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Radiobiology experiments with laser-induced radiation sources: exploring the UHDR regime

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Since the development of the Chirped Pulse Amplification (CPA) technique, both the generation of ultra-short and ultra-intense laser pulses, and its applications in nuclear physics have become a very active field of research. When a laser pulse of these characteristics impinges on a solid target, different particle acceleration mechanisms can take place depending on several parameters such as the laser intensity on focus, its angle of incidence or the target thickness [1]. This results in the capability of generating pulsed radiation sources such as x-rays or polyenergetic proton beams for preclinical research. In addition, the particle acceleration occurs due to the generation of electric fields of the order of TV/m within a few microns, so laser-driven acceleration gives rise to compact alternatives to conventional radiofrequency accelerators. These laser-induced radiation sources can produce relevant doses in short periods of time, which makes them suitable for radiobiological research related to Ultra High Dose Rate therapy techniques (UHDR/FLASH) [2].

The Laser Laboratory for Acceleration and Applications (L2A2) of the University of Santiago de Compostela (USC) is equipped with two laser beamlines. With the low energy line (1 mJ per pulse, 35 fs, 1 kHz repetition rate) impinging on a copper target, we have developed a stabilized, table-top x-ray source for *in vitro* irradiation in radiobiology experiments. The dose deposition has been measured with radiochromic films, and we report a peak dose rate of 10^9 Gy/s. To test its suitability for systematic experiments, we have irradiated an *in vitro* model of alveolar epithelium using the A549 human lung adenocarcinoma cell line at several exposure times and dose values. DNA double-strand breaks (γ-H2AX foci) and DNA damage response events (53BP1 foci) were quantified, showing a linear response with the delivered dose in this first proof-of-concept.

At the same time, we have set up a proton source using the high energy laser output, which delivers 1.2 J, 25 fs pulses at a 10 Hz repetition rate. We have designed and built an experimental setup for *in vitro* irradiation of cell cultures, which comprises a magnetic energy selector that allows for the separation of the broad energy proton spectrum into monoenergetic beamlets with energies up to a few MeV [3]. In addition, several passive (CR-39, RCF) and active detectors (TOF, online dose monitor) have been developed and installed to fully characterize the proton spectrum in terms of fluence and dose delivery. We expect a proton fluence of 10^6 cm^{-2} over the surface of the cell culture dish, and a dose deposition ranging from 18 to 65 mGy per shot, depending on the chosen proton energy beamlet.

[1] A. Macchi, A superintense laser-plasma interaction theory primer, Springer (2012).
[2] P. Chaudhary et al, Frontiers in Physics 9 (2022).
[3] A. Torralba et al, Quantum Beam Science 6(1), 10 (2022)

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