<u>A.S. Zhigalin</u>, A.G. Rousskikh, V.I Oreshkin, A.V. Shishlov, R.K. Cherdizov, V.A. Kokshenev, R.B. Baksht.

Comparative Analysis of the Rayleigh–Taylor Instability Suppression During Implosion of Metallic gas-puff Z Pinch at the MIG and GIT-12 Facilities

7th International Congress on Energy Fluxes and Radiation Effects (EFRE-2020)
September – 2020

High Current Electronics Institute

Abstract

We present experiments on implosion of metallic gas-puff Z-pinches. Experiments were performed on the MIG and GIT-12 pulse power generators. The MIG is a multifunctional pulse power generator with current amplitude of 2.5 MA and a current rise time of ~ 100 ns [1]. The GIT-12 is an Arkadiev-Marx pulse power generator. It provides the current of 4.7 MA with the current rise time of 1.7 μs in the short-circuit load [2]. Metallic gas-puff Z-pinch was the main element of the load on both generators. Metallic gas-puff Z-pinches were formed using plasma guns where plasma production was initiated by a high current vacuum arc discharge [3]. All of the plasma gun electrodes were made of magnesium or aluminum. An HSFC-Pro 4-channel, 12-bit intensified charge-coupled device (ICCD) camera was used to take 4 successive images in a single shot. The image analysis had shown that during compression of metallic gas-puff Z pinch, Rayleigh-Taylor instabilities were suppressed.

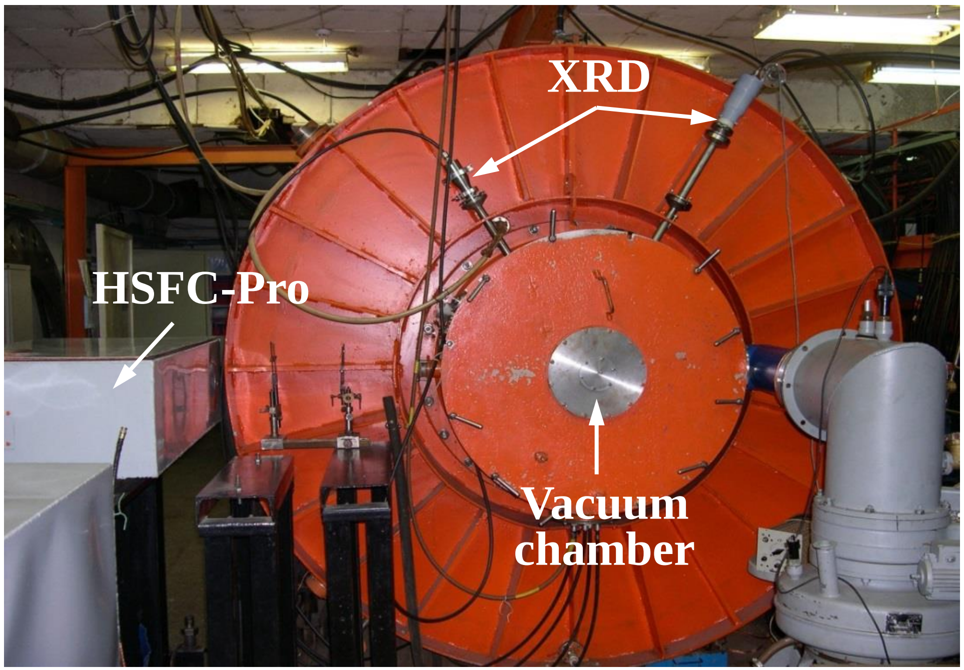
[1] I. E. Gorelchanik, A. F. Korostelev, V. K. Petin, N. A. Ratakhin, A. N. Shepelev, V. F. Fedushchak, & S. V. Shlyakhtun, “High-power electron beam generator MIG”, IEEE book series: 13th International Conference on High-Power Particle Beams, BEAMS 2000, Nagaoka, Japan pp. 172-175, 20-25 June 2000.

