LCLS-II-TN-19-01

Average Current Monitor Beam Generated Signals*

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Contents

1 Introduction

Excessive beam power could thermally damage beam dumps. The Beam Containment System uses Average Current Monitors (ACM) to monitor the average beam current and turn off the beam if the current is above a beam energy dependent threshold. The current sensor of an ACM consists of a simple RF cavity through which the beam passes and induces an oscillating and decaying electromagnetic field. Two small holes in the side of the cavity couples out RF signals which are detected and processed to determine the beam current average. A rendering of the proposed cavity is shown in Figure 1, and design details can be found in [1], [2], [3], and [4]. ACM electronics determine the average beam current by performing a running integration of a signal proportional to the magnitude of the cavity voltage. The duration of the integration window, ΔT, is set at 1 ms. The value of the running integral is compared with a threshold for safe operation.

There are three possible sources beam current in LCLS-II: photo-electrons from the gun, field emission (dark current) electrons from the gun, and field emission from the superconducting accelerating cavities. The range of possible bunch spacing varies considerably among them. Photocurrent bunches can be in any arbitrary pattern of roughly 1 MHz buckets. Dark current from the gun occurs at the gun RF frequency of 187 MHz. Field emission current from superconducting cavities is at 1.3 GHz. This note looks at the theoretical sensitivity of the ACM to bunch spacing, types of beam current, and test signals.

2 Beam-cavity interaction

In this section we first discuss, in a general way, the cavity voltage due to an arbitrary bunch pattern. Then we introduce the important assumption of constant bunch phase with respect to the cavity voltage and show how that simplifies the calculation of the probe power and the signal used to determine the

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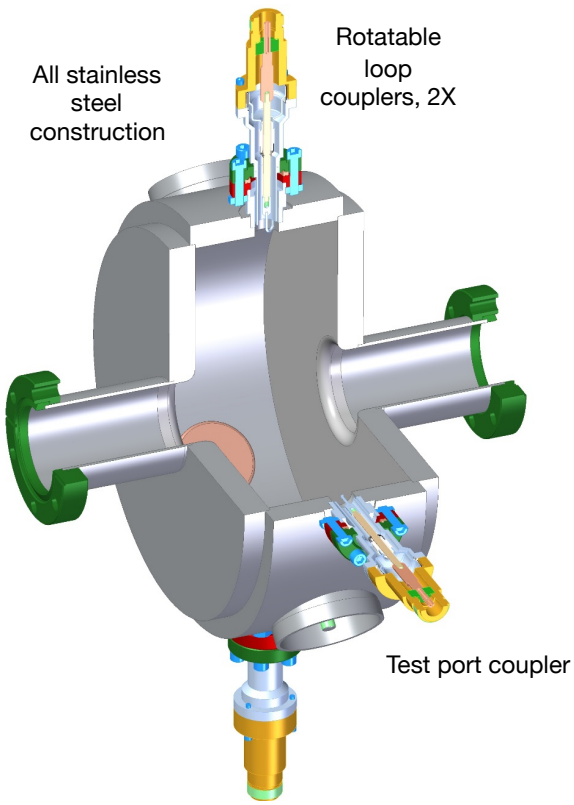

Figure 1: Rendering of the proposed ACM cavity [5].

average current.

When a single bunch goes through an ACM cavity it excites all electromagnetic modes. Those modes above the cutoff frequency of the beam tubes connected to the cavity are rapidly damped, while those below cutoff 'ring'. The energy in these ringing modes is partly dissipated by the cavity walls and partly through coupling ports. Based on the beam tube dimensions of the proposed ACM [5], the cutoff frequency is about 4.29 GHz. Assuming a pillbox shaped cavity there are only three modes with frequencies below cutoff: the fundamental mode at 1.3 GHz, a dipole mode at 2.07 GHz, and a higher order monopole mode at 2.98 GHz. While fields from the two trapped, non-fundamental, modes are excited and persist in the cavity, they are filtered out by a low pass RF filter at 1.7 GHz. In the following discussion we are only considering voltage due to the fundamental mode.

