Date: Sept. 11, 2019

To: RSC, M. Palmer, M. Fedurin

From: K. Yip

Subject: Review of the UED Upgrade Program


Mark Palmer and Mikhail Fedurin presented 1 the UED (Ultrafast Electron Diffraction) Upgrade Program to the Radiation Safety Committee (RSC) on Sept. 10, 2019.

i. Mark first showed routine operation parameters (energies, pulse charges, repetition rates and power) and the maximum parameters approved in 2015 2. The main intended upgrade is to increase the repetition rate from 10 Hz to 50 Hz.

ii. One main phenomenon is that the radiation during the UED operation is mainly due to dark current, rather than the laser induced pulsed beam. M. Fedurin illustrated this from his experiment on Aug. 23, 2019.

iii. Nevertheless, compared to the operation in 2017 and before, they have or will have two improvements.

a. When the photocathode was first moved from SDL (Source Development Laboratory) to Bldg. 912 around 2016, the surface was damaged. But in the summer of 2018, the photocathode was removed and re-polished with the help of Instrumentation Division. M. Fedurin later showed that the net radiation was found to be reduced 0.69 mrem/hour to 0.42 mrem/hour, a reduction of ~61%.

b. Another maneuver that they intend to take is to reduce the pulse width of the klystron high-voltage from 2.5 µs to about 1 µs (though this has not been tested and implemented yet and the final value needs to be determined by stability requirements). This can give rise to a 40% reduction in radiation.

c. If all go according to the plan, the current power (due to dark current) of 3 mW will be 3 mW × 0.61 × 0.4 × 5 or 3.7 mW.

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2 https://www.c-ad.bnl.gov/esfd/RSC/Memos/7_17_15 UED.pdf
iv. In the meeting, I have promised to check the radiation calculation that Dana Beavis did for the Klystron. After the meeting, I have found the RSC memo of Apr. 8, 2016 \(^3\) and apparently, there was not enough information (still true to this day) to accurately evaluate the radiation from this Klystron and some educated guesses and fudge factor have been introduced. The following is my re-evaluation:

a. The average current for this Klystron should be 8 mA \((400 \text{ A} \times \frac{2 \mu s}{1 \text{s}} \times 10)\) instead of 26 mA as Dana wrote in the 2\(^{nd}\) paragraph, as Mark has helped verify this.

b. I have found the MCNPX input/output files (“KLY2” and “o_KLY2o”, dated Apr. 8, 2016”) that Dana has used to get the simulation result mentioned in his RSC memo. I have verified Dana’s arithmetic calculation in arriving at the result of \(3.7 \times 10^5 \text{ mrem/hour}\) stated in his memo (which did actually use 8 mA).

c. Dana applied a fudge factor of 0.1 (due to the fact that past history has not detected any such big fault, among others), in addition to \(~1.25 \text{ cm}\) of lead shielding (which Chris Cullen and Mark have verified for me with their drawing). The maximum dose rate after taking the shielding and fudge factor into account is almost 100 mrem/hour.

d. After the upgrade, the \(2 \mu s\) mentioned in Dana’s memo would be \(1 \mu s\) only and the repetition rate is 5 times higher. Therefore, the current will be \(8 \text{ mA} \times 0.5 \times 5\) or 20 mA. Calculated in the same way as Dana has done (as the shielding remains the same), the dose rate would be about 250 mrem/hour, which I consider as the same order of magnitude as in the old case. Because of the fudge factor (and the lack of information about this Klystron), all these may be not very realistic and I believe that a radiation survey is a more realistic approach. Past survey result showed only radiation at the level of 1 mrem or so.

v. After Peter also showed us the parameters used in the safety analysis for UED \(^4\). Among others, 3 MeV and 3 mW were used in the analysis. Apparently, a USI (Unreviewed Safety Issue) document is needed to be written for the upgrade.

vi. Mark also prepared us for another upgrade of going to about 10 MeV for their beam energy. From the above-mentioned exemption document, Mark and I have checked that the exempt accelerator is defined by DOE 420.2C, paragraph 3.c.(1) \(^5\), which has a limit of “below 10 MeV” for X-ray generators. Therefore, it is probably safe to allow beam energy only up to 9.9 MeV for the future UED operation.

vii. During the meeting, the committee members are generally satisfied with Mark’s proposal and plan such that they will do radiation survey for the upgraded Klystron and will do fault study for the upgraded operation. The RSC can then make the final judgement based on the results of the radiation survey and fault study.

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\(^3\) https://www.c-ad.bnl.gov/esfd/RSC/Memos/4_08_16_UED.pdf
\(^5\) https://www.directives.doe.gov/directives-documents/400-series/0420.2-BOrder-c/@@images/file
viii. There is also a consensus that we should make the chipmunk to be an interlocking device so that if there is any unexpected radiation, it will be interlocked and stopped promptly without any necessary human action.

ix. It is understood that our Chief Electrical Engineer will review the electrical safety aspect of the Klystron, which is outside the scope of this Committee.

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