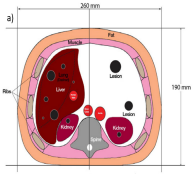
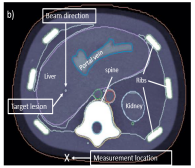
Proton Beam Range Verification Using Ionoacoustics

The Bragg peak located at the end of the ion beam range is one of the main advantages of ion beam therapy compared to x-ray radiotherapy. However, verifying the exact position of the Bragg peak within the patient online is a major challenge. To compensate uncertainties it is clinical practice to intentionally irradiate a larger volume than the clinical target volume. The presented technology uses ionoacoustic measurements for a precise localization of the Bragg peak.





Submillimeter Resolution in Bragg Peak Localization

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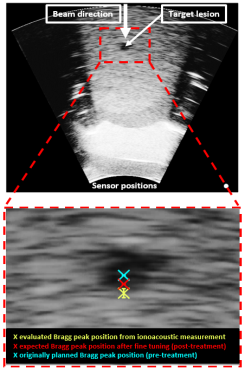
2022

Proton range verification via ionoacoustics is based on the emission of an acoustic wave due to local energy deposition caused by a pulsed ion beam. Through optimized analyzing tools and in combination with ultrasound imaging the technology allows the positioning of the Bragg peak relative to the lesion or nearby organs with sub-millimeter resolution in clinical situations.

01 Submillimeter range verification of proton beam Bragg peak
02 Excellent signal-to-noise ratio of ionoacoustic information
03 Optimization of beam parameters and application of matched filter
04 Technology validated in water and abdominal phantoms



The accuracy of determining the Bragg peak position was demonstrated irradiating a potential lesion in an abdominal phantom by 126 MeV protons obtained from a synchro-cyclotron (left fig.). Ultrasound image of the irradiated region of the phantom highlighting the target lesion is shown in the fig. above. The difference between the red and the yellow cross amounts to 1 mm due to the systematic uncertainty of the lateral beam position impinging on the phantom.

REFERENCES:

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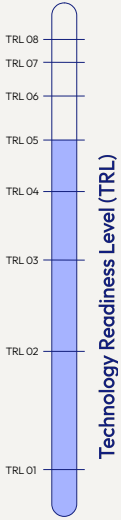
CHALLENGE

The Bragg Peak location can be precisely steered by the initial kinetic energy of the particles. However, an imprecise knowledge of the traversed integral tissue stopping powers within the patient results in range uncertainties becoming most problematic with an organ at risk closely behind the target. The main challenge in ionoacoustics is to obtain sufficient information from the weak signals to obtain the desired accuracy of 1 mm in determining the Bragg Peak position and bring it in relation to the lesion or organs at risk.

INNOVATION

The invention optimizes the signal-to-noise ratio of the ionoacoustic information. This is achieved by optimizing the beam parameters beam current, pulse duration, pulse shape and repetition rate. Ideal pulses are obtained without further beam manipulation from synchro-cyclotrons but also beams from other accelerators may easily be pulsed as required for optimized acoustic signal generation. Additionally, a matched filter has been applied to the detected signal. By co-registering an ultrasound image from the same position as the ionoacoustic detector, systematic uncertainties in determining the Bragg Peak position relative to organ at risks or the lesion itself can be kept below 1 mm.



01 Basic principles observed · **02** Technology concept formulated · **03** Experimental proof of concept · **04** Technology validated in lab · **05** Technology validated in relevant environment · **06** Technology demonstrated in relevant environment · **07** System prototype demonstrated in operational environment · **08** System complete and qualified

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