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Are encounters between negative and positive streamers likely to produce X-rays?

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The underlying processes responsible for the production of high-energy radiation (X- and gamma rays) recently discovered in thunderstorms are not fully understood [e.g., Dwyer et al., Space Sci. Rev., 2012]. In particular, it has been shown that stepped leaders produce X-ray bursts synchronized with the occurrence of new steps [Dwyer et al., GRL, 32, L01803, 2005]. However, as the physical processes responsible for the mechanism of stepping are also unknown, the complete causal chain between leader propagation and X-ray production is not established yet. Laboratory studies of spark and leader discharges and their associated X-ray production are performed precisely to address this point.

A consensus exists that in the case of production by leaders, X-rays are due to bremsstrahlung emission from thermal runaway electrons. Thermal runaway electrons are produced through the acceleration of thermal electrons by extreme electric fields (E>250 kV/cm at ground pressure). These electric fields could be produced over short durations at the tips of streamer discharges [Moss et al., JGR, 111, A02307, 2006; Celestin and Pasko, JGR, 116, A03315, 2011]. Some authors have recently suggested that encounters between negative and positive streamers could strongly enhance the electric field, and hence would be responsible for X-ray production [Cooray et al., JASTP, 71,1890, 2009; Kochkin et al., J. Phys. D: Appl. Phys., 45, 425202, 2012]. Moreover, encounters of streamers with different polarities are very common. Indeed, during the formation of a new leader step, the negative streamer zone around the tip of a negative leader and the positive streamers initiated from the positive part of a bidirectional space leader strongly interact. In laboratory sparks, when positive streamers are approaching a sharp cathode, negative streamers are initiated from the cathode and collide with the positive streamers. Given that positive and negative streamers carry positive and negative charges at their fronts, respectively, it is reasonable to consider that the electric field between a negative and a positive streamer would increase as the two streamers are getting closer. However, this problem is more complex than it seems because an increase of the electric field above the breakdown threshold will increase the charge density at this location, which in turn, will tend to screen out the electric field. One clearly sees that this is in fact a complex non-linear problem that depends on the dynamics of both streamers.

In this work, we will simulate numerically encounters between negative and positive streamers in order to examine the behavior of the maximum electric field that can be reached. We will determine if such collisions are likely to increase the electric field up to magnitudes sufficient to produce thermal runaway electrons and the associated X-rays.