Workshop on "Pulsed electric fields: a multi-level view from molecular interactions to medical treatments"

Developments on High-Voltage Generators and Exposure Chambers for Nanosecond Pulsed Electric Fields (nsPEFs)

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In this abstract, we propose current developments and trends on high-voltage generators and exposure chambers for nanosecond pulsed electric fields (nsPEFs). Using the frozen-wave concept [1], a high-voltage generator delivering nanosecond duration unipolar pulses or with a second delayed positive or negative polarity is presented [2]. A new designed 2-port coaxial box allows to introduce a time delay between the positive or the negative polarity of the generated pulses. For this generator configuration, one photoconductive switch (PCSS) is embedded in the 2-port coaxial box and one PCSS in a 3-port coaxial box [2,3]. The PCSS are triggered through an aperture in the boxes with a high-energy mode-locked Nd:YAG laser (PL2241A, Ekspla, Lithuania) operating at 1064 nm and generating 2 ns optical pulses. Unipolar, bipolar, or paired pulses are generated by connecting a 50 Ω terminator, short circuit, or open circuit, respectively, at the output of the 2-port coaxial box. The duration of the interphase delay is determined by the length of the transmission line at the output of the 2-port coaxial box. Electromagnetic measurements and numerical simulations allowed to assess frequency characteristics of the 2-port coaxial box and time domain evolution of the generated pulses. High-voltage measurements of the generated pulses with various conditions (bias voltage, duration of the delay, positive or negative polarity) were carried out. Ultra-short pulses with durations between 2 ns and 30 ns and voltages up 12 kV were delivered with this generator by varying the length of the coaxial cable connecting the two boxes. We explored the limitations of different components such as the PCSS switching times and recovery, the connectors frequency bandwidth, the pulses rise times and durations as a function of the optical energy. Using this type of generator, we have also measured and simulated the applied pulses on typical exposure chambers such as wire electrodes and electroporation cuvettes [2,4]. We currently explore exposure chambers designs for delivery of pulses with subnanosecond durations. In the past years, several biomedical studies investigated the effects of nanosecond bipolar pulses with delayed negative polarity, within the 0.1–50 µs interval, in the context of electropermeabilisation [5,6]. With the generator proposed in this study, we are able to go beyond the time interval considered so far exploring bipolar cancellation for interphase delays as short as few ns [3]. These developments would allow further exploration with asymmetric and delayed ultra-short pulse generators of biological effects.

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