FRICKE TOTAL ABSORPTION – AN INSIGHT INTO A PRIMARY STANDARD FOR ABSORBED DOSE TO WATER IN ELECTRON BEAMS

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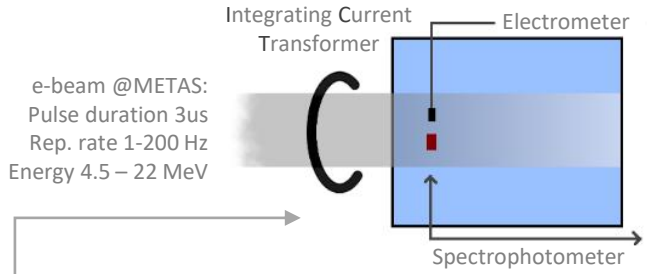
As with conventional radiotherapy, QA in clinic for FLASH radiotherapy is based on a traceable measurement of absorbed dose to water. At METAS, it was shown that the Fricke chemical dosimeter is suitable for use as a reference in FLASH beams. Irradiation of the closely water-equivalent ferrous ammonium sulfate solution with ionizing radiation causes oxidation of Fe2+ to Fe3+. The resulting concentration of Fe3+ is proportional to the absorbed dose and is determined by measuring the change in absorbance of the solution at well-defined wavelengths in the UV spectral range. A primary standard for absorbed dose to water for electron beams is achieved by calibrating the response of this dosimeter with a total absorption experiment. This calibrated solution is then filled into small bags for use in clinical quality beams. This Fricke dosimeter has been in use at METAS for over twenty-five years.

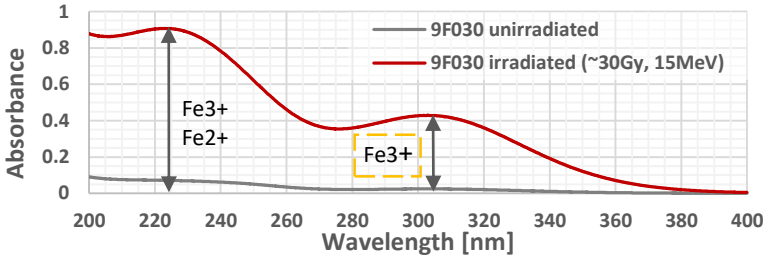
A precisely characterized narrow and monoenergetic electron beam with known charge is totally absorbed in a large volume of Fricke solution. The well-known deposited energy of the beam and the mass of the solution are used to calculate the applied dose. Thereof the radiation chemical yield of the Fricke dosimeter is determined. This chemical yield relates the oxidation of Fe2+ to the absorbed dose to water.

The chemical yield is derived with an uncertainty of less than 1% (k=1) including all corrections factors and Monte Carlo simulations allowing traceable absorbed dose measurements in the conventional and FLASH radiotherapy regime.



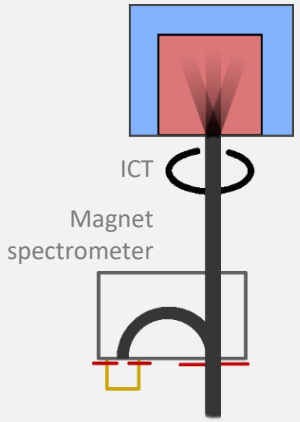
$$D_W = D_F \cdot f_{F/W} = \frac{\Delta c \cdot f_{F/W}}{\rho \cdot G} = \frac{\Delta A \cdot f_{F/W}}{\rho \cdot l \cdot \varepsilon \cdot G}$$

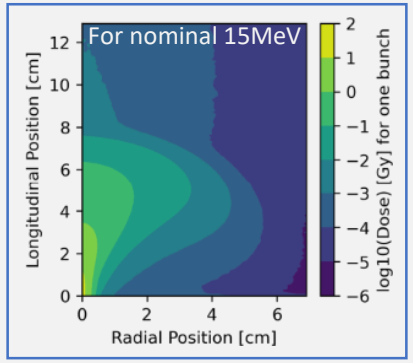
Absorbed dose in Fricke solution | Transfer factor (here for bags) | density of Fricke | length of cuvette



Influencing factors

Total Absorption





$$\varepsilon \cdot G = \frac{\Delta A}{\rho \cdot l \cdot D_F} = \frac{\Delta A}{\rho \cdot l} \cdot \frac{m}{E_{el} \cdot N \cdot f_p}$$

electron energy | number of electrons

> Glass vessel, closed using a 50µm polyethylene foil (volume: 1L or 2L)
> continuous steering of the whole Fricke solution
> Temperature stabilised at 25°C using circulating water
> Number of electrons (N) are measured using a calibrated ICT
> Fraction of incident beam electrons energy deposited in the Fricke solution: f_p: 92 – 97% (depending on energy and vessel)

Fricke dosimetry is suitable as a primary standard and can also be used as a secondary standard, thus forming a basis for QA in FLASH radiotherapy in clinic.

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