WF-Note-224

Results of the X-ray Radiation Measurements within the 366 Wakefield Electron Accelerator Facility

A. L. Justus and G. Mosho
October 2004

Introduction

The authors were requested by Wakefield electron accelerator facility personnel to investigate x/γ radiation levels within its shielded cell at those areas that might eventually be occupied by expensive CCD camera equipment. On October 7, 2004, a series of x/γ radiation measurements were performed. This report documents the results of those measurements.

Radiation Source

The radiation at the facility is apparently comprised of only bremsstrahlung x-ray photons. These are due to both beam-related as well as non-beam-related phenomena. This non-beam-related radiation is due to so-called parasitic electrons pulled from relatively unconditioned surfaces by high electric fields and subsequently impinging on high-Z (i.e., metallic) surfaces.

Radiation Measurements

A precision ionization chamber/electrometer system was chosen as the measurement system to utilize. This system allows energy measurements over a relatively wide x-ray energy range, albeit with no knowledge of exact x-ray energy (i.e., no energy resolution what so ever). Our system utilized an Exradin model A5 precision guarded ionization chamber. This is a vented 100 cc chamber with a 0.5 mm thick air-equivalent wall and a 2mm thick (i.e., ^{137}Cs energy) build-up cap. Its serial number was #125 and its calibration factor was $3.29 \cdot 10^7$ R/coulomb. Most measurements were made with the 2 mm build-up cap in place. However, in order to maximize the response to low-energy x-rays, the build-up cap was later removed during the last few measurements.

About 50-foot of very-low-noise triaxial cable was used to couple the ionization chamber within the Wakefield cell to a Victoreen model 530 electrometer (s/n 175) co-located with the investigators safely outside the bulk radiation shielding. A polarization voltage of +301 V was used throughout the measurements. Measurements were obtained in either a ratemeter mode of operation (with a time constant on the order of one second and a direct readout in R/min), as well as an integral mode of operation (with an integral time of 1 minute and a direct readout in mR). Background measurement results were made prior to the first measurement and were monitored throughout the series of measurements. No corrections were made for density of air on the day of measurement.

The measurements commenced at approximately 11:30 A.M. on October 7, 2004 and ended at about 1:00 P.M. on the same date.

Measurement Results and Interpretation

The series of x/γ radiation measurements were performed at the six positions listed and described in Table 1. These six positions are labeled as Position A through Position F.

The measurement data are presented in Table 2. With the exception of the first measurement at Position A (i.e., Position A-I), all other measurements were performed at a beam repetition rate of 5 pps. Also, with the exception of the fourth measurement at Position A (i.e., Position A-IV), all other measurements were performed with the Laser on. The net R/h values in the last column were obtained simply by correcting the measured R/min values for the background response and renormalizing to 1 hour.

The measured levels for Positions A through C ranged from 0.34 R/h near the floor level to 13 R/h at beam-line height. It was noted during the conduct of each measurement that the magnitude of each initial level always seemed to appear to decrease somewhat within the few-minute time interval involved in each new measurement position. It is seen that the forwardly-directed radiation levels (i.e., at Position C) are not significantly different from those at the sideward Position A. That the x-ray fields are more or less isotropic then leads to two important points. First, this implies that the x-ray fields are not strongly beam-related since the bremsstrahlung x-ray fields due to 20 MeV electrons are forwardly directed. Additionally, this therefore implies that the x-ray fields are predominantly non-beam-related and of significantly lower energies.

In an attempt to understand the potential effectiveness of localized shielding for the CCD camera equipment, measurements were performed at Position D with both the build-up cap in place and, in order to maximize the response to low-energy x-rays, with the build-up cap removed. It was observed that the response increased by over 50%, indicating an overall softer x-ray spectrum than the ^{137}Cs energy at 662 keV. Additionally, measurements were performed at Position E with both a ¼-th inch Pb shield in place and with the Pb plate removed. The ¼-th inch Pb plate was observed to have a shielding effectiveness equivalent to 1 HVL.

Summary and Recommendation

A series of radiation measurements were performed of the x/γ radiation levels within the Wakefield cell at those areas that might eventually be occupied by expensive CCD camera equipment. The radiation at the facility is apparently comprised of only bremsstrahlung x-ray photons. These are due to both beam-related as well as non-beam-related phenomena. The electron beam energy was up to 20 MeV, however, the beam current was quite small. The non-beam-related radiation, due to parasitic electrons pulled from unconditioned surfaces and impinging on metallic surfaces, was apparently the predominant source term of the measured bremsstrahlung x-ray photons.

The photon exposure rate is due primarily to x-rays with energies that appear to be less than ^{137}Cs energies (i.e., ≤662 keV). The measured levels ranged from a fraction of an R/h near the floor level to about 14 R/h at beam-line height. The magnitude of the levels always seemed to appear to decrease somewhat within the few-minute time interval involved in each new measurement position.

It is recommended that relatively-thin Pb plate or Pb brick be utilized as localized shielding directly about these areas when eventually occupied by the expensive CCD camera equipment.

Table 1. List of measured positions.

Position	**Location within Wakefield cell**
A	On main table, at windowed flange, YAG #2
B	On floor, at future CCD camera position
C	On rear table, at forward (0°) position
D	On main table, YAG #1
E	On main table, back to YAG #2
F	On floor, directly under Positions A and E

Table 2. Measurement data at each measured position.

Position #	**Beam rep rate**	**Laser on/off**	**Build-up Cap**	**Pb Plate**	**Measured R/min**	**Net R/h**
Bkgd	NA	NA	On	NA	0.0004±0.0001	NA
A-I	**1 pps**	On	On	NA	0.06±0.01	3.6
A-II	5 pps	On	On	NA	0.22±0.01	13
A-III	5 pps	On	On	NA	0.12 integral	7.0
A-IV	5 pps	**Off**	On	NA	0.14±0.01	8.4
B	5 pps	On	On	NA	0.006±0.0001	0.34
C-I	5 pps	On	On	NA	0.114 integral	6.9
C-II	5 pps	On	On	NA	0.070 integral	4.2
D-I	5 pps	On	On	NA	0.1	6
D-II	5 pps	On	**Off**	NA	0.158 integral	9.5
E-I	5 pps	On	**Off**	NA	0.232 integral	14
E-II	5 pps	On	**Off**	**0.25″**	0.15	9
F	5 pps	On	**Off**	NA	0.0075	0.45