Laser Beam Power Limitation to assure electron beam power limitation

The electron beam power will be limited by limiting the maximum possible current produced at the photocathode by the laser. This will be accomplished by introducing a fixed attenuation into the laser beam line and measuring the maximum laser power deliverable to the photocathode, P_{lmax}, at the full laser repetition rate. Once P_{lmax} is determined, the attenuator will be locked out. The value of P_{lmax} must then be entered in the control program and verified by the shift leader. The shift leader will make a notation of the value and the fact that agreement with the program value has been verified on the Radiation Safety Committee (RSC) checkoff list before operation begins. Changes to P_{lmax} during the operations run must also be verified and logged by the shift leader.

The control program uses P_{lmax} to determine maximum values of the parameters that determine the laser duty factor, as described below, and this limits the maximum electron beam power. Different machine tests require different combinations of bunch charge and repetition rate. Larger bunch charges must be run at lower repetition rates in order to comply with the maximum beam power requirement. This means that different settings of P_{lmax} are required for different machine tests.

The laser runs internally at a constant repetition rate of 9.38 MHz, and pulses are released to the photocathode through a gated electro-optic switch which can open and close on nanosecond time scales. The frequency f and the width w of the gates are under the control of the control program, and the duty factor χ is equal to their product, $\chi=fw$. As P_{lmax} is measured with the laser running at its full 9.38 MHz repetition rate, the laser power reaching the photocathode is then $P_{lc}=\chi\, P_{lmax}=fwP_{lmax}$. The beam current produced at the photocathode I_c depends on the efficiency ξ of the cathode, $I_c=\xi P_{lc}$. The efficiency is measured before the cathode is inserted, and verification of its value in the control program will also be required on the RSC checklist checklist prior to operation.

The control program will then limit values of f and w such that I_c remains below a pre-determined current I_0. For example, if we take $P_{lmax}=1W$, and $\xi=5mA/W$, then with I_0 = 4 microamperes, we obtain:

$$fw \leq \frac{I_0}{P_{lmax}\xi} = \frac{4\times 10^{-6}\ A}{(1W)(5\times 10^{-3}A/W)} = 8\times 10^{-4},$$

and the control program will check the product fw whenever a request to change either value is made by the operator, and prohibit operation if their product exceeds 8×10^{-4}.

The value I_0 of will be set by the C-AD Radiation Safety Committee Chair. The value of 4 microamperes given above represents a factor of 5 safety margin below the maximum allowed beam power of 70 W (at the maximum beam energy of 3.5 MeV, a 4 microampere beam has a power of 14 W). Any change in the value of I_0 must be approved by the C-AD Radiation Safety Committee Chair, and under no circumstances may I_0 be increased beyond 20 microamperes.