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Electric Field Measurements in Nanosecond Pulse Discharges in Air over Solid and Liquid Dielectric Surfaces

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Electric field in nanosecond pulse discharges in ambient air is measured by picosecond four-wave mixing, with absolute calibration by a known electrostatic field. The measurements are done in a discharge between two parallel cylinder electrodes covered by quartz tubes, and in a discharge between a razor edge high-voltage electrode and a plane grounded electrode covered by a quartz plate or by a layer of distilled water. In the positive polarity discharge between the parallel cylinders, peak electric field, 140 kV/cm, considerably exceeds DC breakdown threshold. In the negative polarity discharge between the razor blade and quartz surface, the field follows the applied voltage until "forward" breakdown occurs, after which the field in the plasma decays due to charge separation. When the applied voltage is reduced, the field reverses direction and increases again, until the "reverse" breakdown occurs, producing a secondary reduction in the field. Spatially resolved measurements show that the discharge develops as a surface ionization wave. Measurements of electric field vector components demonstrate that the vertical field in the wave peaks ahead of the horizontal field. Behind the wave, the vertical field remains low, while the horizontal field is gradually reduced. In the discharge over water surface, electric field is measured for both positive and negative pulse polarities, with durations of about 10 ns and about 100 ns, respectively. In the positive polarity pulse, breakdown threshold is 85 kV/cm, and no field reversal is detected during the voltage reduction. In the negative polarity pulse, breakdown occurs at 30 kV/cm, due to much longer pulse duration, and the field reverses direction when the voltage is reduced. After the pulse, the residual field over quartz and water surfaces decays on a microsecond time scale, due to surface charge neutralization by charge transport from the plasma. The results demonstrate considerable potential of the present technique for electric field measurements in atmospheric pressure discharges, providing quantitative insight into charge transport and plasma kinetics near plasma-liquid interface.