2.1 Cavity voltage

The electromagnetic field excited in the cavity is a complex function of space, so it is usual to refer instead to the 'cavity voltage', V_c. The cavity voltage is defined as the magnitude of line integral of the electric field a beam electron would see due to fields already present in the cavity. See pp. 42 and 333 in [6]. For a typical accelerating cavity the cavity voltage is equivalent to the energy gain, divided by the electron charge, of a high energy electron passing through the cavity. In the case of the passive ACM cavities, bunches actually lose a small amount of energy to the cavity.

The cavity voltage excited in an ACM cavity by the passage a single electron bunch, with no field present initially, can be represented as

$$V_i = V_{i0} e^{i\omega(t-t_i) - \frac{\omega}{2Q_L}(t-t_i)} h(t-t_i),$$

where V_{i0} is the initial amplitude of the oscillating and decaying electric field, t_i is the arrival time of the bunch and $h(t-t_i)$ is a unit step function equal to zero for $t-t_i \leq 0$ and otherwise equal to one. The time varying magnitude of the field is

$$|V_i| = V_{i0} e^{-\frac{\omega}{2Q_L}(t-t_i)} h(t-t_i).$$

When there are multiple bunches exciting the cavity, the net cavity voltage V_{total} is,

$$V_{total} = \sum_i V_{i0} e^{i\omega(t-t_i) - \frac{\omega}{2Q_L}(t-t_i)} h(t-t_i).$$

In general, for arbitrary bunch arrival time t_i, the magnitude of the total field, $|V_{total}|$, is then a quite complicated and a rapidly oscillating function of time. However, considerable simplification results if all the bunches arrive at the cavity at the same phase, so that each bunch induces a cavity voltage that simply adds to the voltage already present in the cavity. In this case the magnitude of the net cavity voltage is the sum of the individual magnitudes induced by individual bunches.

With the same-phase assumption the factors $e^{i\omega(t-t_i)}$ in the general expression for net cavity voltage are equal to one. The running time integral of the magnitude of the cavity voltage, $S(t)$, becomes

$$\begin{aligned} S(t) &\equiv \int_{t-\Delta T}^{t} |V_i| dt' \\ &= \int_{t-\Delta T}^{t} \sum_i V_{i0} e^{-\omega(t'-t_i)/2Q_L} h(t'-t_i) dt'. \end{aligned}$$

The integral, $S(t)$, depends on whether bunch arrival times fall within or before the integration window. But because for our parameters $\Delta T \gg \tau$ the voltage excited by nearly all bunches will be essentially entirely integrated when the pulse arrival time is within the integration window. That is almost all pulses will contribute to the integral an amount

$$S_i \approx \int_0^\infty V_{i0} e^{-\omega t'/2Q_L} dt' = 2V_{i0} Q_L/\omega$$

when they are in the integration window. In this approximation $S(t)$ is then just the sum of S_i over bunches that are within the integration window, otherwise the bunch pattern has no effect on the value of the integration window.

2.2 Constant bunch phase

The constant-phase assumption is only partially justified. In order to be accelerated to high energy, all bunches, including dark current bunches, must be more or less in phase with the SC linac RF. Since the ACM cavity is the same frequency as the SC linac RF, high energy bunches will arrive at an ACM an integral number of RF cycles apart and have the same ACM cavity phase. Even dark current which is not accelerated to high energy is affected by 'velocity bunching' by the SC linac RF that tends to bring low energy dark current bunches into constant phase with respect the linac RF and therefore also constant phase with respect to the ACM cavity.

The one exception to the constant-phase condition is the possibility of backward traveling current from field emission generated electrons from the SC cavities. Backward traveling electrons will get accelerated on the opposite phase from forward traveling electrons. Depending on the longitudinal location of the ACM with respect to the SC RF cavities, backward traveling current will either add to or subtract from the voltage of forward traveling bunches. Such a beam is not expected have much current, and in any case will be lost as soon as it encounters a bend magnet.

3 Probe Power and ACM Signals

It turns out that widely separated bunches and closely spaced bunches produce different cavity voltage signals even if they have the same bunch charge or the same average current. In this section, starting with some basic RF relations we separately calculate, for each case, the probe power and the value of the window-integrated cavity voltage magnitude that is monitored against the trip threshold.

