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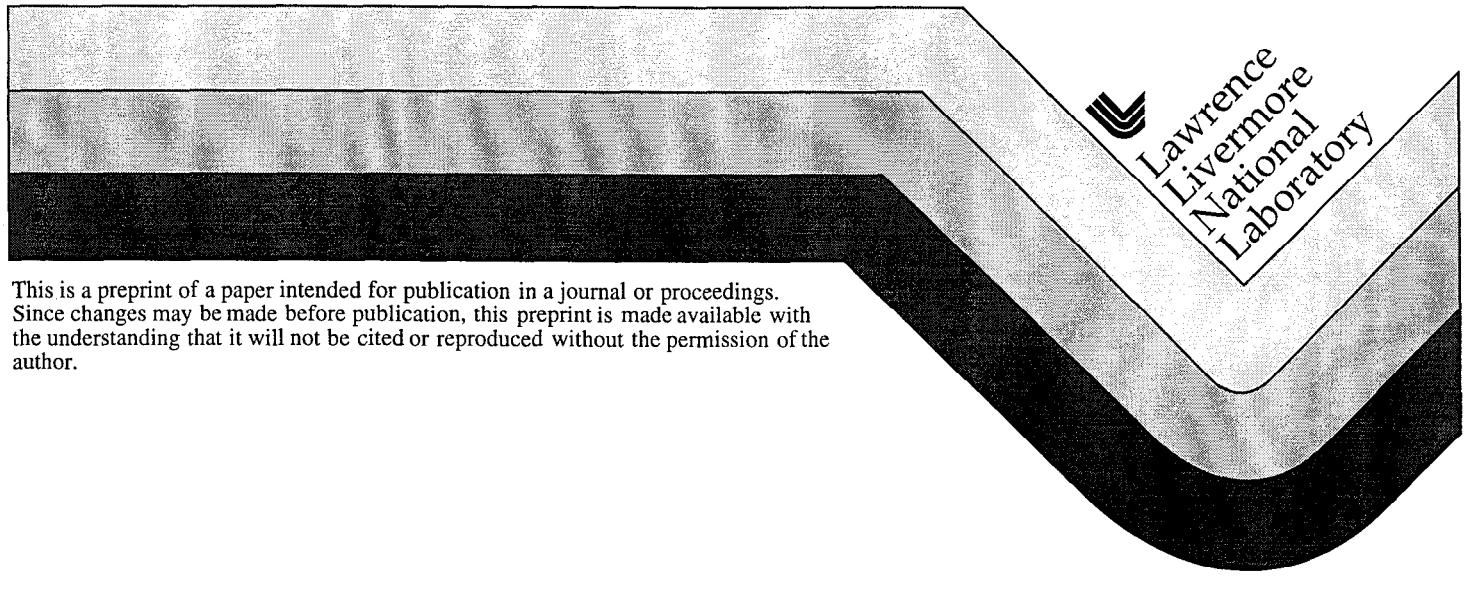

Modeling Multileaf Collimators with the PEREGRINE Monte Carlo

Don H. Fujino, Norman Albright, D.Jay J. Wieczorek

Multileaf collimators (MLCs) are becoming increasingly important for beam shaping and intensity modulated radiation therapy (IMRT). Their unique design can introduce subtle effects in the patient/phantom dose distribution. The PEREGRINE 3D Monte Carlo dose calculation system predicts dose by implementing a full Monte Carlo simulation of the beam delivery and patient/phantom system. As such, it provides a powerful tool to explore dosimetric effects of MLC designs. We have installed a new MLC modeling package into PEREGRINE. This package simulates full photon and electron transport in the MLC and includes tongue-and-groove construction and curved or straight leaf ends in the leaf shape geometry. We tested the accuracy of the PEREGRINE MLC package by comparing PEREGRINE predictions with ion chamber, diode, and photographic film measurements taken with a Varian 2100C using 6 and 18 MV photon beams. Profile and depth dose measurements were made for the MLC configured into annulus and comb patterns. In all cases, PEREGRINE modeled these measurements to within experimental uncertainties. Our results demonstrate PEREGRINE's accuracy for modeling MLC characteristics, and suggest that PEREGRINE would be an ideal tool to explore issues such as 1) underdosing between leaves due to the 'tongue-and-groove' effect when dose from multiple MLC patterns are added together, 2) radiation leakage in the bullnose region, and 3) dose under a single leaf due to scatter in the patient.

