Field Enhancement and Radio Emissions from Head-on Collision of Streamers

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Streamers are cold ionized filaments that advance due to electron impact ionization at their tips [Bazelyan and Raizer, p.6, 2000]. The polarity of positive or negative streamers can be identified by the sign of the charge in their heads. It is believed that encounters of positive and negative streamers are very common in negative leader stepping processes and in laboratory discharges as streamers with different polarities propagate in opposite directions. From recent experimental results of meter-scale sparks, it has been proposed that head-on collisions between positive and negative streamers could produce extremely strong electric fields that might be responsible for the production of thermal runaway electrons and X-rays [Cooray et al., J. Atmos. Sol. Terr. Phys., 71, 1890-1898, 2009; Kochkin et al., J. Phys. D: Appl. Phys., 45, 425202, 2012]. However, more recent theoretical studies suggested that the head-on collision of streamers (with lengths <0.4 mm) was unlikely to produce significant X-ray emission due to the collapse of the strong field in an extremely short timescale of a few picoseconds [Ihaddadene et al., Geophys. Res. Lett., 42, 5644-5651, 2015; Köhn et al., Geophys. Res. Lett., 44, 2604-2613, 2017].

Our previous 2-D modeling studies of isolated streamers initiated from hydrometeors in $1.5E_k$ ambient field show that the peak electric field in the streamer head is not strong enough to produce thermal runaway electrons, and that the radio emissions from the streamer current can reach high frequency and very high frequency bands of the electromagnetic spectrum [Shi et al., J. Geophys. Res. Atmos., 121, 7284-7295, 2016]. In this talk, we will report the simulation results of streamer collision that leads to strong field enhancement, exceeding the critical field for production of thermal runaway electrons during the encounter of positive and negative streamers with lengths of ~1 cm. The streamers are initiated in overbreakdown field conditions, $\sim 1.5E_k$, which may be found during the corona flash stage of negative leader stepping [Bazelyan and Raizer, p.197, 2000]. The results show that when the distance of the initiating plasma clouds is larger, the maximum field during the head-on collision of streamers becomes larger, and the duration of the high field ($>10E_k$) also becomes longer. Under otherwise the same conditions, when one streamer encounters another with bigger streamer radius, both the maximum field and its duration become larger. Finally, we find that ultra high frequency or even super high frequency radiation can be emitted during the head-on collision of streamers under overbreakdown field conditions.