3.1 General RF relations

The power dissipated in the cavity walls is

$$P_c = \frac{V_c^2}{R} = \frac{V_c^2}{(R/Q_0)Q_0} \tag{1}$$

where V_c is the cavity voltage, R is the shunt impedance and Q_0 is the unloaded Q-factor (p. 47

of [6]). The power delivered to a probe with coupling β_e is (p. 148 of [6]):

$$P_e = \beta_e P_c.$$

The reference design has two equal probe ports, with $\beta_e = 0.5$, loaded Q, Q_L of 1300, and unloaded Q, $Q_0 = 2600$. As a result, half the power is dissipated in the cavity walls and half the power is delivered to the probes. Relevant cavity RF parameters, consistent with those in the Statement of Work for the procurement of cavities, are listed in Table 1.

3.2 Widely spaced bunches

For widely spaced bunches, such as those of the photocurrent, the integral of the magnitude of the cavity voltage produced by bunches arriving within the integration window is essentially the same as the sum of the integrals of individual bunches in the window. The pattern of bunches does not matter to value of the running integral, since the voltage signal from each bunch does not appreciably overlap with that of any other bunch.

For the photocurrent beam, even in the highest repetition rate case of 1 MHz (where there could be as many as one-thousand bunches in the integration window) the cavity voltage has decayed to about 5% of the peak by the time a subsequent bunch arrives. This case is plotted in Figure 2. This is the desired behavior of the ACM [7] because it measure the average current independent of the bunch pattern, which can be arbitrary.

More generally, for widely spaced bunches such that $\tau/T \gg 1$, where $\tau = 2Q_L/\omega$ is the field decay time, and T is the time between subsequent bunches; the voltage produced by one bunch does not overlap substantially with the voltage from the subsequent bunch. In that case the cavity voltage just after the passage of a bunch charge q is

$$V_q = \frac{\omega}{2}\frac{R}{Q}q, \tag{2}$$

where $\omega = 2\pi f$ and f is the resonant frequency of the ACM (see eq. 15.13 in [6]). After the bunch passage the cavity voltage exponentially decays with a time constant $2Q_L/\omega$ from the peak value V_q

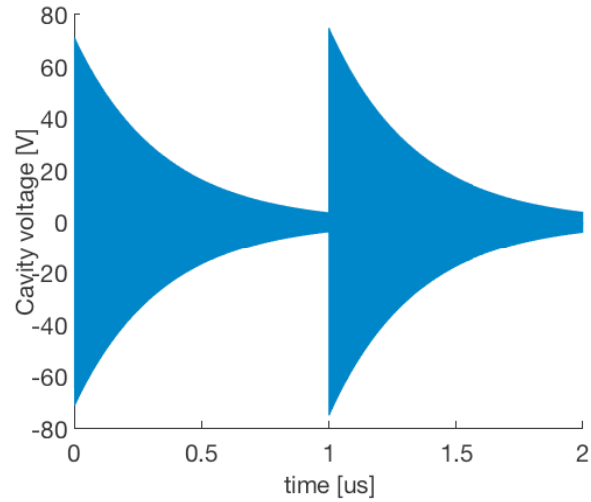

Figure 2: Calculated cavity voltage from a 1 MHz bunch train of 100 pC bunches turned on at $t = 0$.

The power delivered to a probe just after passage of a single bunch is then

$$P_e = \beta_e \frac{V_q^2}{(R/Q_0)Q_0} = \beta_e \left(\frac{\omega}{2}\right)^2 \frac{R}{Q}\frac{q^2}{Q_0}.$$

For widely spaced bunches the peak probe power depends only on bunch charge and the cavity parameters. For a single bunch of 1 pC and the design parameters mentioned, the peak power delivered to the probe is $P_e = 0.513\ \mu W$. The running time integral of the magnitude of the cavity voltage after the passage of a single bunch is

$$S(t) = \int_{t-\Delta T}^{t} V_q e^{-t'/\tau} dt' = V_q \tau,$$

where ΔT is the width of the integration window. For a bunch train that has many bunches within the integration window (but still widely separated compared with the cavity decay time), the running integral is

$$S(t) \approx V_q \tau \frac{\Delta T}{T}.$$

It is approximately equal to the number of bunches within the integration window multiplied by the integral contribution a single bunch would make. See Section 4 for a discussion of this approximation.

