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Ionoacoustics for range verification in pre-clinical and clinical proton beam therapy

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The spatially and temporary localized energy deposited by pulsed protons and heavier ionsbeams gives rise to the emission of thermoacoustic waves [1], hereafter referred to as ionoacoustics. The initial pressure subsequent to the brief thermal heating of the irradiated volume is proportional to thedose and the medium properties, namely the mass density and the material-specific efficiency of the conversion from energy to pressure (Grüneisen parameter). Therefore, the detection of the ionoacoustic emissions at several positions on the patient's surface allows inferring information on the incident proton beam either to locate the Bragg peakin vivo or to reconstruct the underlying dose [2].The relative simplicity, low cost, and promising feasibility of near real-time range verification that could be combined with ultrasound images of the patient's anatomy haverevived interest in ionoacoustics, notably facilitated in recent years with the development of new synchrocyclotron accelerators and the emergence of ultra-high dose rate radiotherapy. Advancement in ionoacoustics is however challenged by the intrinsically low frequency of the weak pressures resulting from the energy deposition of pulsed clinical proton beams (typically a few mPa at a frequency around 50 kHz for conventional therapy) both several orders of magnitude lower than ultrasound imaging, which hampered the pre-clinical and clinical implementation of ionoacoustics. This talk will introduce ionoacoustics in the context of proton therapy, giving insights into the ongoing efforts of several groups in translating it to clinical applications. Emphasis will be placed on the critical need for dedicated sensor technology meeting the demanding sensitivity requirements as a part of a small animal system development and recent accomplishments with anthropomorphic phantoms will be discussed.

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