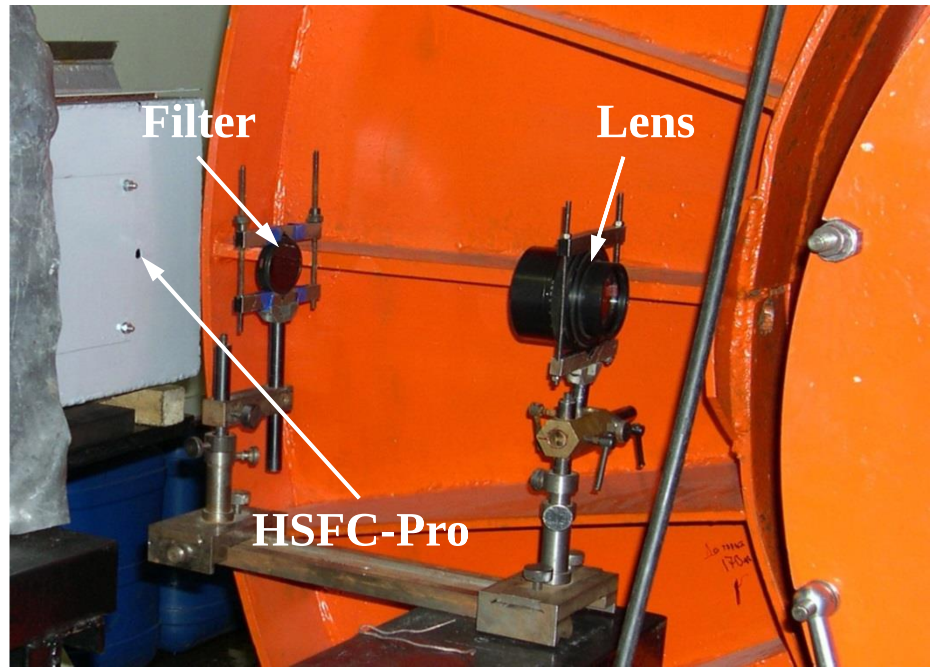
[2] A.V.Shishlov, R.B.Baksht, S.A.Chaikovsky, A.V.Fedunin,et al, “Formation of tight plasma pinches and generation of high-power soft x-ray radiation pulses in fast Z-pinch implosions” Laser Physics, vol.16, No.1. – Pp.183-193 January 2006.

[3] Baksht R, Oreshkin V, Rousskikh A and Zhigalin A, “Energy balance in a Z pinch with suppressed Rayleigh–Taylor instability” Plasma Physics and Controlled Fusion, vol. 60, № 3, 035015, February 2018.

