Head-on collisions of two supersonic plasma jets

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Supersonic plasma flows are common in the universe. Based on the magnetohydrodynamic scaling, they can be experimentally studied in a controlled manner, i.e., in the laboratory environment. We are studying interactions between two counter-propagating supersonic plasma jets generated by two conical-wire arrays facing each other. Experiments are conducted on a 1-kJ pulsed-power system called "Pulsed-power Generator for Space science (PGS)" with a suite of diagnostics[1].

The PGS machine consists of twenty 1-μF capacitors. Two capacitors are connected in series forming a brick. Five bricks are connected in parallel forming a wing. Finally, two wings are connected in parallel providing a total capacitance of 5 μF. The PGS machine is charged to 20 kV. When it discharges, it provides a pulsed current with a peak of ~100 kA with a rise time of ~1.6 μs. In addition, the PGS machine is equipped with several imaging systems, including time-integrated cameras in the visible light region taking images from the side and from the top, time-resolved laser-camera imaging systems taking images from the side. The laser-camera imaging system uses a Q-switch laser with a pulse width of 5 ns in 532 nm for taking shadowgraph images, schlieren images, and an interferometry. The PGS machine is the experimental platform for studying laboratory astrophysics and space sciences.

In this study, a bi-conical-wire array was driven by the PGS machine. The design and the photo of the bi-conical-wire array are shown in Fig. 1. The bi-conical-wire array consisted of two identical conical-wire arrays connected in series and facing each other. In other words, the same current flowed through both wire arrays and provided the same drive to both wire arrays. In each conical-wire array, four tungsten wires with a diameter of 20 μm were used. The inclination angles of both conical-wire arrays were 30° with respect to the z axis. When current flowed through each conical-wire array, the tungsten wires were heated ohmically such that neutral cold wire cores were surrounded by lower-density, hot coronal plasma. Then, the jxB force pushed the ablated plasma toward the center of the wire array. Since the current had a radial component, the imploding velocity was slightly upward for the bottom conical-wire array and slightly downward for the top conical-wire. Eventually, plasmas merged at the center. Therefore, an up-going plasma jet from the bottom conical-wire array and a down-propagating plasma jet from the top conical-wire array were generated. The measured velocity of the plasma jet was ~170 km/s, corresponding to a Mach number greater than 5[1]. Finally, two counter-propagating supersonic plasma jets collided with each other at the center of the bi-conical-wire array and a plasma disk was formed[2]. Figure 1(c) is a time-resolved schlieren image. Two plasma jets and the plasma disk are clearly observed. It demonstrated that bi-conical-wire arrays driven by a pulsed-power system can be a platform for studying supersonic plasma jets and plasma disks. Details of the experiment will be presented.

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Reference

[1] P.-Y. Chang *et al*, Rev. Sci. Instrum. 93, 043505 (2022).
[2] M.-H. Kuo, Master's thesis, "Study of the plasma disk generated from the head-on collisions of two plasma jets" (2022)

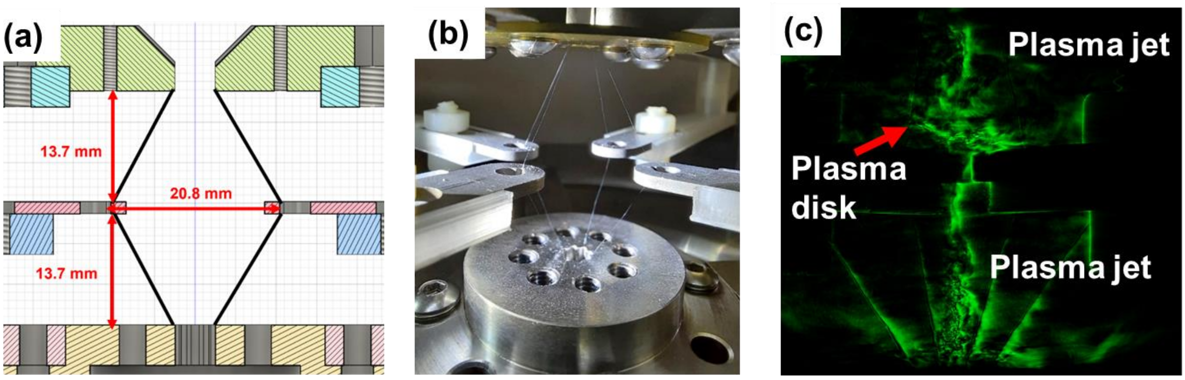

Figure 1. (a) The design of the bi-conical-wire array. Four tungsten wires with a diameter of 20 μm were used. (b) A picture of the bi-conical-wire array before being imploded. (c) A schlieren image of the imploded bi-conical-wire array. Two plasma jets, one from top and one from the bottom, collided at the middle plane of the bi-conical-wire array and formed a plasma disk indicated by the red arrow.