Fiber-based Realtime Dosimetry for Advanced Radiotherapy Techniques

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Résumé

The sensitive volume of state-of-the-art real-time dosimeters used in radiotherapy (RT), as ion chambers and semiconducting diodes, has become too large to resolve accurately high dose gradients inherent in highly conformational irradiation fields (advanced IMRT techniques) or micro-beams (stereotactic RT). Because of their even larger outer dimensions, diodes are furthermore likely to impair the dose delivery when used for in-vivo dosimetry (IVD) in miniaturized fields. In addition, these dosimeters work based on a radio-electric conversion which is basically not adapted to most recent and near-future RT practices (electromagnetic environment in MRI-guided RT, high-dose rate pulses in high-energy protontherapy and flash-RT). Silica optical fiber-based dosimetry is a most promising technology to overcome such limitations. The decisive advantage of silica fibers is their small size (external diameter down to 125 microns, sensitive volume diameter down to 10 microns) which offers increased spatial resolution and "invisibility" to radiation beams. Optical processes in fibers are independent of the azimuthal angle with transverse beams (cylindrical symmetry), virtually insensitive to ordinary fluctuations in humidity, pressure and temperature. They are also immune to electromagnetic perturbations, as expected for operation under MRI-guided RT conditions. Due to their one-dimensional character and flexibility, silica fibers can provide *distributed* dose measurements in a variety of geometries. They could notably enable the implementation of IVD in brachytherapy treatments thanks to their insertion in catheters alongside with the radioactive seeds. Radiation effects in fibers are of three types: radiation-induced luminescence (including radioluminescence, RL, for real-time dose-rate monitoring), radiation-induced attenuation (RIA, optical losses growing with cumulated dose) and radiation-induced refractive index change (RIRIC, that also increases with total dose). Each effect offers a metrological opportunity. The RL signal, proportional to the dose rate across decades, is the optical analog of the radiation-induced current in ion chambers or diodes. However, the radio-optical conversion is not subject to the limitations affecting the radio-electric one at high dose rate (it is by contrast enhanced!). RL is therefore particularly suited to high-energy protontherapy and flash-RT conditions. RIRIC might be probed by optical backscattering reflectometry to provide distributed dose measurements along the fiber with a spatial resolution below 50 microns. The talk will introduce a brief description of special silica fibers, their tailormade fabrication (notably at INPHYNI, Nice) and advantages. It will present some important points of their assessment for dosimetry applications in RL and RIRIC modes for x rays and/or protons beams.

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