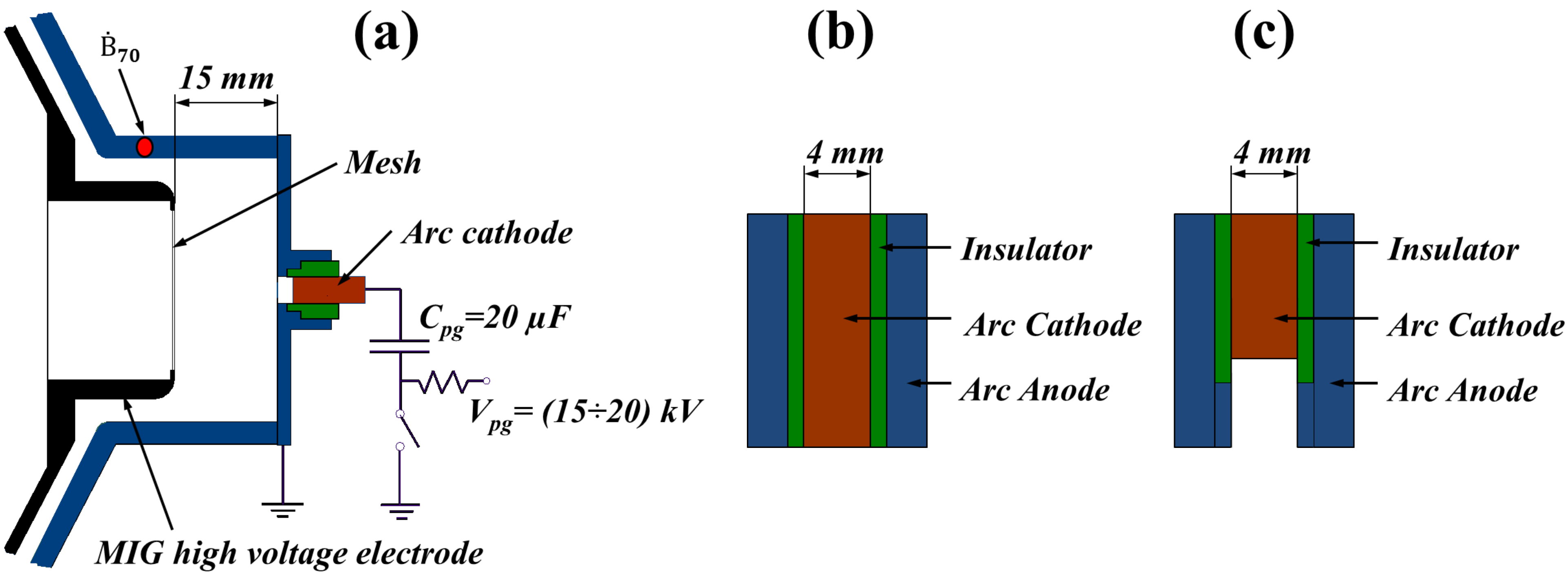
MIG generator

- Capacitive voltage divider
- B-dots
- Rogovsky coil
- Vacuum X-ray diodes (XRDs)
- 4-frame HSFC-Pro optical camera, (the exposure time is 3 ns)



