Publishable JRP Summary for Project T2.J07 (EBCT). External Beam Cancer Therapy

Project objectives

In the European Union there are about 2.3 million cancer incidents every year. In terms of the number of deaths caused per year, cancer ranges second in the European mortality statistics. Given the massive extent of the cancer threat, decisive measures are required to improve cure rates. In this project, efforts are being made within the scope of an interdisciplinary approach to combat cancer. Experts from the fields of ionising radiation and ultrasound have formed a team in which very different methods are employed, having one objective: improving patient survival. The participants in this project are confident that they will form a highly successful team which can draw substantial advantages from enriching each other across the disciplines: for example, dosimetry techniques are well-understood in ionizing radiation, but these concepts are only just being addressed for High Intensity Therapeutic Ultrasound (HITU). Metrology for ionising radiation has a long history, and much experience has been gained in radiation therapy in clinical environments, a field where ultrasound can draw advantages from. Metrology of ultrasound will bring new ideas into this field and will also stimulate a desirable and healthy competition between the two fields.

On 1 April 2008, the project 'External Beam Cancer Therapy' (EBCT) was launched. The central objective of this project is to provide reliable measuring techniques for all forms of cancer therapy based on external radiation. This includes freshly emerging techniques such as High Intensity Therapeutic Ultrasound and modern forms of cancer therapy using ionizing radiation, like Hadron Therapy and Intensity Modulated Radiation Therapy (IMRT).

Description of work

a) HITU

The overall goal of this part of the project is to improve the efficacy, safety and range of applicability of clinical HITU treatments by providing validated methods for ultrasonic field characterization, HITU system performance testing, quality assurance and patient exposure monitoring. To achieve this aim, the HITU part will address both the basic calibration and specification of equipment, and the repeatable and controllable clinical use of HITU systems. In general, the methodologies used will build on and extend the techniques used for diagnostic and low intensity physiotherapy ultrasound, by sensor development, computational modelling and materials characterization.

b) Hadron Therapy

Cancer treatment with proton and heavier ion beams is characterised by a paradoxical situation: Compared to other forms of radiotherapy it allows the realisation of probably the highest degree of conformity between the treatment volume and the dose distribution. Unfortunately, this advantage is - at least partially - compensated by an increase in the uncertainty of the dosimetry. Therefore efforts will be made to establish reliable primary standards for this kind of radiation fields.

Purpose-built calorimeters will be employed for providing traceability for measurements of the absorbed dose to water in hadron beams. The use of both water and graphite calorimeters and comparisons between them will enhance the robustness of the dose to water measurement and provide information on the physical process of energy deposition, i.e. on stopping powers and W-values.

c) IMRT

Important aims of this part of the project are the development of graphite and water calorimeters as primary standards for absorbed dose measurements in small radiation fields and – by using these devices – the investigation of promising radiation detectors with regard to their applicability as secondary standards. The properties of several types of detectors will be investigated and compared systematically in radiation beams as they are used in modern radiation therapy. For those detectors, which are capable of fulfilling the requirements of clinical dosimetry in small and irregularly shaped radiation fields, the basic parameters needed for dose evaluation will be determined. By using the secondary standards, the capabilities of treatment planning systems used in radiation therapy will be investigated by comparing calculated and actually generated dose distributions in situations of increasing complexity. Difficulties and problems of dose calculation algorithms will be identified, which will help to improve the treatment of patients in radiation therapy.

Impact

For this project to achieve its full potential in terms of impact, the results of the technical work packages need to be disseminated successfully to the user communities. There are two fundamental aims. Firstly, to increase the knowledge about as well as the capability and quality of measurements carried out by the participating laboratories by sharing the existing expertise and the results from the technical work packages, so that scientific progress is maximised. Secondly, to provide end users with access to data, practical guidance and standards to ensure that they derive the maximum benefit from this scientific progress and are capable of making valid traceable measurements.

Kick-off meeting Mai 2008, Braunschweig, project meeting October 2008, Rome

In the kick-off meeting held in May all managerial issues relevant to the project were addressed and the rules on how the partners plan to run the project were agreed. At the first project meeting held in Rome the delegates from all partner institutes reported on the progress achieved so far in the project. Although no deliverables were due at the time of the meeting all delegates reported that the work was progressing according to schedule. Three delays were identified, which are expected to occur in the later stages of the project. They concern the working packages on HITU and hadron therapy; they will neither endanger the respective work package as a whole nor parts of it.

The project meeting in Rome was held in parallel to that of the thematically related project T2.J06 'Brachytherapy'. In order to foster exchange of ideas between the projects and to promote mutual understanding between the ultrasound and ionizing radiation disciplines a half day joint workshop was held. First encouraging steps were undertaken to examine to what extend well established concepts in ionizing radiation dosimetry could be applied in or adopted for high intensity ultrasound.

