# Shock wave in water generated by corona-like multi-streamer discharge

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**Abstract**

The paper reports on the first results of apparatus for converging cylindrical shock wave in water (SHOW device). The first part of this paper describes parameters of the corona-like multi-streamer discharge. In the second part the results of a combined schlieren/shadow diagnostic technique are reported. The experiment is aimed at obtaining parameters of the shock wave and its focus.

**Keywords:** Shock wave in water, Corona-like multi-streamer discharge

**Introduction**

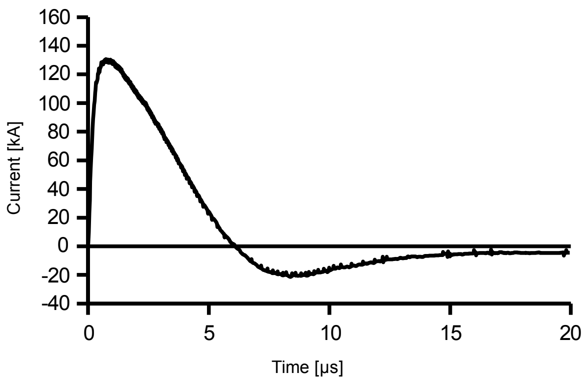
Spherically focused (into one point) shock wave in water produces extreme pressures that have various applications [1]. However, there is another class of applications (X-ray lasers at shorter wavelengths [2], alternative concepts for inertial confinement fusion [3, 4], etc.) that require cylindrical symmetry with extreme parameters on the axis. This can be reached either by exploded cylindrical nest of wires in water [5], or by a pulsed multi-streamer discharge generated at the cylindrical wall of the experimental chamber filled with well conducting water. Our preliminary estimates show that the pressure close to 1 GPa in line focus is quite realistic [6].

Last year a new apparatus - SHOW (SHOck Wave) was designed and built. The apparatus is intended to produce focused cylindrical shock wave and consists of a capacitor bank, a spark gap and a conducting water filled cylindrical experimental chamber Ø40x20 cm. The capacitance of the bank is 18 μF/50kV. The shock wave is initiated by a pulsed multi-streamer discharge generated at the inner cylindrical wall covered by porous ceramics (that serves as a grounded electrode). A co-axial metallic mesh placed on the diameter of 30cm, serves as a high-voltage electrode, which is transparent for the shock wave. Evidences of the shock wave have been published earlier [6, 7]. Among the main characteristics of the shock wave belong the dependence of pressure amplitude on time and the dimensions of shock wave focus (volume with the maximum pressure amplitude). Schlieren/shadow diagnostic technique and piezoelectric pressure sensors were used.

**Shock wave generation**

Corona-like multi-streamer discharge used for generation of the shock wave had the following parameters: the multi-streamer discharge current amplitude was approximately 130 kA and the current rise time (from 10% to 90%) was ~1.5 μs (Fig. 1a). In this case the charging voltage of the capacitor bank was 30 kV (energy output ~8.1 kJ). A current density was 518 kA/m$^2$ and the surface energy density was 32 kJ/m$^2$. Both these last parameters were measured at the inner surface of the experimental chamber (at the ground electrode).

a) b)