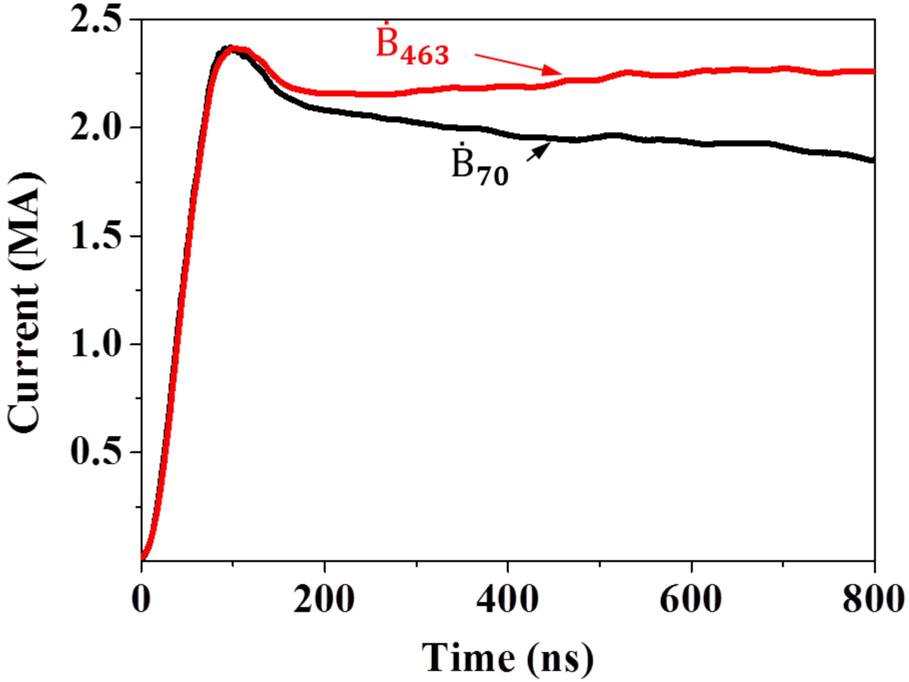


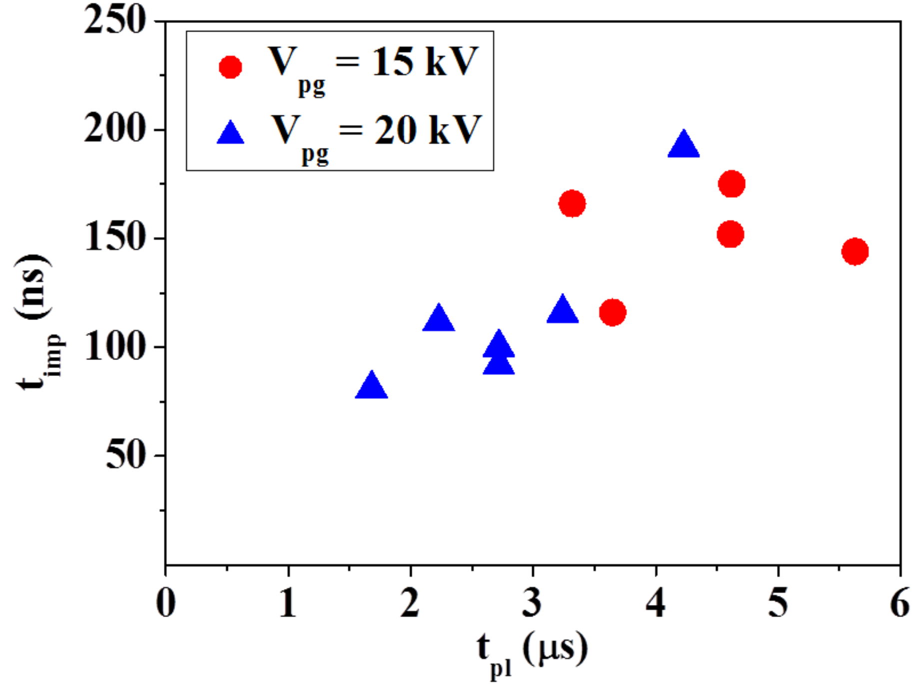
Scheme of the load (a). In the first setup the electric arc operates in the plane of the anode (b), in the second setup, the electric arc is deepened into the anode (c).



C_{pg} and V_{pg} are the capacitance and the voltage of the arc plasma gun.

Experimental results





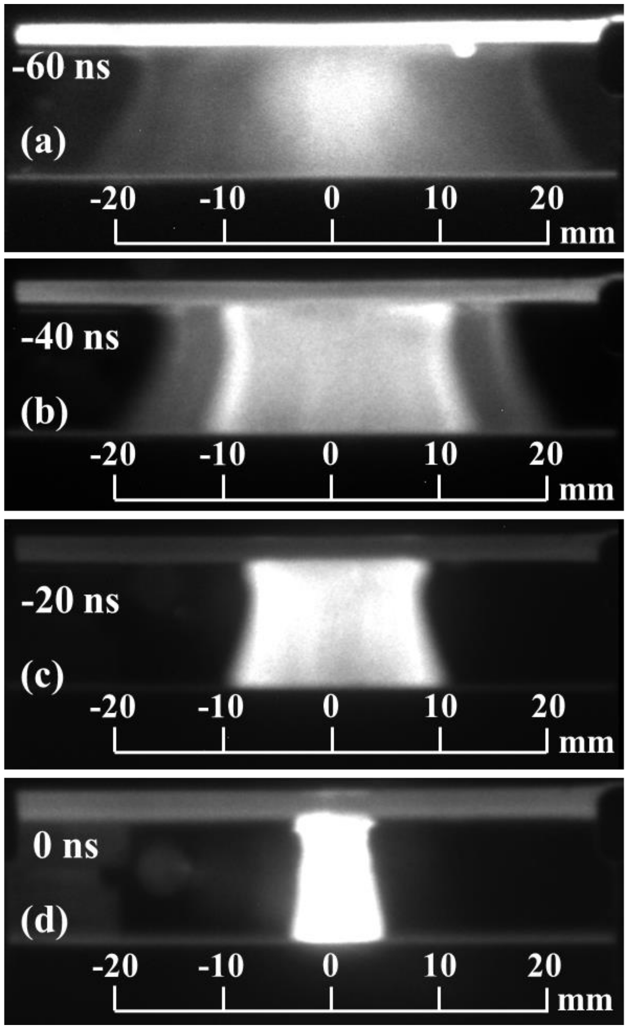
The derivative of the current of the MIG generator was recorded using B-dots $\dot{B}_{463}$ and $\dot{B}_{70}$. B-dots were installed at distances of 231.5 and 35 mm from the pinch axis respectively.