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Introduction

Multileaf collimators (MLCs) are becoming increasingly important for beam shaping and intensity modulated radiation therapy (IMRT). Their unique design can introduce subtle effects in the patient/phantom dose distribution and can be investigated by employing Monte Carlo techniques to provide accurate dose determination through full-physics modeling of the radiation treatment process. PEREGRINE is a Monte Carlo-based dose calculation engine supported by sophisticated computer hardware that makes real-time Monte Carlo dose calculation possible. The aim of this study is to introduce and validate the PEREGRINE's MLC package.

Material and Methods

The PEREGRINE MLC package contains full leaf shape geometry including tongue-and-groove features and curved/straight leaf ends. In order to validate the model, we compared PEREGRINE predictions with ion chamber, diode, and photographic film measurements taken with a Varian 2100C using 6 and 18 MV photon beams. Profile and depth dose measurements were made in a water phantom with the MLC configured into annulus and comb patterns. The comb patterns (Fig. 1) consisted of apertures and blocked regions that were one to five leaves in width and 6 cm across. Individual leaves were 1 cm wide. The two pattern were complementary such that a blocked region in the first shape was an aperture in the second.

Results

Fig. 2 shows the PEREGRINE calculated dose at 5 cm depth for (a) MLC shape 1 and (b) MLC shape 2. Fig 2(c) shows the dose summed from the two shapes. Instead of delivering a uniform dose over the 6x26 cm^2 region, underdosing occurs at the boundaries of each rectangular aperture due to the 'tongue-and-groove' effect when dose from multiple MLC patterns are added together. This results from the tongues from one shape protrudes into the aperture regions of the other shape. Fig. 3(a) shows a vertical profile for shape 1 at 5 cm depth. PEREGRINE accurately models the diode measurements to within experimental uncertainty including the radiation leakage under the blocked regions due to scatter in the water and transmission through the leaves. Fig 3(b) is a vertical profile for the summed patterns. Again, PEREGRINE accurately computes the underdosing from the tongue-and-groove effect, as seen by the 20-30% dips in dose. The underdosing is nearly as prominent at 20 cm as it is at 5 cm depth.

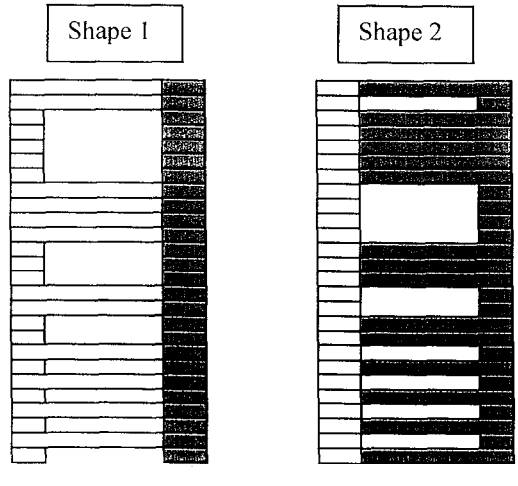

Figure 1. MLC leaf pattern for the two complementary comb patterns. The left (right) leaves are colored yellow (blue). The rectangular apertures are 1 to 5 leaves wide by 6 cm across.

