DNA Damage Studies with a Compact Laser Plasma Soft X-ray Source

D. Adjei[1], A. Wiechec[2], P. Wachulak[1], M. Ayele[1], J. Lekki[2], W. Kwiatek[2], A. Bartnik[1], Ł. Węgrzyński[1], M. Davidkova[3], L. Vysin[4], L. Juha[4], L. Pina[5], H. Fiedorowicz[1]*

[1]*Institute of Optoelectronics, Military University of Technology, Warsaw, Poland*
[2]*Institute of Nuclear Physics, Cracow, Poland*
[3]*Institute of Nuclear Physics, Prague, Czech Republic*
[4]*Institute of Physics, Prague, Czech Republic*
[5]*Faculty of Nuclear Sciences and Engineering Physics, Czech Technical University, Prague, Czech Republic*

**E-mail: henryk.fiedorowicz@wat..edu.pl*

Abstracts: *Application of a compact laser plasma source of soft X-rays in radiobiology studies is demonstrated. The source is based on a gas puff target approach. It allows irradiation of biological samples with X-ray pulses in the "water window" spectral range in vacuum or helium atmosphere at very high-dose rates and doses exceeding the kGy level. The source has been used to study strand breaks in DNA plasmids.*

The radiation damage of biological systems with soft X-ray radiation has been routinely studied to understand the mechanism of ionizing radiation effects at the cellular and sub-cellular levels, especially in DNA. It was shown that the biological damage produced by this low energy radiation is more effective as compared with higher energy radiation. The conventional X-ray tube has been the most widely used source of soft X-rays for these studies, however, such sources deliver radiation to the sample at a low dose rate, and thus a relatively long irradiation time is needed to induce measurable biological effects. Synchrotrons, emitting radiation in the soft X-ray spectral region, are recognized as the state-of-the-art facilities for cutting-edge experiments with relatively high photon flux and therefore have become useful for radiobiology studies. However, these facilities offer limited accessibility, and have high operating and maintenance costs. Clearly, this field of study can be broadened by the availability of laboratory sources with similar characteristics for routine radiobiology experiments.

A compact laser plasma source of soft X-rays developed for radiobiology studies is presented in this report. The source is based on laser plasma produced as a result of irradiation of a double-stream gas puff target with nanosecond laser pulses from a commercially available Nd:YAG laser. The source allows irradiation of samples with soft X-ray pulses in the "water window" spectral range (wavelength: 2.3–4.4 nm; photon energy: 280–560 eV) in vacuum or helium atmosphere at very high-dose rates and doses exceeding the kGy level. Single strand breaks (SSBs) and double strand breaks (DBSs) induced in DNA plasmids pBR322 and pUC19 have been measured. The different conformations of the plasmid DNA were separated by agarose gel electrophoresis. An exponential decrease in the supercoiled form with an increase in linear and relaxed forms of the plasmids has been observed as a function of increasing photon fluence. Significant difference between SSBs and DSBs in case of wet and dry samples was observed that is connected with the production of free radicals in the wet sample by soft X-ray photons and subsequent affecting the plasmid DNA. Therefore, the new source was validated to be useful for radiobiology experiments.