Z Pinch of Divergently Aligned Two Wires

Keiichi TAKASUGI, Mineyuki NISHIO[1)], Miharu TAKAO[2)], Hiroaki ITO[2)] and Masayuki WATANABE

Institute of Quantum Science, Nihon University, Tokyo 101-8308, Japan
[1)]Anan College, National Insitute of Technology, Tokushima 774-0017, Japan
[2)]Faculty of Engineering, University of Toyama, Toyama 930-8555, Japan

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Research on a new type of wire-array z pinch based on a slow generator was conducted. When a current was applied to divergently aligned two Cu wires of 25 μm in diameter, the wires were interrupted near the inner electrode and contracted locally. A soft x-ray pulse was generated, and a spatially isolated hot spot was observed near the inner electrode. A new method for converging a wire array to a single point was presented.

Keywords: divergent z pinch, wire array, hot spot, soft x-ray radiation, implosion

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The onset of Rayleigh-Taylor instability is essential and inevitable in the implosion process of inertial fusion [1, 2]. The plasma focus is a unique system that does not cause Rayleigh-Taylor instability in contracting plasmas, and can reproducibly converge the plasma to a single point [3, 4]. The divergent gas-puff z pinch forms a divergent gas distribution in vacuum and can efficiently realize the plasma focus [5, 6].

Higher electron temperature has been obtained by z pinch using heavier elements [7]. In order to realize a divergent z pinch using a substance other than a gas, research on a divergently aligned wire-array z pinch was performed. A similar system is conical wire-array z pinch [8, 9]. Normally, when a current is applied to a wire using a slow generator, the wire evaporates, turns into plasma and explodes. To prevent this, a fast generator that starts current in less than 100 ns is used in the wire z pinch [10]. As a result, in the conical wire-array z pinch, the wires sequentially collide on the central axis while maintaining the shape. Then the pinch plasma is extruded axially to close the zipper, forming a jet. The plasma does not converge to a single point in the conical wire-array z pinch. X pinch is a system in which the plasma converges to a single point [11, 12]. In the x pinch, x-ray is emitted when the plasma is broken at the intersection of the wires. The x pinch also requires a fast generator, and the resulting x-ray includes hard component. This study shows a new approach to dynamically shrink a wire array using a slow generator to focus the plasma at one point.

In the experiment, the SHOTGUN III-U device was used, and the capacitor bank of 18 μF was charged to −25 kV [6]. Cu wires of 25 μm in diameter were used as discharge medium. Figure 1 shows the arrangement of the experiment. The outer electrode was connected to the vacuum chamber and was at ground potential. Negative high voltage was applied to the inner electrode. The inner electrode was 20 mm in diameter, and two Cu wires were connected to the outer electrode. The inner diameter of the outer electrode was 60 mm, and the distance between the inner surfaces of both electrodes was 30 mm. The chamber was evacuated and the base pressure was 3×10^{-3} Pa.

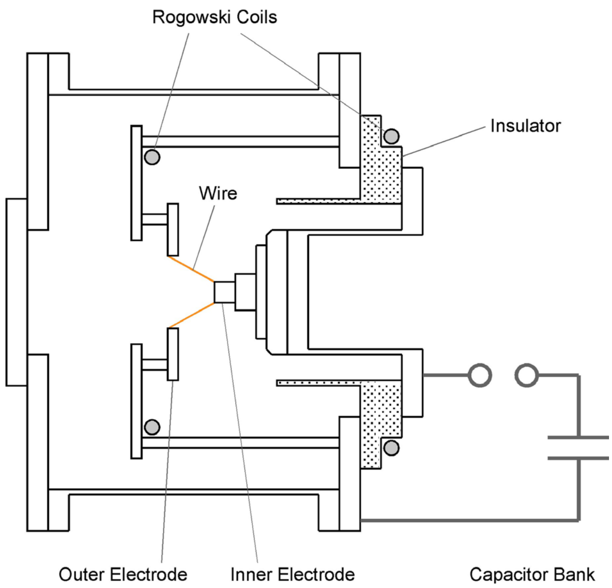

Fig. 1 Experimental set up of the z pinch of divergently aligned two wires on the SHOTGUN III-U device.

Discharge currents were measured by Rogowski coils placed on the input and load sides of the device. In order to monitor soft x-ray, a scintillation probe (SCI) using a plastic scintillator was used. Soft x-ray of less than 700 eV was eliminated by a 5 μm thick Be window. An x-ray diode (XRD) with a Ni photocathode without a filter was used to monitor extreme ultraviolet light. Figure 2 shows the in-

author's e-mail: takasugi@phys.cst.nihon-u.ac.jp

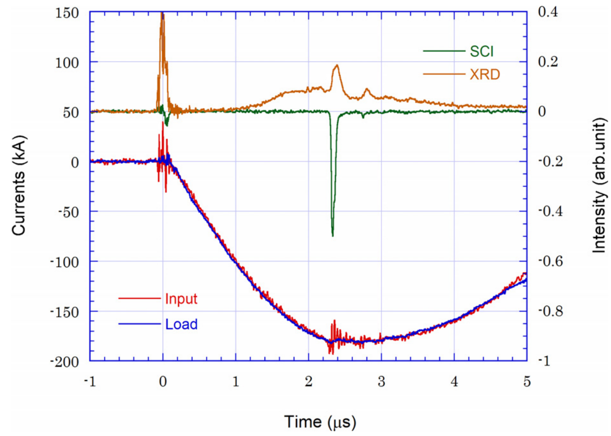

Fig. 2 Discharge currents and radiation signals (SCI and XRD) of the z-pinch discharge.

