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Implosion Dynamics of Multi-material Wire-arrays on S-300 Pulsed Generator.

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On "S-300" generator (3 MA, 100 ns) at the Kurchatov Institute, the experimental studies with multi-material wire array units are carried on aimed at creating the powerful X-ray source. One of the purposes of these experiments was investigation of the wire array chemical composition influence on the implosion dynamics and stability.

The experiments were performed on various fashions of loads distinct from each other by the geometry and materials, including nested arrays fabricated form wires of different substances. The liners were made of Al or W wires, or of there combinations. To investigate the implosion dynamics and determine the soft X-ray yield, the following set of diagnostics was used: optical streak-camera photography, scintillator power recorder operating in the range of 50-500 eV, time-integrated three pinhole cameras, X-ray spectrograph on convex mica crystal. As an active diagnostics in the visible range, the five-frame laser shadowgraphy with 1 ns time resolution was used. One of the features in some shadow pictures is an appearance of transparency space for the probing laser light. These are light strips, parallel to *Z* axis, on the continuous penumbra of the rare plasma (see Fig. 1). This phenomenon manifests itself, most distinctly, in the case of great number of wires (80 or more) in the array. Instead of the successive diminution with time, the width of separate transparent strip enlarges. Such an effect may be explained, probably, by the "bunching" and "adhesion" of the parallel current-carrying conductors. In the next two frames (Fig.1) rapid rebuilding of the plasma configuration is reflected. It is connected with the residual of wires evaporation and formation of a pinch. We should notice that such tungsten plasma, highly diffused in both radial and axial directions in the intermediate phase, doesn’t counteracts an achievement of the thin filament state at the last stage of compression. In this case the minimum pinch size was recorded equal to ~ 0.4 mm, and more homogeneous luminescence consisting of rather large quantity of hot spot, uniformly distributed (the lower X-ray image in Fig.1). Just opposite plasma behavior reveals itself in the Al-wire array, where the most compact state gives 2-3 mm at the initial diameter of 12 mm. Aluminum and mixed arrays had more heterogeneous structure: hot spots of larger size, less quantity and not uniformly distributed along the axis of the pinch. On the both aluminum and mixed arrays spectral lines of the hydrogen-like and helium-like aluminum ions were recorded by means of an X-ray spectrograph. The aluminum plasma temperature estimated by the recombination continuum was 400-500 eV. Study of the nested (tungsten inside aluminium) wire-array dynamics shows that the minimal liner radius at the stagnation moment of time (2r ~4 mm) recorded in the visible range by the streak camera Fairly coincides with the initial diameter of the inner tungsten array. In Fig.2 two pinhole images are presented: in rays of 1.5 keV and of 100 eV that correspond to the K-shell band of aluminium and to the spectral maximum of radiation, accordingly. They demonstrate that shapeless Al radiator is located inside a solid irradiant

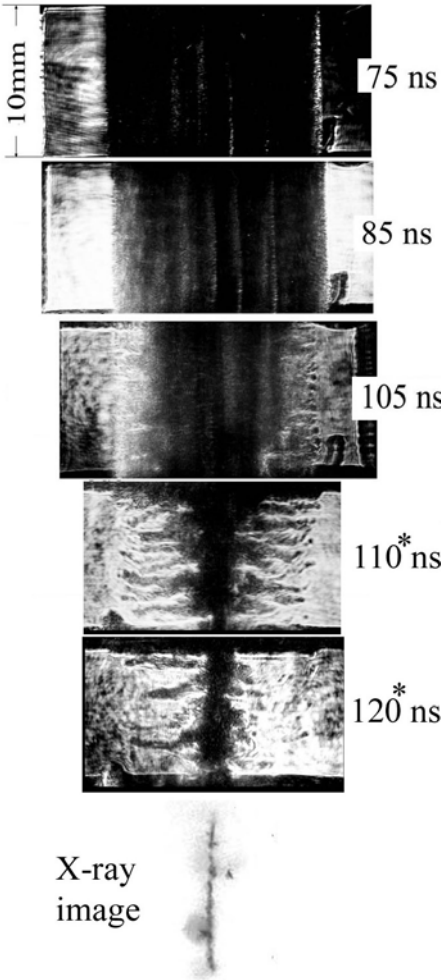

Fig.1.
The shadow laser photographs made at the time moment 75, 85, 105, 110, and 120 ns after the current start. The lower snap is time-integrated.