Table 1: Reference design values for various RF cavity parameters

Parameter	Symbol	Value	Units
fundamental frequency	f	1.3	GHz
unloaded Q	Q_0	2600	
loaded Q	Q_L	1300	
field decay time	τ	0.32	μs
R/Q_0	R/Q_0	160	ohms
number of probe ports		2	
probe port coupling factor	β_e	0.5	per port
probe port power for 1 ADC count	$P_{e,min}$	4.78E-10	W
min. current threshold	I_{min}	0.5	μA
max. current	I_{max}	300	μA
max. bunch charge	q_{max}	1000	pC
integration time	ΔT	1	ms
pilot tone input power (dBm)		23	dBm
pilot tone input power (W)	P_{PT}	0.2	W
test port coupling to probe (at f)	α	-40	dB
test port coupling to probe detuned		-50	dB
Test tone current eqv	I_{test}	10	μA
ADC input power limit		10	dBm
Probe net attenuation		17.1	dB

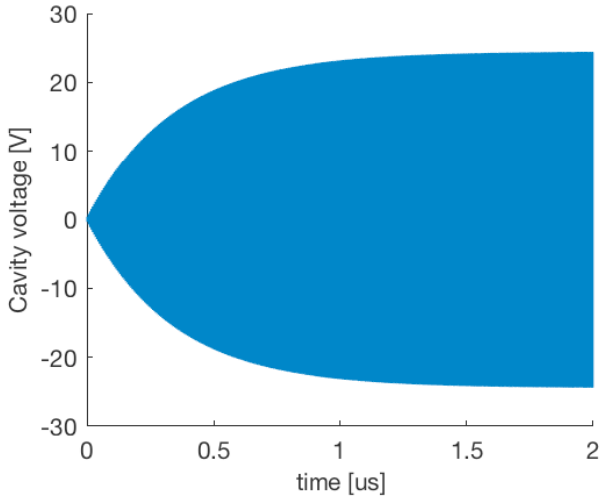

Figure 3: Build up of the cavity cavity voltage when a 186 MHz, 0.54 pC bunch train is turned on at $t = 0$.

3.3 Closely spaced bunches

Bunches from gun dark current and cavity field emission occur with much closer spacing than that of photocurrent. The cavity voltage signal each bunch generates overlaps with that of other bunches, and there is a net build up of the cavity voltage. Figure 3 shows the buildup of the cavity voltage due to gun dark current that commences at time equal to zero, as calculated directly from general relations of Section 2. The average dark current in this case is the same as the average photocurrent beam current which produced Figure 2, yet the cavity voltage is a quite different function time.

Generally bunches may be regarded as closely spaced when the bunch spacing T is much less than the cavity decay time, i.e. $T/\tau \ll 1$. In that case the cavity voltage builds up to an approximate equilibrium value such that the decay of the cavity voltage between bunches is just equal to the increase in cavity voltage by a single bunch. If the beam is composed of a train of equally spaced bunches with the same the same charge, and if a solitary bunch induces a peak cavity voltage of V_q, and V_c is the peak cavity voltage after build up to equilibrium, the change in the net cavity voltage between subsequent bunches is

$$dV_c \approx (V_c/\tau)T \approx \quad V_q.$$

Equivalently

$$V_c \approx (\tau/T)V_q. \tag{3}$$

The factor τ/T can be viewed as a 'build-up' factor of the cavity voltage over that produced by a single bunch. For closely spaced bunches, the peak power delivered to a probe port after the voltage builds to equilibrium up is equal to the peak power delivered by a single bunch times the square of the cavity voltage build up factor. In the case of 186 MHz gun dark current bunches we have $T/\tau = (1/186)/0.343 \approx 0.0157$, which is much less than one, so the bunches are closely spaced. A steady train of 186 MHz bunches will therefore build up a cavity voltage that is about $1/0.0157 \approx 64$ times the peak cavity voltage of one bunch with the same charge. The equilibrium probe power will be about $64^2 \approx 4100$ times larger (36 dB) than the peak power from one bunch of the same charge. The cavity voltage build-up factor for 1.3 GHz cavity field emission current is about 450. For such bunches the probe power will be $450^2 \approx 2 \times 10^5$ times larger (53 dB) than the peak power from a single field emission bunch.

