# MEASUREMENT OF GAS-PLASMA TORCH TEMPERATURE

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Experimental studies of gas-plasma torch optical spectra were performed and the torch temperature on different distances from the target irradiated by high-current REB was measured.

PACS: 79.20.Kz.

High-current relativistic electron beams (REB) influence on solid state target leads to crater formation and ionized vapor of target matter forms a gas-plasma torch (GPT). It is necessary to know the main characteristics of GPT (density and temperature) to calculate radiation loss from GPT.

In this paper the experimental method for registration of GPT extreme parameters was developed taking into account optical opacity of collector plasma. That will enable to obtain radiation loss of GPT and its influence on the depth of crater formed.

Experimental studies of GPT optical spectra were carried out on MIG-1 accelerator [1] (Fig. 1 – photo of accelerator, Fig. 2 – scheme of experiment). REB has the following parameters: energy ≅ 0.5 MeV, current ≅ 5 kA, pulse duration = $5\cdot10^{-6}$ s. It is known that GPT formed near the surface of irradiated target looses the part of energy because of radiation based on radiation diffusion mechanisms.

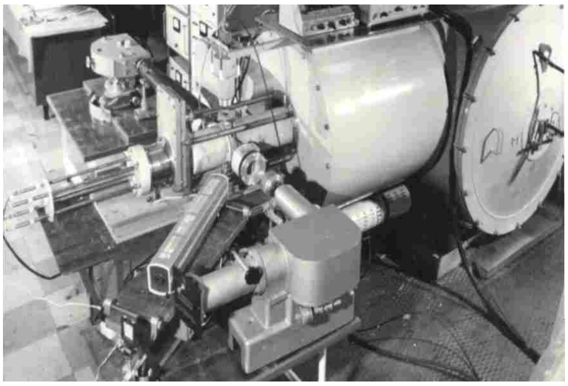

***Fig. 1.*** *MIG-1 accelerator*

To obtain the temperature of target (steel 12X18H10T) surface when interacting with REB integral (at one discharge) spectra in visible range were measured with STE-1 spectrograph in regimes of tubular and continuous beams. In the case of continuous cylindrical REB GPT radiation has a line spectrum (Fig. 3). Radiation intensity has a maximum near the target surface at the distance $l \leq 0.5$ cm and decreases as $1/l$ at the distance $l = 5.0$ cm. The glow is practically uniform in the whole beam cross-section. FeI, CrI, NiI atoms lines are the most intensive in the spectrum, ion lines are absent and qualitatively spectrum is similar to arc discharge spectra. When using tubular beam GPT radiation is substantially different both in topography and spectrum view. Near the target ($l \leq 2.0$ cm) to regions of glow stand out – central region with diameter ≅ 0.5 cm with intensive continuous spectrum and separate absorption lines and peripheral region (in the place of REB incidence on the target) with line spectrum. Central and peripheral GPT regions stand out more distinctly if the strip of st. 12X18H10T was applied as a target. That allowed revealing processes that were hidden from observation when tubular REB acted on disk target. In this case absorption lines of GPT central region are represented with FeI and CrI atoms lines.

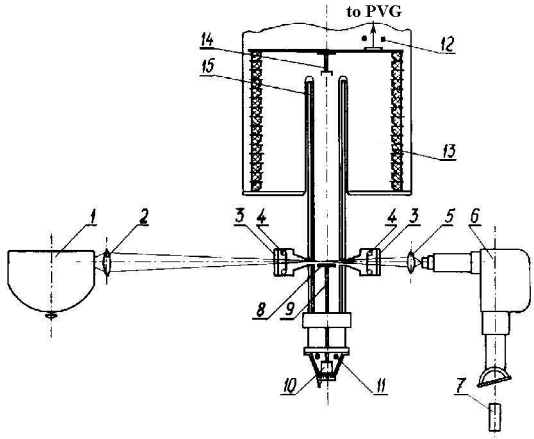

***Fig. 2.*** *Scheme of experiment: 1- VPR chamber; 2 – lens; 3 – lavsan film; 4 – device; 5 – lens; 6 – spectrograph; 7 – laser; 8 – target; 9 – collector; 10 – camera obscura; 11 – Rogovsky belt for beam current measurement; 12 - Rogovsky belt for general current measurement; 13 – accelerating tube; 14 - cathode; 15 - anode*

When moving away from strip target intensity of continuous spectrum decreases and lines appear at the distance $l \geq 2.0$ cm. Emission lines and absorption lines are substantially broadened ($\Delta\lambda$ = 0.1 ... 0.2 nm), that can be explained with very high density of GPT central formation (~ $10^{19}$ ...$10^{21}$ cm$^{-3}$). It correlates well enough with results on tubular REB interacting with solid target obtained with dark field photography method.

GPT temperature was estimated by relative intensity of spectrum lines [2]. This method can be applied to optically transparent plasma, that in our case corresponds to continuous cylindrical REB interacting with target regimes, peripheral regions and regions of GPT central formation when tubular REB generated that are distanced enough from target surface.