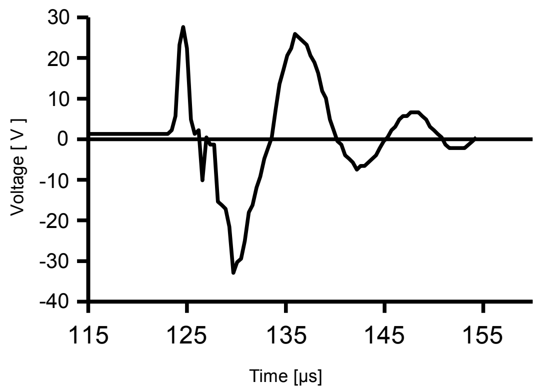
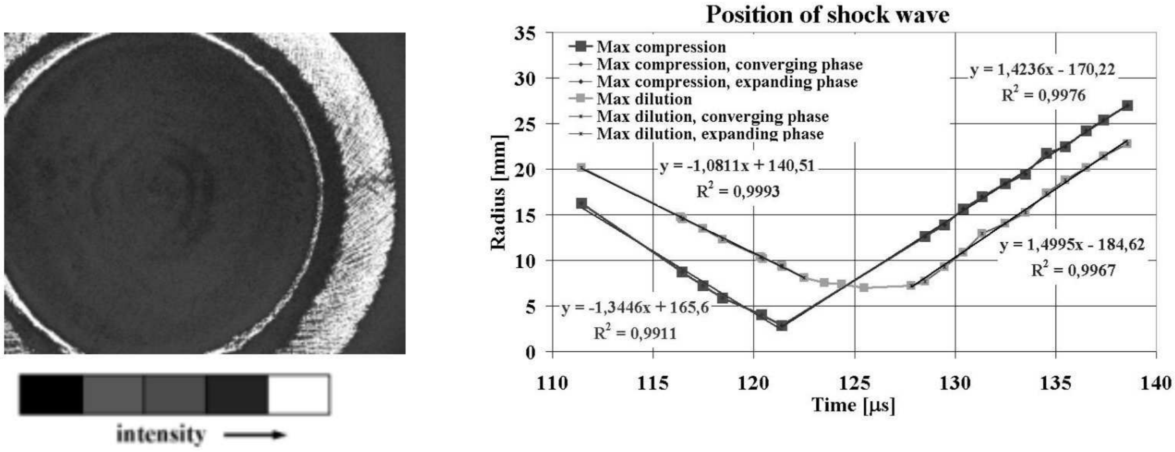




Figure 1: a) The current time-curve of the corona-like multi-streamer discharge, charging voltage 30kV b) Signal of piezoelectric pressure sensor.

**Shock wave observation**

For imaging of the shock wave a combined schlieren/shadow diagnostic technique was used, which can show a shape of the shock wave. The diagnostic set-up consists of CCD camera, schlieren target (Ø31/5 mm), lens (focal length 310 mm, Ø80 mm), experimental chamber, telescope (Ø2x60 mm ) and laser (wave length 532nm, energy 400mJ, pulse duration 5 ns). Figure 2a displays the shape of the shock wave (field of view is 47 mm). The inner thin circle represents the compression phase, while the outer thick circle is interpreted as a rarefied phase. Other measurements indicated that maximum compression takes place ~125 μs after the discharge. Another characteristic of the shock wave is the time development of the pressure amplitude. For the first estimates of the pressure amplitude we took the focus radius $r \sim 1$ mm; in this case the pressure in the focus is of the order of 1 GPa [6]. The dependence of position of the shock wave on time – as measured by combined schlieren/shadow diagnostic - is shown in Fig. 2b. Time is measured from the beginning of the discharge.

According to this Fig. 2b the shock wave arrives to the focus ~122-125 μs after the discharge and the focus radius is ~2,8 mm.




a) b)

Figure 2: a) Axial schlieren photography taken 107 μs after the discharge b) Position of maximum compression and maximum dilution as a function of time – evaluated from the off-axis shadowgraphy

A piezoelectric pressure sensor was used to measure the dependence of pressure on time. The sensor (piezoelectric foil 7x30 mm) was stuck on PMMA stick (Ø 10 mm) and placed into the experimental chamber in coaxial position. It means that the pressure sensor was placed ~4 mm from expected volume with maximum pressure amplitude. The voltage temporal response of the sensor is shown in Fig. 1b and it shows that the shock wave reaches the sensor ~124 μs after the discharge. Similar result was obtained by the combined Schlieren/shadow diagnostic.

## Conclusion

At charging voltage of the capacitor bank 30 kV the current amplitude of the corona-like multi-streamer discharge reached 130 kA. The combined schlieren/shadow diagnostic technique was used for imaging of the shock wave as well as for the first measurement of the dependence of the shock wave position on time. The diagnostic showed that the maximum compression takes place slightly before 125 μs after the discharge. This was confirmed also by the piezoelectric foil pressure sensor.

The time when the shock wave reaches the axis of experimental chamber is very important not only for other experiments connected with the shock wave, but also for a wire explosion in a locally compressed water.

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