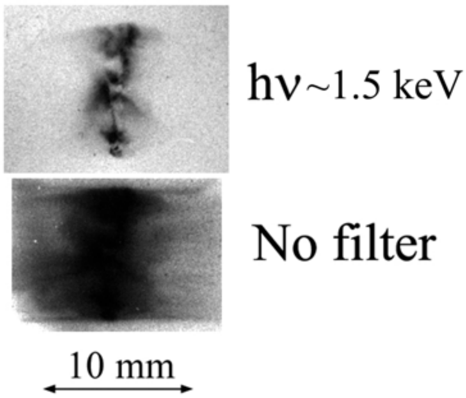

Fig.2
The integral pinhole pictures obtained in the X-ray range. Aluminium compressed plasma seems to be inside tungsten envelope.

column. An inductance function and the effective radius where an electrical current flows through the load were determined by means of the electro-technical measurements. This diagram associated with the visible light streak-camera image is presented in Fig.3. From there one can see that inner almost immovable tungsten array intercepts an electrical current flow at the moment when outer aluminium array flies past. Hence, the quantity of the acquired kinetic energy is affected by the radius where each wire-array is placed. As illustration of this statement is Fig.4 with three X-ray K-shell spectra from different experiments are presented. Here it should be noted that with increase in 1.5 times of the radius of the inner W-array location aluminium spectrum disappears in fact. Corresponding to the foregoing properties nested wire-array didn't display any instability flattening or regulatory function in the wire-arrays dynamics. There was no immediate interaction between two nested arrays, except of the electrical current reconnection. Such nested loads could be used in future to constitute required spectrum of X-ray radiation by means of the geometry and chemical component choice.

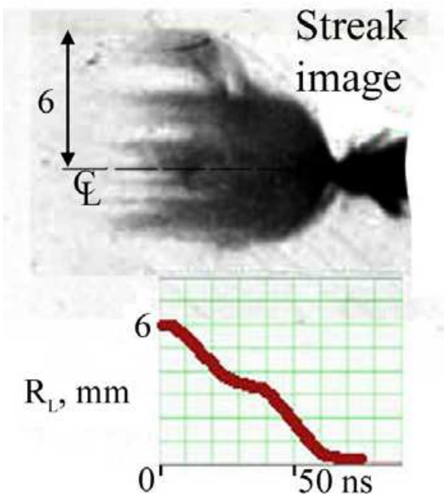

Fig.3
Visible streak-camera image and associated with it radius where electric current flows.

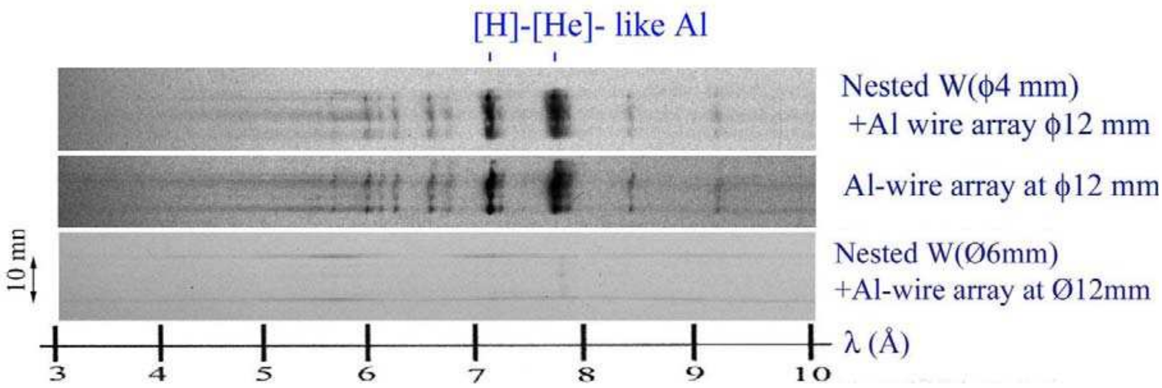

Fig.4. Three X-ray K-shell aluminium spectra from different experiments.

