Clinical introduction of a CCD based beam imaging system for patient specific dose verification in Intensity Modulated Proton Therapy (IMPT)

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Introduction

The most traditional and still predominant approach in proton therapy is the passive scattering technique. A more advanced delivery technique uses dynamic beam scanning in which the position and relative weight of each individual Bragg peak can be chosen freely in three dimensions such that the dose can be precisely tailored to the three dimensional shape of the target volume. The practical feasibility of this approach has been demonstrated clinically at the Paul-Scherrer-Instiute (PSI) in Switzerland and is now being recognized internationally as the preferred delivery technique for charged particles because of its potential for intensity modulated particle therapy (IMPT). However, due to the inherent complexity of IMPT, patient specific dosimetric verification is evidently an essential part in clinical implementation and operation of IMPT.

Material and Methods

Dosimetric verification in IMPT typically consists of comparative evaluation of calculated (predicted) and measured (delivered) dose distributions in a homogeneous phantom. For this purpose we have recently utilized a beam imaging system based on a scintillating screen and a CCD (charged-couple device) camera (see figure 1). The measurement depth can be varied by placing an appropriate stack of lucite plates in front of the scintillator screen. IMPT plans have been generated by our in-house treatment planning system for actively scanned proton beams. The planning system has a built-in option for recalculating patient specific IMPT fields in a homogeneous phantom for dose verification. The technical usability of the beam imaging system for dose verification has been investigated on a number of clinical IMPT fields. We have also tested its reliability in detecting dose deviations by deliberately introducing delivery errors such as missing or misplaced spots for a number of test cases.

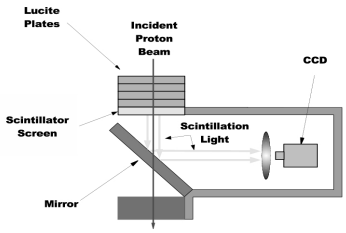

Fig. 1: Schematic view of CCD beam imaging system

Results

The CCD based beam imaging device has proven to be suitable for fast and reliable patient specific dose verification for IMPT delivery. This applies in particular to the verification of large fields and to measurements in which high spatial resolution is desired. The device is now used complementary to a conventional ion chamber array for routine IMPT dose verifications at PSI.

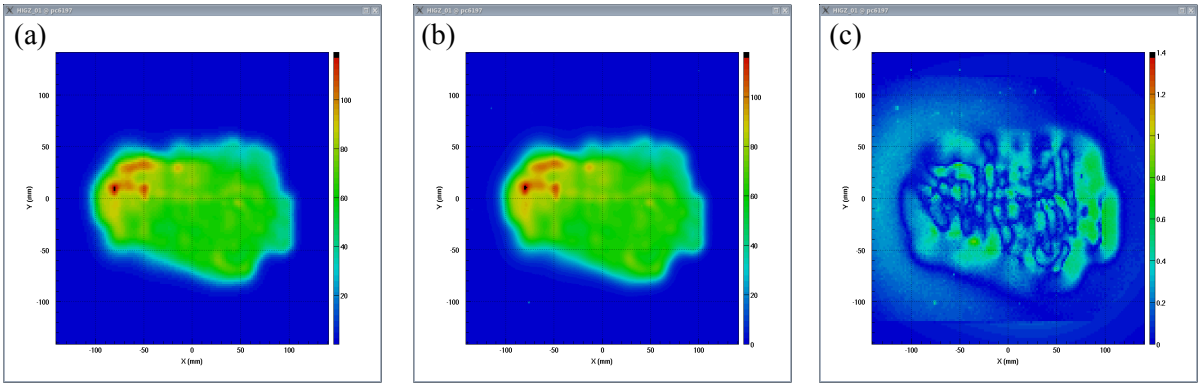

Fig. 2: Dose verification results for a large IMPT field (sacral chordoma case). (a) Calculated dose, (b) dose measured with CCD beam imaging system and (c) γ-Evaluation with ΔD=3% and Δd=3mm acceptance criteria for maximum dose and distance deviations.