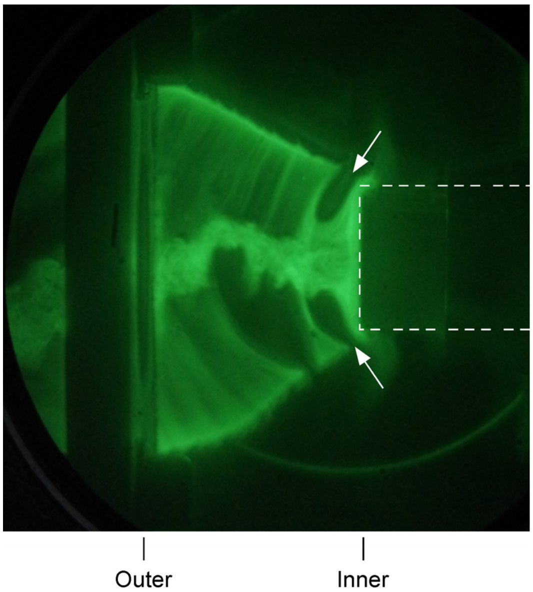

Fig. 3 Gated image of the z pinch of divergently aligned two wires. The white dotted line shows the inner electrode. The wires were interrupted at the positions shown by arrows.

put and load currents and the waveforms of SCI and XRD. The XRD signal started to increase at 1.0 μs after the start of discharge, and a spike occurred in the SCI signal at time 2.3 μs. At this time, both currents were −180 kA. It is considered that warm plasma was generated at time 1.0 μs and pinch plasma was generated at time 2.3 μs. The two currents were consistent over the discharge and no reconnection of the currents occurred. This is different from gas discharge.

In order to observe the shape of the plasma, a gated camera with an image intensifier Hamamatsu V3063U was used. The gate width was 20 ns. Figure 3 shows the gated image of the plasma at 0.64 μs before the pinch. The surface of the two wires evaporated and a discharge ran along the wires. Although the shapes of two wires remained, the generated plasma was accelerated toward the central axis

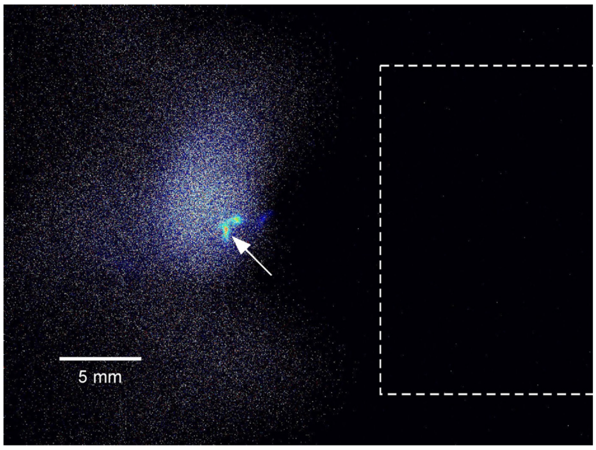

Fig. 4 Soft x-ray pinhole image of the z-pinch plasma. The white dotted line shows the inner electrode. A hot spot was generated in front of the inner electrode.

to form a plasma column on the axis. This is considered to be the warm plasma observed by XRD. The wires were interrupted near the inner electrode as indicated by the arrows in the figure. These parts of the plasma contracted toward the central axis, creating a shape like plasma focus.

Spatial observation of soft x-ray emitted from the pinch plasma was performed using a pinhole camera. The CCD used was manufactured by Laser-Laboratorium Göttingen e.V. The sensitivity range is < 1 - 1,100 nm, the pixel size is 6.45 μm (1,392 × 1,040 pixels). An Al-coated 4 μm thick mylar was used to block ultraviolet light. Figure 4 shows the soft x-ray image of the plasma captured by the pinhole camera. Since the SCI signal was observed only at the moment of the pinch, the image shows the hot plasma created at this moment. The white dotted line indicates the inner electrode. An isolated hot spot was observed 9 mm to the left of the inner electrode.

By arranging the wires divergently, a similar arrangement as in the divergent gas-puff could be formed. The formation of an isolated hot spot is due to axial nonuniformity and the use of slow generator. These are the essence of plasma focus. A new type of wire z pinch was realized.

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