The soft X-ray plasma radiation spectral dynamics in the quanta energy range of 50–2000 eV was recorded by the multi-channel spectrometer (polychromator) with time resolution of 1-2.5 ns and energy resolution of 5-20%. The apparatus performance principle was based on the spectral selection and registration of quanta by using multi-layer interference mirrors in every channel and X-ray edge filters coupled with semiconductor detectors. The main part of the radiation power falls at the spectral interval 60-220 eV. In these experiments it

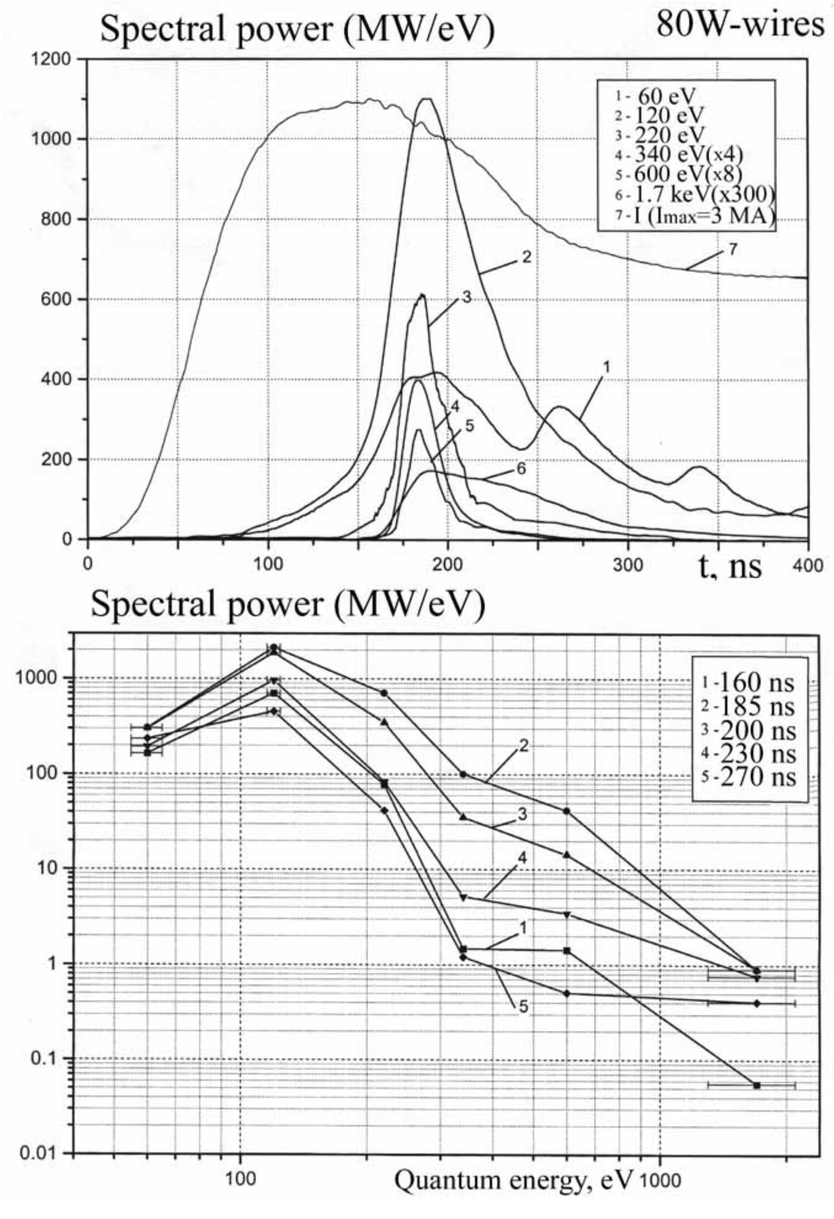

Fig.5. Temporal and spectral X-ray distribution from polychromator measurements.

reached 0.6 TW, and full radiated energy was close to 30 kJ. Oscillograph traces of the current through the 80-wire tungsten array and soft X-ray power distribution in the range of 60-600 eV during the implosion process are presented in Fig.5. This spectral distribution can be matched with blackbody's spectrum with temperature of 40-50 eV. The temporal data obtained by means of the polychromator were in near resemblance with those obtained by means of the scintillator X-ray power recorder, but the measured magnitudes time-to-time differ essentially.