Scientists Control Plasma Bullets

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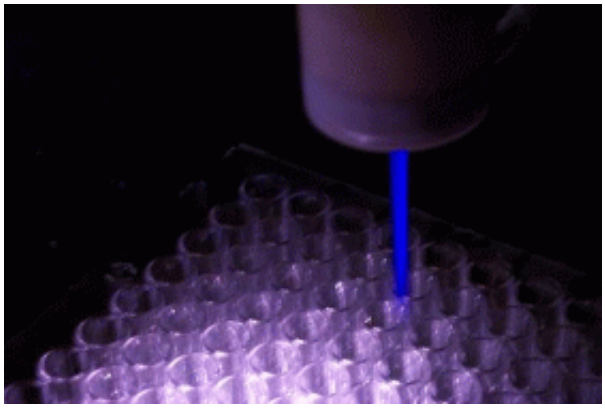
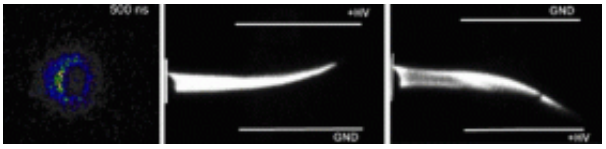


An image of the plasma pencil, where the blue beam is the cold plasma plume. Image credit: Plasma Pencil, Photo courtesy M. Laroussi, Old Dominion University.

(PhysOrg.com) -- On the nanoscale, things aren't always what they seem. What first looked like a continuous plasma jet has turned out to be a train of tiny, high-velocity plasma bullets. Using a camera with an exposure time of a few nanoseconds, researchers have further investigated the plasma bullets, and have even found a way to control them.

Using a high-speed intensified charge coupled device (ICCD), Professor Mounir Laroussi and his students from the Laser & Plasma Engineering Institute at Old Dominion University in Norfolk, Virginia, has taken an up-close look at the little-known plasma bullets. Their study is published in a recent issue of the *Journal of Physics D: Applied Physics*.

The plasma bullets are created by a "plasma pencil," which is a pulsed plasma source that the researchers previously developed. The plasma pencil is a hollow tube about 2.5 cm in diameter that contains two copper electrodes. To ignite the plasma, the researchers sent a gas mixture of helium and oxygen through holes in the electrodes, and applied high-voltage electric pulses between the electrodes. When the gas ignited between the electrodes, it launched a plasma plume through the hole of the outer electrode up to 5 cm into the air.



(Left) Photograph of a plasma bullet taken with an ICCD camera, illustrating the bullet's donut shape. (Right) An externally applied dc voltage causes the plasma plume to bend in the opposite direction. Image credit: Mericam-Bourdet, et al.

The plasma plume (which is actually a train of plasma bullets) moves at a velocity of up to 100,000 meters per second - much faster than the velocity of the gas coming out of the device, which is just 8 meters per second. Although previous research has explained that photoionization could be responsible for the high velocity, Laroussi and his students at Old Dominion have now found clues to the bullets' original formation.

In their study, the researchers found that the length of the electrically-driven plume depends mainly on two parameters: the applied voltage between the two electrodes and the helium gas flow. Also, the average bullet velocity increases when the voltage increases. By analyzing images from the ICCD camera, the scientists also found that the bullets always become extinguished when the voltage pulse ends.

By viewing the plasma bullets at multiple angles, the researchers found another surprise: the bullet is not round, but is shaped like a donut, with a hole in the middle. Based on this shape, the researchers proposed that the plasma bullets are surface waves that travel along the interface between two media - helium and ambient air.

In addition, the researchers found that they could

control the initiation time and distance of the plasma bullets by applying an external dc electric field. The applied field decreased the bullets' average velocity and distance traveled. Also, by applying the electric field perpendicular to the axis of the plasma plume, the negatively charged plume is deflected away from the negatively charged field.

As Laroussi explained, the aim of the study was to attempt to understand the physics behind the formation and propagation of these cold plasma bullets. "There has been a lot of debate as to how these bullets propagate. So we hope that we have contributed some interesting ideas to this debate," he told *PhysOrg.com*, adding that still more work needs to be done.

Laroussi also said that the plasma bullets could be used for biomedical purposes, such as dental and wound healing applications. Teaming up with microbiologists, Laroussi has already used the tiny plasma bullets to inactivate bacteria, especially those of dental relevance such as *Streptococcus mutans* which are implicated in the onset and progression of dental caries (tooth decay).

More information: Mericam-Bourdet, N.; Laroussi, M.; Begum, A.; and Karakas, E. "Experimental investigations of plasma bullets." *J. Phys. D: Appl. Phys*. 42 (2009) 055207 (7pp).