If the peak cavity voltage were used as a measure of the average beam current, the ACM would be 64 times more sensitive to gun dark current than to photocurrent bunches. Likewise, the ACM would be 450 times more sensitive to cavity field emission than to photocurrent. This property of build-up of cavity voltage by closely spaced bunches is exploited in the design of the dark current monitor for the European XFEL [8].

To calculate the probe power for a train of closely spaced bunches we substitute V_q from Equation 2 and $\tau = 2Q_L/\omega$ into Equation 3 to get steady-state built-up cavity voltage

$$V_c = \frac{\omega}{2}\frac{R}{Q_0}q\frac{2Q_L}{\omega T} = \frac{R}{Q_0}q\frac{Q_L}{T}. \tag{4}$$

Using Equation 1 the power delivered to a probe, P_e, is then

$$P_e \quad = \quad \beta_e \frac{V_c^2}{(R/Q_0)Q_0} \tag{5}$$

$$= \quad \beta_e \frac{\left(\frac{R}{Q_0} q \frac{Q_L}{T}\right)^2}{(R/Q_0)Q_0} \tag{6}$$

From $Q_0 = \omega U/P_c$ and $Q_L = \omega U/(P_c + P_e + P_e)$, where U is the total stored energy in the cavity, and the second P_e term is due to the second identical probe port, one can find that the above expression for P_e reduces to

$$P_e = \frac{\beta_e}{(1+2\beta_e)^2} \frac{R}{Q_0} Q_0 I^2. \tag{7}$$

For the ACM cavity parameters in Table 1, P_e evaluates to

$$P_e = 5.20 \times 10^4 I^2.$$

where P_e is in watts and the average current I is in amperes.

We can see explicitly in Equation 7 that the probe power generated by a train of closely spaced bunches depends only on the average current and the cavity RF parameters.

Since the cavity voltage is nearly constant for closely spaced bunches, the running time integral of the magnitude of the cavity voltage, $S(t)$, is

$$S(t) = \int_{t-\Delta T}^{t} V_c dt' = V_c \Delta T,$$

where V_c is obtained from Equation 4.

3.4 Pilot and Test tones

The 'Pilot tone' is a CW RF signal introduced through the Test port and detected at both Probe ports. It is used to verify the ACM is operating properly. The Pilot tone frequency is slightly detuned from the beam SC RF frequency (which is same as the ACM cavity resonant frequency) and is filtered out using a very narrow band filter. By detuning the Pilot tone, the narrow band cavity signals from dark current and cavity field emission, which are at the resonant frequency, won't be affected by the filter.

The fraction of power of the relatively wide band beam signals filtered out by the narrow band Pilot tone filter is of order the filter bandwidth divided by the bandwidth of the signal from a signal bunch. For a filter bandwidth of 1 Hz this amounts to $\sim 1 \times \tau = 0.343 \times 10^{-6}$ and is completely negligible.

We define a coupling factor

$$\alpha = \frac{P_e}{P_{PT}},$$

where P_{PT} is the input Pilot tone power, as the ratio Pilot tone input power to the probe power in steady state with no beam present and with the Pilot tone tuned to the cavity resonance.

The coupling from the Test port to a Probe port at f in Table 1 refers to the coupling when measured at the resonant frequency of the cavity. Because the Pilot tone will be detuned from the cavity resonance the effective coupling to the Probe port will be about 10 dB less [4]. The cavity voltage generated by the Pilot tone can be calculated from $P_c = \beta_e P_e = \beta \alpha P_{PT} = V_c^2/R$ with the result:

$$V_c^2 = \frac{R}{Q_0} Q_0 \beta_e \alpha P_{PT},$$

where the coupling factor α is chosen as appropriate for an on-resonance or detuned Pilot tone.

Since the cavity voltage is well-coupled to the Probe ports and the net Test port to Probe port coupling is very small, it is clear that most of the Pilot tone power from the generator must be reflected at the Test port and does not enter the cavity. The small fraction that is coupled into the cavity is dissipated in the cavity walls and through the Probe ports. Presumably a negligible amount of power is lost from the cavity through the Test port coupling.

