Radiation effects on silica-based optical fibers and sensors: recent advances and future challenges

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Abstract: Silica-based optical fibers present key advantages for integration in harsh environments associated with radiation constraints such as their low weight, high bandwidth, multiplexing capability or electromagnetic immunity. In addition to these well-known advantages, optical fibers can typically resist to higher doses of radiation than microelectronic components and then are selected for integration in the most challenging applications under irradiation. However, radiation alters the fiber properties by creating point defects in the silica-based material of the fiber core and cladding where the signal is propagating. These microscopic defects are responsible for two main macroscopic effects: the radiation-induced attenuation (RIA) that corresponds to an excess of optical losses at the signal wavelength and the radiation-induced emission (RIE) that is a parasitic light adding to the signal. The amplitudes and kinetics of RIA and RIE depend mainly on the nature of the created point defects and today the basic mechanisms of radiation effects on amorphous pure or doped silica glasses even if well-known are still too complex to be fully predictable by simulation. These mechanisms will be reviewed and recent advances made through ab initio simulations briefly presented. Among the parameters that influence the fiber response, the main ones are: the fiber composition, the fiber profile of use and the environmental parameters. In the past, RIA was the limiting factor for most of the targeted applications. However, today with the diversity of fiber profiles of use and the increasing interest in optical fiber sensors technologies, additional radiation phenomena have to be considered such as the glass compaction that affects the performances of sensors exploiting the signatures of silica structural properties (FBGs or distributed Rayleigh, Brillouin sensors) or the differential RIA that affects the Raman-based sensors. As a consequence, the radiation hardening strategy strongly evolved in the recent years, from the classical radiation-hardening-by-device approach to more complex radiation-hardening-by-component and radiation-hardening-by-system studies. Recent examples of achievements and new applications will be described by focusing on the results obtained by previous students of Palermo University through the long-term collaboration between the LAMP group and the Laboratoire Hubert Curien.