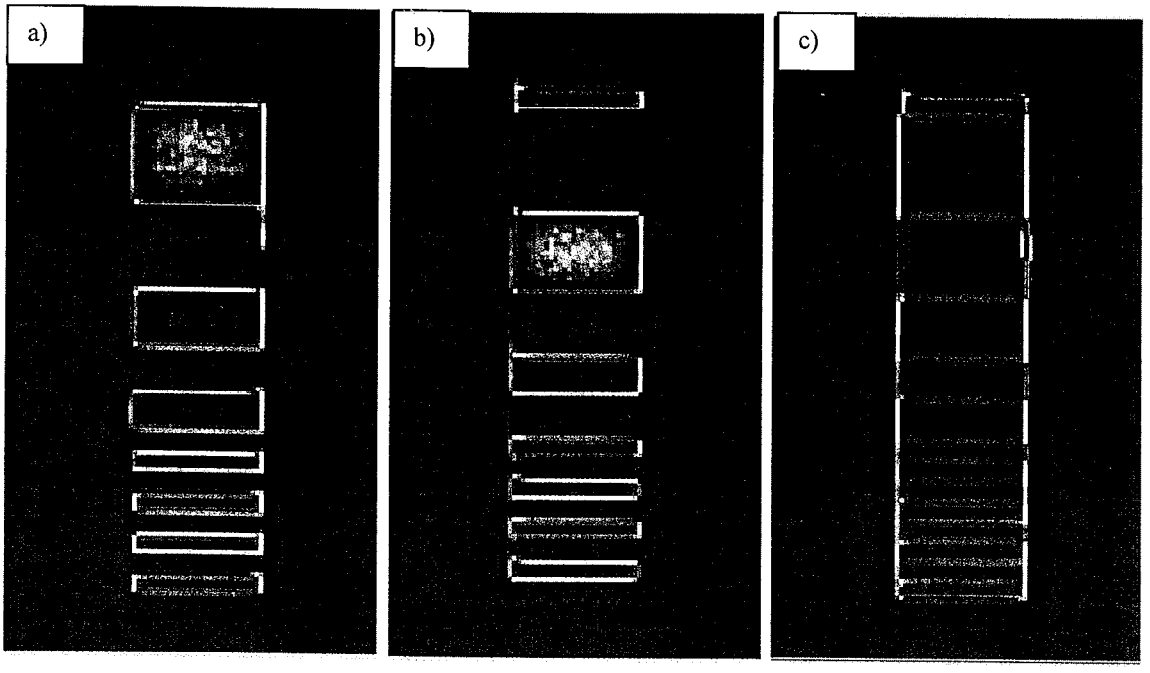

Figure 2. PEREGRINE dose calculation at a depth of 5 cm for (a) MLC shape 1, (b) MLC shape 2, and (c) sum of dose from the two patterns.

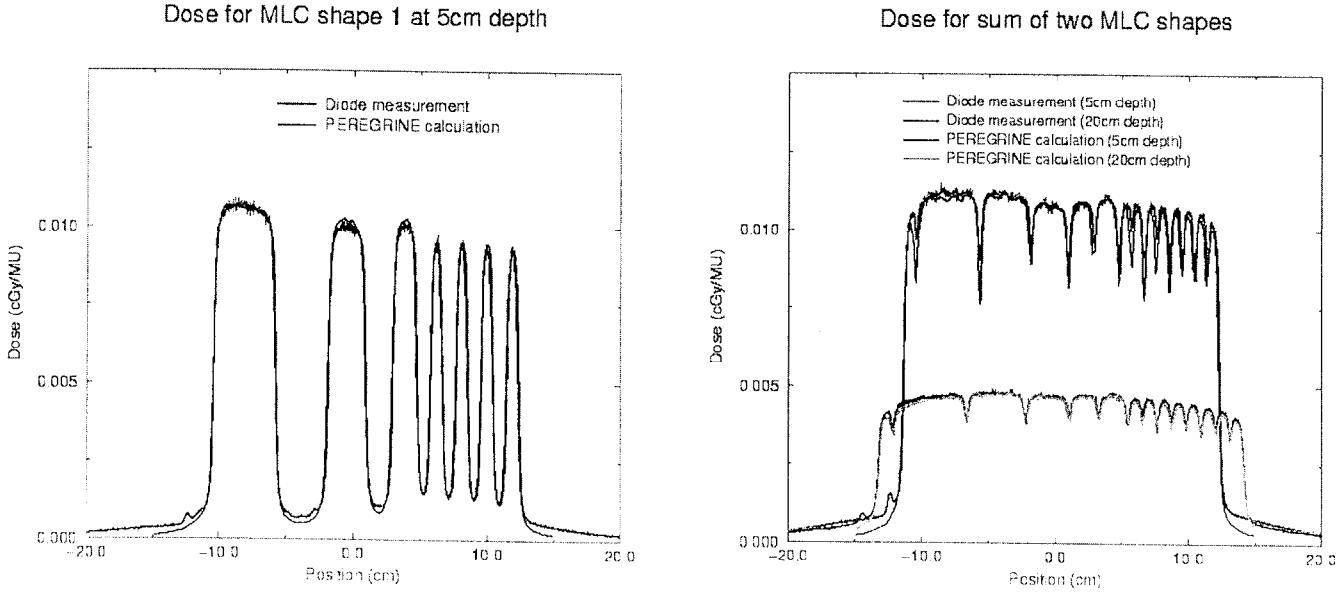

Figure 3. (a) Profile dose distribution for MLC shape 1 at 5 cm depth for diode measurements and PEREGRINE calculations. (b) Profile dose distribution for the dose summed over both shapes at 5 and 20 cm depth. PEREGRINE accurately models the underdosing deviations from an open field.