The Pilot tone signal can be compared with signals a beam would produce, but the comparison is somewhat complicated. The comparison can be made either on the basis of peak cavity voltage, or on the basis of the integral of the magnitude of the cavity voltage. Referring to Table 2 the cavity voltage produced by a detuned Pilot tone is about 0.64 V. Scaling from the 1 pC widely spaced bunches entry, this peak cavity voltage would be produced by a single bunch of charge $(0.64/0.65) \times 1\ pC = 0.99$ pC. That is, the Pilot tone produces a peak voltage (or peak power) that is about equal to that of a 1 pC single bunch. But a single 1 pC bunch contributes

only 10 $count \cdot \mu s$ to the integral which is compared with the trip levels, whereas the detuned CW Pilot tone contribution is 64610 $count \cdot \mu s$. Clearly the pilot tone must be well-filtered out of the signal before it is integrated, or the measured current will be too high.

The 'Test tone' is another CW RF signal introduced through the Test port. It is used to force a trip and is only used during testing. Unlike the Pilot tone, it is not detuned or filtered out of the signal that is integrated. The test tone should be able to generate a signal that will cause the ACM to reach trip levels. For example, we may wish to trip the machine at 10 μA of photocurrent, where the running value of the integral is 104337 $counts \cdot \mu s$. To generate this level of signal via the Test port, on-resonance, requires Test port power to get 104 counts on the ADC, which is about CW 5.2 μW (-23 dBm) out of the Probe port. Given the (on-resonance) Test to Probe port coupling of $-40\ dB$, the test Tone generator needs to supply 52 mW or 17 dBm to the Test port.

3.5 Examples

Table 2 contains predicted outputs based on the formulae derived above using the parameters in Table 1 for various charges and bunch patterns. The different cases are separated first by whether the current is closely spaced, (i.e. gun dark current or cavity field emission), or widely spaced (i.e. photocurrent bunches), or the output is due to CW Pilot or Test tones.

In Table 1 the column labeled 'Peak ADC reading' represents the theoretical output of an analogue to digital converter. The ADC sensitivity is chosen so that it outputs exactly 2^{15} when the bunch charge is the maximum possible 1000 pC. Calculated values for the peak ADC counts are rounded to the nearest integer. The column labeled 'probe port power for 1 ADC count' lists the peak power produced at the Probe port by a 1000 pC bunch divided by 2^{15}. The column labeled 'Probe net attenuation' refers to the need for attenuation between the Probe port and the ADC, to limit the power the ADC sees when a 1000 pC bunch goes through the cavity to less than the 'ADC input power limit'.

In all examples, as expected, the integrated ADC values only depend on the average current, but the peak ADC values depend greatly on whether or not the bunches are closely spaced. A very wide dynamic range is seen in the Integrated ADC counts that is compared with the trip threshold.

Though it is theoretically possible for charges and currents from Cavity field emission and Gun field emission (dark current) to be quite large, they are in fact expected to be low compared with that of photocathode generated beam. The operational limit for Gun dark current is 400 nA [9]. If the actual dark current turns out to be higher than this we will lower the gun voltage. Such a low current will be barely detectable with the ACM as it will only register 4 counts on the ADC. Cavity field emission currents are expected to be even smaller.

The photocathode generated beam examples range from the minimum detectable single bunch, (1 count for a single 0.037 pC bunch) to the maximum possible bunch charge (limited by space charge in the gun) of 1000 pC. Operationally, the maximum charge is 300 pC. A typical case is given which is a beam of 40 kW (at 4 GeV) with a bunch charge of 11 pC and an average current of 10 μA. Such a beam would produce 353 peak counts on the ADC each time a bunch went through. When the bunch charge is 1 pC, the peak ADC value, 33, is low enough to degrade the precision of the measurement by roughly 3%.

In terms of average current the ACM is required to operate from 0.5 μA to 300 μA with a required accuracy of $\leq 0.5\mu A \pm 10\%$ of the current [7]. At the low end of the current range the peak ADC output, for the lowest charge highest bunch frequency case of photocurrent, is only 18 counts. A single count corresponds to roughly 5% of the current. Aside from possible noise effects, there should be enough signal to meet the accuracy requirement.

