implosion features of composite multiwire arrays powered by microsecond current pulses with amplitude up to two megamperes

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This paper presents the results of experiments performed in RFNC-VNIIEF. The experiments concerned the implosion of multi-wire cylindrical arrays (including composite arrays with the wires of different diameters) powered by microsecond current pulses with the amplitude up to two megamperes. The goal of the performed laboratory studies was to reveal peculiarities of the plasma ablation and implosion of the tungsten arrays at microsecond current rise time. The experiments were carried out for validation of the three-dimensional calculation models of the imploding Z-pinches and for finding optimum parameters of the load to obtain high-power soft x-ray radiation (SXR) pulses

Recording of the spectral and time-amplitude parameters of the SXR pulses was carried out using scintillation detectors (SD). Total energy of the SXR pulses was measured by wire and film bolometers. Recording of the space-time pattern of the plasma pinch in the x-ray range was made using X-ray streak camera, where the scintillator was located in the plane at an angle of ~40 degrees to the incident radiation. Further transmission of the optical signal was carried out using the fiber array, which projected the image to the streak camera slit.

Numerical simulation of the dynamical Z-pinch was carried out in the frameworks of the magneto-hydrodynamic code FLUX-3D taking into account a discrete spatial structure of the multi-wire array. It considered thermal radiation transfer in the diffusive (3-T) approximation and the model of prolonged plasma formation was used. It is shown that the calculation method is the powerful tool allowing us to reveal (during ‘post factum’ simulation) the physical features of the implosion processes of the multi-wire cylindrical arrays.

Preliminary experimental mass scaling of the imploding single cylindrical arrays was carried out for benchmark of the calculated model. The arrays consisted of 45 tungsten wires of the diameters from 4 to 15 µm and height of 30 mm. The wires were evenly located on the cylindrical surface of   
3 cm radius.

In experiments and calculations the optimal yield of the SXR radiation from the multi-wire   
Z-pinches depending on the wire diameter was obtained. The calculations showed that the whole mass of the array composed with thinnest wires was involved into implosion process. While using the wires of larger diameter, the portion of the involved mass decreases to range of 61 to 75% of the initial one.

Features of the imploding arrays composed of the wires of different diameters are analyzed. Different regimes of the current distribution on subsystems of the wires of different diameters are considered. It was revealed that application of the composite arrays decreases efficiency of the SXR pulse generation. The reasons are: unsimultaneity of the plasma ablation end in different wires subsystems and appearance of large azimuth heterogeneity that negatively affects the tightness of final compression of the plasma. Results of the composite arrays numerical simulation match the   
X-ray streak camera data and bolometer measurements.