A web-accessible project server has been put into operation (http://bscw.ptb.de). As a first step registered project partners may down- and upload project relevant documents in an area with restricted access. Currently work is under way to establish a public web site through which the results achieved in the project can be rapidly communicated to interested circles.

Reporting period 1st November 2008 to 31 October 2009

In the HITU part of the project good progress was achieved in the sensor development. A fiber-optic hydrophone setup was developed for the measurement of the spatial pressure distribution in the sound field with an accuracy of 15 % and with standing peak negative pressures up to 15 MPa. Further, reliable measurements of total acoustic output power of HITU transducers for applied power levels up to 500 W could be realized.

Within the scope of the main project part IMRT the measurement quantity absorbed dose to water was realized using a graphite calorimeter (LNHB) as well as a water calorimeter (PTB) in several beam qualities (6 MV, 12 MV, both with flattening filter and 6 MV without flattening filters (LNHB)) with field sizes of 10 cm x 10 cm and 4 cm x 4 cm in minimum. The calibration coefficients of ionisation chambers and the responses of alanine dosemeters determined in these fields show within the uncertainties no dependence on the field size. This is a very interesting and important result for IMRT dosimetry. The aim is to perform measurements in fields with a size of about 2 cm x 2 cm or 3 cm x 3 cm.

A diamond prototype detector was developed at ENEA in co-operation with the Electronic Engineering Department of “Roma Tre” Rome University. The suitability of this detector for reference measurements of absorbed dose to water in high energy photon beams has been investigated. In a first step the energy and field size dependence of its response have been determined by Monte Carlo simulations in 6 MV and 10 MV photon beams with field size from 10 cm x 10 cm to 0.5 cm x 0.5 cm in order to calculate the quality correction factors needed for absorbed dose to water measurements. For further characterisation of the detector measurements will be performed in high energy photon fields with small sizes.

The suitability of the storage foil system “KODAK CR 2000RT plus” for the determination of the exact position of field boundaries in high energy photon fields was investigated. The exact position is necessary for the calorimetric and alanine measurements. With a special experimental set-up and evaluation software the field geometry in a PMMA phantom or at the surface of the water phantom can be determined with a spatial resolution of only about 0.2 mm.

Investigations with the aim to identify difficulties and problems of dose calculation algorithms are an important project item. For this purpose STUK and VSL have gained extensive knowledge for dosimetric measurements using the radiochromic film Gafchromic® EBT, i.e. energy and dose responses and spatial resolution for dose distributions. A multipurpose water filled phantom applicable both for external beam dosimetry in IMRT and for brachytherapy dosimetry was developed by STUK. Its special feature is that conventional direct reading dosimeters as well as radiochromic films can be inserted in the phantom.

One important deliverable is the preparation of an international symposium to present the results achieved in the project to the user and scientific communities. This symposium will be held together with the thematically related project T2.J06 'Brachytherapy' after the end of both projects, i.e. in November 2011, at the PTB in Braunschweig (Germany). The organisation has begun and will be ongoing the future project duration.

Reporting period 1st November 2009 to 30 April 2010

HITU: A new developed coaxial heating element without any conduction loops and a MR-compatible HITU transducer have been tested successfully in the new MR

scanner at PTB which has been put into operation in December 2009. An interlaboratory comparison of acoustic output power measurement capability was carried out and completed successfully. The results were published. A new phantom for checking the focal temperature rise generated by clinical HITU systems has been developed and tested.

Hadron Therapy: Because the 72 MeV proton accelerator facility at SMU is not available for the project a cooperation with Clatterbridge Center for Oncology (CCO), where a 60 MeV proton accelerator is operating, was established. Measurements could be performed successfully at CCO. The general problem for dosimetric research in this field is to obtain enough beam time at an ion accelerator facility.

IMRT: The unit of absorbed dose to water, D_w, was realized with a water calorimeter in a 3 cm x 3 cm and 10 cm x 10 cm field size for 6 MVX and 10 MVX radiation. For both radiation qualities and field sizes, the k_Q factors of an ionisation chamber were determined. Within the uncertainties no significant dependence on the field size could be found. The same shows the responses of alanine dosemeters. For the investigation in smaller fields (down to 1 cm x 1 cm) a new graphite calorimeter was constructed. It is expected that a field size dependence will occur in these small fields.
The radiochromic film Gafchromic® EBT which was characterized in detail is well-suited for the investigations in the scope of this project. However, it is no longer available and was superseded by the EBT-2 film. A couple of dosimetric investigations has been performed again for this new film.

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