Rapid bursts of bunches will be used to test the ACM system with real beam. Such bursts will have high current but such a short duration that they are not a hazard. With 300 pC charge per bunch, the peak ADC value from a burst is 9830. Such bursts can be accurately measured by the ACM and used to trip the machine.

The Pilot tone will not actually produce any ADC counts since it is filtered out before the ADC. In Table 2, for comparison purposes counts are listed as if the Pilot tone was not filtered out. One can see that if there is no filtering, the Pilot tone would correspond to a powerful beam.

The Test tone will produce counts at a fairly low ADC level, because the Test tone is a CW source. As noted before, the Test tone is not normally present.

4 Windowing effects

Even for a constant repetition rate beam, there is a fluctuation in the value of the running integration window depending on the number of bunches that arrive in the cavity within the integration time ΔT. For example, if the beam repetition rate is slightly above 1 kHz and $\Delta T = 0.001\ s$, then most of the time the voltage from only one bunch will contribute to the integral, but periodically two bunches will be integrated and the integration window value doubles. Roughly, this windowing effect introduces an uncertainty in the measured current that is equal to the bunch charge divided by the integration window duration: $q/\Delta T$. At the operational maximum bunch charge of 300 pC the uncertainty is 0.3 μA given ΔT of 0.001 s. In this case the windowing effect can cause a trip at an actual current that is lower than the limit by 0.3 μA.

5 Summary

The ACM can be expected to measure average beam current independent of whether it is photocurrent, gun dark current, or cavity field emission current. Bunch spacing and repetition rate dependence of the integrated signal from ACMs should be negligible. This is because

- bunches are expected to arrive at the same cavity phase independent of the source, and
- the duration of the integration window is much larger than the decay time of the cavity.

Output signals expected for various beam conditions are calculated and found to be appropriate for the range of operation required of the ACM.

6 Acknowledgements

I would like to acknowledge the help to prepare this document that I received from my colleagues: T. Allison, E. Jongewaard, Z. Li., and J. Sikora.

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Table 2: RF, ADC, and window-integrated ADC output for calculated various beam conditions and test tones based on RF parameters in Table 1.

Source	Bunch charge	Average current	Bunch repetition rate	Peak probe power		Peak ADC reading	Integrated ADC value	Peak Cavity voltage	Notes
	pC	μA	bunches/s	W	dBm	counts	counts·μs	V	
Closely spaced bunches									
Cavity FE	7.69E-06	0.01	1.3E+09	5.2E-12	-83	0	0	0.00	max op.
Cavity FE	7.69E-05	0.10	1.3E+09	5.2E-10	-63	1	1000	0.02	
Gun FE	5.38E-04	0.10	1.9E+08	5.2E-10	-63	1	1000	0.02	
Gun FE	2.15E-03	0.40	1.9E+08	8.3E-09	-51	4	4000	0.08	max op.
Gun FE	5.38E-03	1	1.9E+08	5.2E-08	-43	10	10000	0.21	
Widely spaced bunches									
Photocathode	0.037	0.034	9.3E+05	4.8E-10	-63	1	296	0.02	1 count
Photocathode	0.5	0.50	9.3E+05	1.5E-07	-38	18	5320	0.4	min range
Photocathode	1.0	0.93	9.3E+05	5.1E-07	-33	33	9754	0.7	1 pC train
Photocathode	1.0			5.1E-07	-33	33	10	0.7	1 pC single
Photocathode	11	10	9.3E+05	6.0E-05	-12	353	104337	7.0	40 kW
Photocathode	100	30	3.0E+05	5.1E-03	7	3277	312930	65	max op.
Photocathode	100	93	9.3E+05	5.1E-03	7	3277	968594	65	test burst
Photocathode	300	30	1.0E+05	4.6E-02	17	9830	312899	196	max op.
Photocathode	300	300	1.0E+06	4.6E-02	17	9830	3128986	196	max range
Photocathode	1000	30	3.0E+04	5.1E-01	27	32768	312911	653	max charge
Test port inputs									
Pilot (at f)				2.0E-05	-17	204	204314	2.0	
Pilot (detuned)				2.0E-06	-27	65	64610	0.6	
Test		(10)		5.2E-06	-23	104	104337	1.0	

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