Nanosecond Capillary Discharges as Compact Soft X-ray Sources for Water Window Microscopy and Nanotomography

A. Samokhvalov, E. Bolshakov, T. Bronzov, K. Sergushichev, A. Smirnov, S. Eliseev, M. Timshina, D. Belsky, M. Letunovskaya, V. Burtsev

"Burtsev Laboratory" LLC, 5 Nobelya str., Skolkovo Innovation Centre, Mozhajskij region, Moscow, Russia, 121205

Recent years have seen a surge in interest towards compact X-ray sources in the "water window" – a wavelength range from 2.3 (533 eV) to 4.4 nm (282 eV) in which water is transparent to X-rays, while carbon (and organic compounds) absorbs it [1]. The interest is mostly connected with development of X-ray microscopy and nanotomography methods. To date, the main results in visualization of the internal structure of cells have been obtained using bulky and expensive sources of synchrotron radiation [1]. Achieving a comparable level of image quality and detalization but with simpler and more accessible soft X-ray sources will lead to a great progress in a number of fields in biology and medicine. Among the potential ways of achieving this goal is the use of spontaneous emission of a hot dense plasma generated by nanosecond low-inductance capillary gas discharges [1,2]. Although X-rays in the "water window", as well as first magnified images, have been obtained using capillary discharges in nitrogen [2], the state of development of such sources is far from meeting the requirements set by nanotomography methods. In this work we present current state of research on gas-discharge X-ray sources performed at "Burtsev Laboratory" llc. The source prototype under development is based on a low-inductance setup capable of generating current pulses with rise-time less than 20 ns, an amplitude of up to 15 kA and a pulse repetition rate of up to 1 kHz. Results of systematic investigations of discharge properties in a wide range of experimental conditions (gas type and pressure, electrode configuration, pulse parameters) have been performed. Spectral characteristics of the radiation in the range from 2 to 50 nm were examined using an X-ray spectrometer of sliding incidence (GIS-2). General trends in emission properties are analyzed and discussed, a preliminary optimal configuration of the source is suggested.

References

[1] Adam, J. F., Moy, J. P., & Susini, J., Review of Scientific Instruments, 76(9), 091301, 2005.

[2] Valdivia et al., Plasma Sources Science and Technology, 21(2), 025011, 2012.

[3] Wachulak et al., Microscopy and Microanalysis, 21(5), 1214-1223, 2015.