container, which results in the contactless permeabilization of the biological samples. According to the Biot-Savart's law the magnetic field is proportional to the peak current flowing through the coil [3]. The most significant factor limiting the current is the heat that is generated due to the Joule heating [4]. It should be noted that during the treatment the temperature inside the cuvette should not exceed 32 – 37 ^{o} C because it could severely distort the experimental results and overall evaluation of the efficiency of the technique. Therefore, the maximum allowed values of the pulse parameters for each cuvette should be defined. The measurement and calibration setup should be able to measure two main parameters such as the current waveform and the temperature inside the cuvette. The resultant magnetic field and the induced electric field inside the coil could be evaluated analytically or either measured using magnetic field sensors [5]. The block diagram of the proposed measurement facility is shown in Fig. 1.

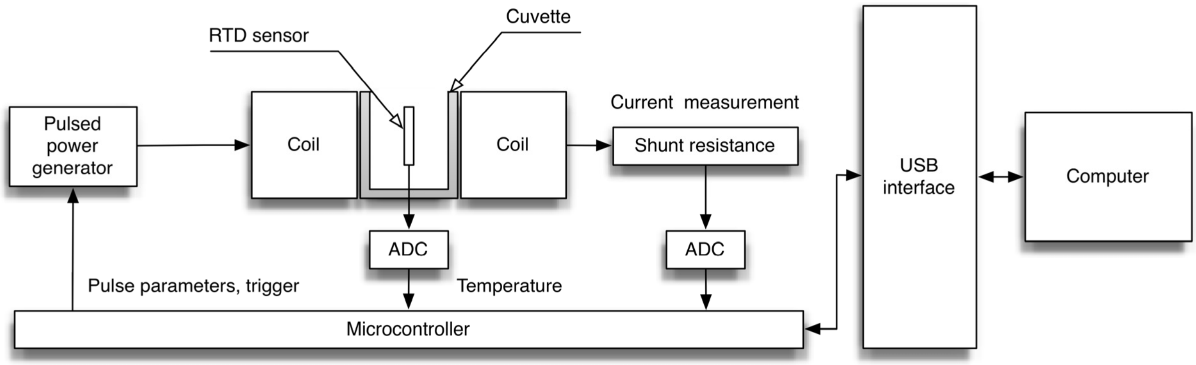

Fig. 1. The block diagram of the proposed measurement and calibration setup

The processing units of the facility are the computer and the microcontroller. The microcontroller based on the instructions received from the computer user configures the output parameters of the pulsed power generator and simultaneously triggers both pulse generation and measurement of the output parameters. The measurement modules are the temperature sensor and a shunt resistance with analog to digital converter for current pulse acquisition. The synchronization is achieved by application of high-speed dual channel optocouplers, which are not shown on the block diagram. The data from the temperature sensor and the microcontroller is further post processed using LabVIEW software package. Based on the coil parameters that are submitted by the user in the beginning of the experiment and the measured current waveform, the program analytically estimates the generated pulsed magnetic and induced electric fields inside the cuvette. The temperature response is also monitored and recorded throughout the whole experiment. It is possible to select an automatic calibration mode when the facility repeats the pulse generation and measurement until the temperature does not exceed the desired value. If the measured temperature value is higher than the desired one, the current is reduced and after a time pause required for the coil to cool down the experiment is repeated. As a result it is possible to classify any coil that is used for the magnetoporation and define the maximum allowed parameters. Also it is possible to determine the parameters required for different coils to generate same magnetic field. If the coil structure is complex, it is possible to connect an external magnetic field sensor. Application of the proposed measurement and calibration facility simplifies the methodology and the analysis of the cuvettes for magnetoporation, which could result in further popularisation of the magnetic permeabilization technique.

3. Results and Conclusions

A computerized measurement and calibration facility for estimation of the parameters of the magnetoporation cuvettes has been developed. The resultant facility is compact and fully automated, which simplifies the analysis of the cuvettes of any shape and size. Application of the proposed setup ensures that during magnetoporation there will be no thermal influence on the samples and the parameters of the generated pulsed magnetic and induced electric fields could be accurately determined. The photograph of the facility in the Vilnius High Magnetic Field Centre is shown in Fig. 2.

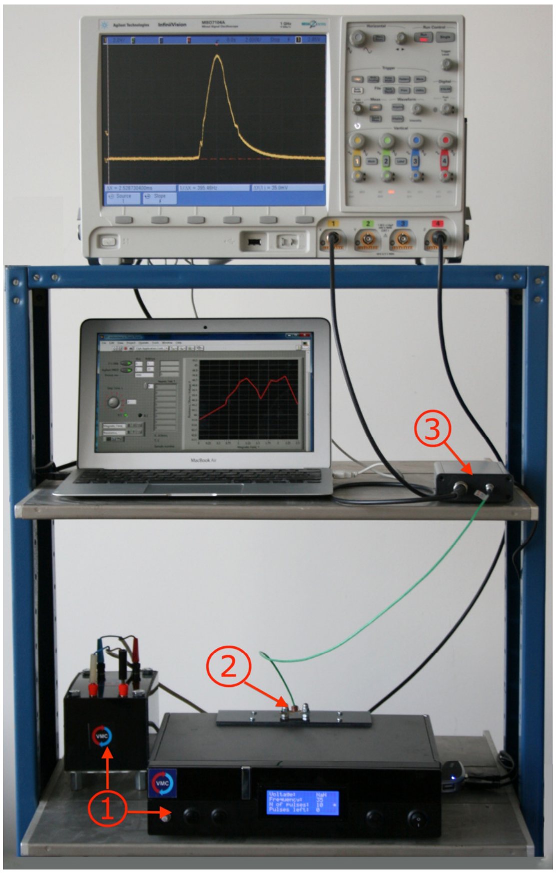

Fig. 2. Photograph of the measurement and calibration facility; 1: pulsed power generator; 2: magnetoporation cuvette; 3: ADC and data processing unit.

The magnetoporation cuvettes could be easily switched. Also other laboratory equipment such as an external oscilloscope could be additionally implemented in the setup as shown in the photograph, which offers flexibility in the acquisition of the experimental data.

References

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