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

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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 detailization 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