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Development of the first pulse powered radiotherapy gantry system for a novel compact laser driven ion beam therapy


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Purpose/Objective: Ion beams due to superior dose profile over photons and electrons may provide higher dose-conformity and healthy tissue sparing. But due to high costs and huge size ion beam therapy is limited to a few centers only. A novel ion acceleration process via ultra-intense laser-matter interaction, promises size and cost reduction. However, laser-driven beams are characterized by intense particle bunches with peak dose rates exceeding conventional values by several orders of magnitude, low repetition rate, broad energy spread and large divergence, thus are diverse from conventional beams. This requires new solutions for developing Laser-based Ion Beam Therapy (LIBT) for clinical application. The presented work is a result of an ongoing joint translational research project of several institutions aiming to establish LIBT with protons and shows the status in five main challenges.

Materials and Methods: 1) Laser-based technology has been established, with protons (upto 20 MeV) via 150 TW laser system, for systematic radiobiological studies with human cell-lines and small animals with fixed beamline. II) For translation towards patient irradiation, increase of proton energy from 20 to 230 MeV by increasing the laser power from 150 TW to ~1 PW is required and in progress. III) Furthermore, a compact ion beam gantry system is designed based on pulsed magnets (PM), with integrated laser-particle acceleration chamber, novel beam capturing and energy selection system. A new pulsed scanning system for wide beams with broad energies is designed for irradiations with clinical accuracy. IV) The light-weight iron-less high-field PMs are being developed for gantry realization. These are non-trivial and extremely challenging to design. V) A new 3D TPS has been developed for new dose delivery and treatment planning strategies for LIBT.

Results: No overall difference in the radiobiological effectiveness between laser-driven and conventional beams was detected to date. Therefore, a comparison of dose plans by treatment planning system is possible to evaluate the features of LIBT. The evaluation of treatment plans shows laser driven broad energetic beams are feasible for clinical application. Our double-achromatic 360° isocentric pulsed gantry design is ~2.5x smaller than conventional gantries (see fig.) and is capable of dispersionless scanning of high acceptance beams through 20x20 cm² field size. For the realization, PMs have been designed and developed. A pulsed solenoid, for particle capturing and focusing, has been successfully tested at laser-driven beams. A novel 10 T compact pulsed 45° sector magnet has been developed and tested. Also, a pulsed high acceptance quadrupole with 250 T/m gradient is being developed.

Conclusions: LIBT is a promising compact alternative and could change IBT, yet requires substantial development towards clinical application. Supported by German BMBF, no. 03Z1N511 & DFG cluster of excellence MAP.

Proffered Papers: Physics 6: Predictive models of outcome

OC-0252

Accurate prediction of PTV and OAR doses for dose-escalation of non-small cell lung cancer patients

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Purpose/Objective: Radiation treatment planning with a commercial TPS is a trial and error process that often leads to sub-optimal organ sparing. We developed a method to predict feasible target and organ at risk (OAR) dose levels prior to the start of the treatment planning process. These predictions can be used i) to guide the treatment planner to achieve optimal OAR sparing or target dose escalation; ii) for quality assurance of the treatment planning process; iii) to identify patients that may benefit from adaptive RT; iv) to