Fluorescence-based verification of the proton beam's position during the irradiation of intraocular tumors

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The proton therapy of intraocular tumors is usually performed at a horizontal beam line. The patient is looking at a fixation light to insure the optimal irradiation position for the eye. The eye position is verified prior to irradiation by orthogonal X-ray imaging. During the irradiation the anterior part of the eye is observed by a video camera (fig.1). For on-line verification of radiation field position and eye movements, a novel method based on proton-induced luminescence in blood vessels of the ocular fundus is being tested.

![Fig.1: Typical patient set-up for ocular proton therapy at a horizontal beam line.](image)

The proton-induced luminescence is measured in a phantom with a blood vessel structure of a typical ocular fundus (fig.2), which can be filled with fluorescein (c = 1.0 g/l). Therefore, the phantom is positioned in water at 18 mm water depth and irradiated with a spread-out Bragg peak. The proton-induced luminescence is detected with a CCD camera (fig.3).

![Fig.2: Technical drawing of the retinal blood vessel phantom including papilla, fovea (macula) and vessels of different diameters (black, blue and red). Upper right of the figure shows a photo of the central region of the tantalum sheet phantom.](image)

The position of the irradiation field can be detected with an accuracy of 0.13 mm for applied doses between 8.4 Gy and 23 Gy. The accuracy depends on the location and number of irradiated vessels (fig.4). A position change of the model in the order of 0.2 mm during the irradiation was detected within 4 s. The proton-induced luminescence on the dye fluorescein allows in vivo verification of the irradiation field and eye movement during proton irradiation (fig.5). Further experiments with more complex cases and optimized imaging are being conducted to demonstrate a clinical implementation.

![Fig.4: X-ray images of the treatment field projected onto the blood vessel phantom with two different collimators (a,b) and the corresponding fluorescence signals during the proton irradiation (c,d). The signal is limited to the vessel structures. Video of 1 mm phantom movement during irradiation (e).](image)