The experimental dependencies of the implosion time of metallic gas-puff Z pinches on the time of formation of the plasma jet (the delay time between the voltage pulse supplied to the plasma gun and the pulse beginning of the MIG pulse power generator).

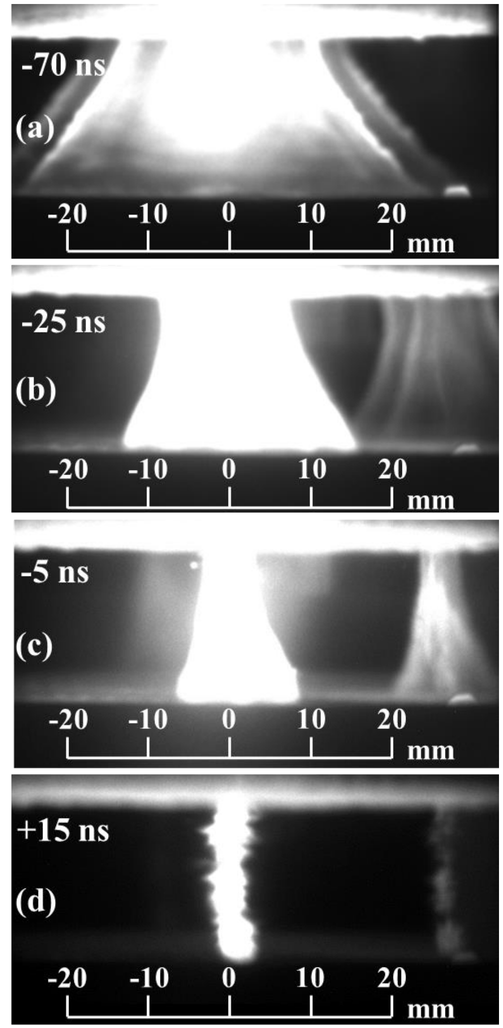
Optical images of an imploding metallic gas-puff Z-pinch

The time shifts relative to t_{imp} are indicated at the each image. The frame exposure time was 3 ns.

MIG



GIT-12



Results

From the obtained images, it can be concluded that in the final stage of metallic gas-puff Z-pinches implosion, there are no the Rayleigh-Taylor instabilities.

The measurements of current and voltage made it possible to obtain the density distribution of the material ρ in a imploding pinch, as a function of its radius (R) [See R. Cherdizov S2-O-003101]. This The shock wave in the pinch with the density of matter increasing towards the axis (tailored density profile) slows down as it approaches the axis, i.e. shock wave acceleration in a pinch with a profiled density distribution $\frac{d^2R}{d^2t} < 0$. In the framework of the zero-dimensional model, the magnetic piston and the shock wave are considered as an infinitely thin shell. In this approximation, for a Z-pinch, the magnetic pressure is proportional to $\frac{I^2}{R^2}$, where I is the pinch current and the R is the pinch outer radius. If the density $\rho(R)$ increases with decreasing radius faster than the pressure of the magnetic field, namely, approximately as $\rho(R) \propto R^{-3}$, then for I = const the sign of the acceleration of boundary between magnetic field and plasma during compression will become negative. The density distribution $\rho\ (R) \propto R^{-1}$ is insufficient to invert the acceleration sign even for I = const. With increasing current, the distribution $\rho(R) \propto R^{-3}$ may not provide suppression of instability, since the magnetic field pressure grows faster than R^{-2}. In our case, for a metallic gas-puff , an increase in the density $\rho(R) \propto R^{-3.5}$ is obviously sufficient to suppress RT instability in the final implosion phase.

Thank you for attention !