Dynamics of mass transport in wire array z-pinches

The mass transport during implosion in wire array z-pinches is realized by plasma "bubbles" arising on breaks in the wires.

Progress in z-pinch physics research has established the wire array z-pinch as the most powerful laboratory source of soft x-ray radiation [1]. Z-pinch physics have provided new directions for fusion studies, dense plasma and radiation physics, laboratory astrophysics, and other areas of science. Recent experiments have demonstrated a broad radial mass distribution during implosion in wire arrays at the 20-MA Z facility [2] and at 1-3 MA facilities [3], where part of the wire mass did not implode and produced trailing mass at stagnation. "Bubbles" in plasma streams formed at the start of implosion have been observed recently at different pulsed power generators.

In research done at the University of Nevada, Reno in collaboration with the Sandia National Laboratory, Albuquerque, and Imperial College, London, an important step has been made in the understanding of fundamental processes involved to wire array implosions. Using multi-frame laser probing techniques in the 1-MA Zebra generator, measurements of the microscopic origins of mass flow instabilities and current distribution were performed [4]. A short probing laser pulse provides instant images of the fast moving plasma. It is shown that the mass transport during implosion is realized by plasma "bubbles" arising on breaks in the wires (see Fig. 1). Bubbles exhibit an initial rapid acceleration, followed by a near constant velocity implosion. The leading edge of the bubbles brings material to the axis of the array with a speed 200-500 km/s and produces a shock during collision with the plasma column on the axis. Complementary images of wire array implosion in different probing diagnostics are presented in Fig. 2. The shadowgram in Fig. 2 (a) shows a collision of the bubbles with the precursor. The interferogram in Fig. 2 (c) shows that the leading edges of the bubbles deliver material from the wire to the axis. The Faraday effect in Fig. 2 (b) shows that current switches from the imploding mass, to the precursor plasma column at the beginning of the x-ray pulse. A bubble-like mass transport is observed in arrays with 8-32 wire (cylindrical, nested, linear, etc). The figure shows the imploding bubbles in the 4-wire aluminum array. Similar plasma implosion mechanisms as those were observed at the MAGPIE generator with optical streak photography and XUV framing images.

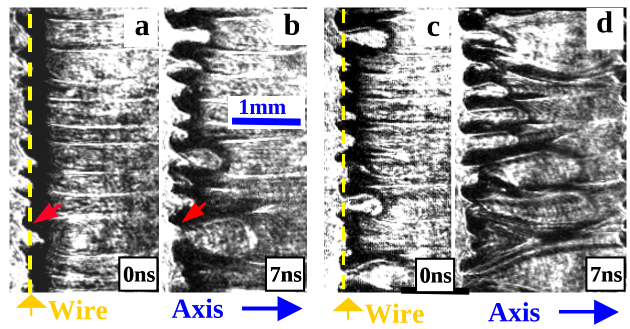

Fig. 1. Two-frame shadowgrams (a, b) and (c, d) from two shots in Al 8-wire arrays. The delay between frames is 7 ns.

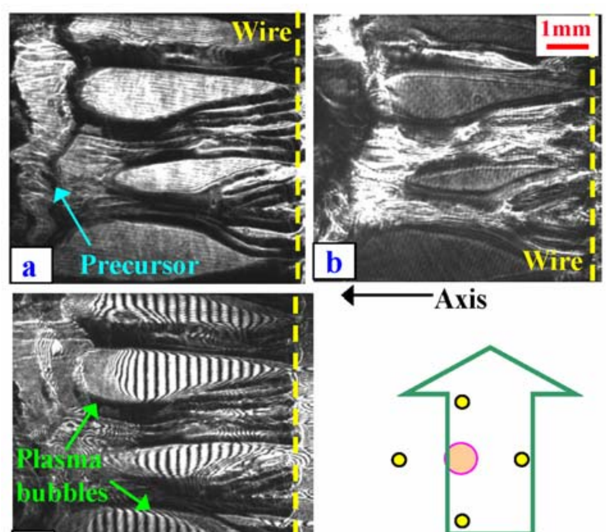

Fig. 2. The shadowgram (a), the Faraday image (b), and interferogram (c) in the figure show the imploding bubbles hitting the precursor plasma column. A pictogram in the bottom left side of image (b) shows a top view of the laser probing in the 4-wire Al array.

References

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