GPT glow spectrograms processing and lines intensities analysis showed that GPT temperature when continuous cylindrical beam interacting with st. 12X18H10T target is evaluated ≅ 0.5 eV at the distance 0.5 ... 2.0 cm from target. Target GPT peripheral region temperature and temperature of central GPT formation is ≅ 0.6 ... 0.7 eV at the distance $l \geq 5.0$ cm from target for tubular REB.

Pulse pyrometry method with photographic registration of GPT and target optical radiation at the wavelength 660 ± 2 nm was applied to measure luminance temperature on the target (graphite, tungsten, st. 12X18H10T, D16 alloy) surface when irradiated with tubular REB. Space resolving of pyrometer registration device was approx. 2 mm. GPT glow was measured at the distance 0 ... 2.0 cm from target surface when gas-plasma formation remained practically opaque. The value of real temperature was estimated from experimentally obtained GPT luminance temperature because GPT emissive power coefficient is unknown.

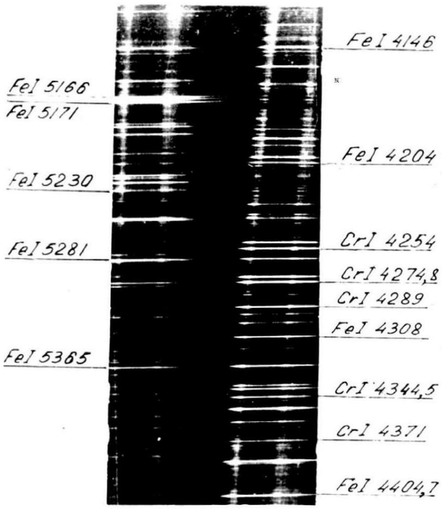

***Fig. 3.*** *GPT radiation spectra*

Fig. 4 represents changes in luminance temperature on the different materials target surface depending on time. One can see that target temperature increases to its maximum values within 2...3 mcs and then slowly decreases within tenths of microseconds. Temperature of graphite target reaches the maximum within 6 mcs and then decreases very slowly. Temperatures' values in maximums are equal to boiling temperatures of corresponding metals and for graphite target – to sublimation temperature. Temperature reaches its maximum within the whole time of REB current pulse faster for materials with higher atom mass. This can be explained by different volume energetic contribution to the target caused by different electron free path in the target matter.

Higher depth of maximum REB energy emission for lighter materials leads to the fact, that temperature maximum on the target surface is registered with higher time delay comparing to heavy elements materials. This is related with time that heat needs to reach the target surface with the help of heat transfer mechanisms.

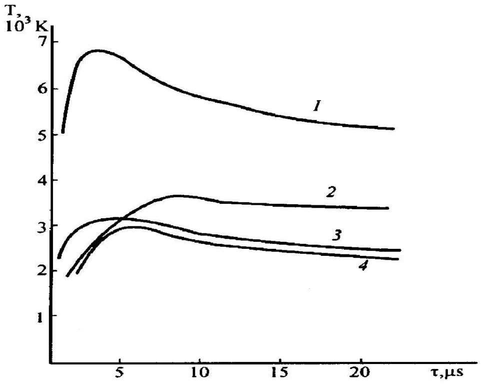

***Fig. 4.*** *Changes in luminance temperature on target surface for different materials versus time: 1 – tungsten, 2 – graphite, 3 – st. 12X18H10T, 4 – D16 alloy*

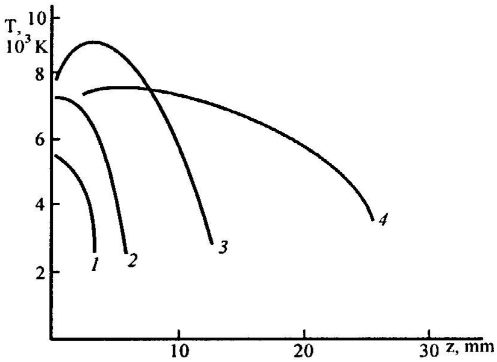

***Fig. 5.*** *Changes in luminance temperature in tungsten GPT versus distance from target surface at different time moments: 1 – 1 mcs, 2 – 3 mcs, 3 – 6 mcs, 4 – 10 mcs*

Fig. 5 represents changes in luminance temperature in tungsten GPT depending on distance from target surface at different registration moments. GPT temperature reaches its maximum at the distances 3 ÷ 5 mm from target surface and equals to $(8 \ldots 5.5) \cdot 10^3$ K. The fact that GPT temperature maximum is located on certain distance from target surface is caused by spreading GPT vapor front dense layers heated up by electron beam which current still remains high to this moment.

Thus optical spectra in GPT central formation (GPT focus) have more intensive spectral lines and continuum radiation, and separate lines are substantially broadened. GPT focus region is characterized with higher temperature and particle density.

## REFERENCES

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