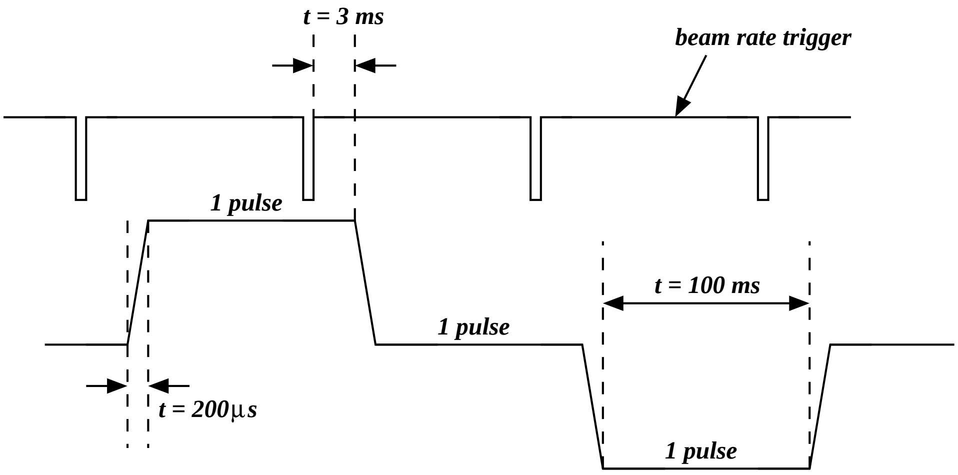
Beam Dithering Timing Test



This figure is NOT drawn to scale!

Test of Dithering Timing

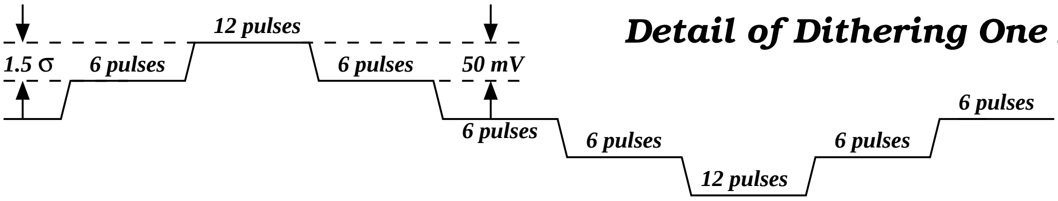
The results of a test of the dithering timing that Mike and I recently performed are shown in the figure above. The figure is not drawn to scale. Basically, what you should get from it is the following:

- The DAC values transition *very* rapidly, reaching their new levels within one or two hundred microseconds.
- The DAC values begin transitioning to their new levels within a few milliseconds after the beginning of a pulse.
- This test was conducted while the machine was operating at 10 Hz. I dithered the DAC values +1, 0, -1, repeatedly, as quickly as possible, staying at each level for only one pulse, or 100 ms.

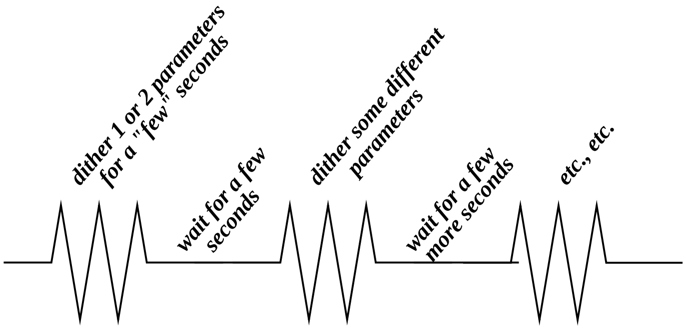
It looks like nothing fundamental will stop this from working at even higher frequencies, though. You should have pulse-to-pulse control over all the DAC values even at 120 Hz, though we won't need this.

Dithering Procedure

Those time constants defined, we can outline exactly what the entire dithering procedure will probably look like. Figure 2 contains drawings that help describe how the dithering procedure will work. The first part of the drawing shows how we will dither an individual parameter. We will go in steps of 1.5 σ, up to +3 σ and then down to -3 σ, and finally back to zero. This will thus take 8 steps. To satisfy symmetry, we want equal data at all points



Detail of Dithering One Parameter



Schematic of Whole Dithering Procedure

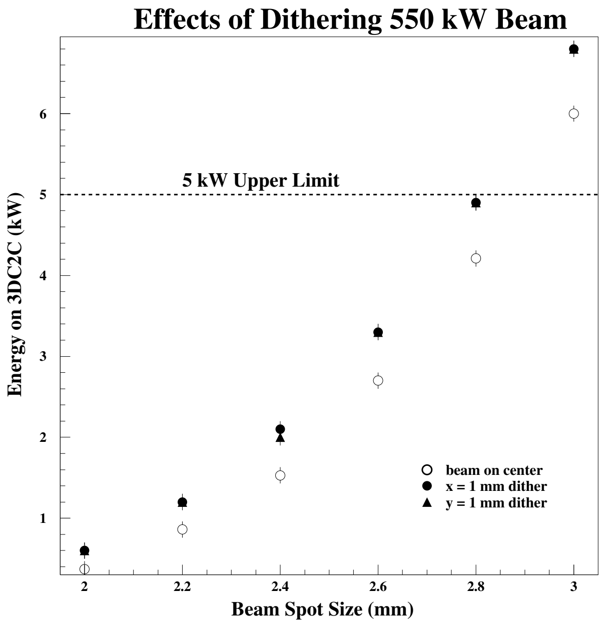
in the dithering cycle, so we need to wait twice as long at the $\pm 3\ \sigma$ positions than we do at the other positions, since we hit them each twice, once on the way up, then once on the way down. Thus, we hold at each position for the number of pulses shown in Figure 2. The figure shows there to be a total of 60 pulses (or half a second at 120 Hz) per parameter. If we dither 7 or so parameters (3 xcor's, 3 ycor's, and energy), that's a total time of 3 or 4 seconds (again, at 120 Hz) actively dithering.

In reality, however, the cycle will take longer. When you switch from one parameter to the next, there is a delay of 2 – 4 seconds. This is not intentional, it is an artifact of the SCP button macro I wrote. When it finishes dithering one parameter, it simply takes a few seconds to set up to dither the next parameter.

Thus, what will happen is that we spend a few seconds (say 5 seconds for concreteness) dithering two parameters, plus the two DAC's associated with these parameters, because you can dither as many as four things at a time with the SCP. Then we have to set up to dither two other parameters, plus their associated DAC's, which will take 3 seconds, say. Then we dither for 5 seconds. And on and on, two more times, for a grand total of about 30 – 35 seconds for a complete dithering cycle.

Now, there are a number of things we can change about this. We can stay at each level for a shorter amount of time, say three pulses instead of six. Or we can stay for a longer amount of time. We don't have to stay for equal lengths of time at each level. Depending on how the magnets respond to small changes, we can dither like {+3, +1.5, 0, -1.5, -3} instead of like {+1.5, +3, +1.5, 0, -1.5, -3, -1.5, 0}.

But all of these possible changes will likely only modify the picture slightly. The bottom line is this: if we just stay at each level for 3 pulses, and are able to choose the {+3, +1.5, 0, -1.5, -3} dithering scheme, it will still take us a minimum of 16 seconds to complete a



full dithering cycle (you can't dither a set of two parameters for less than a second, I don't think). So there's your spread – a complete dithering cycle will take between 15 and 40 seconds.

Now, exactly what percentage of the time we are actively dithering will be determined by two things: how precisely we want to measure the correlation coefficients, and for how long we're willing to go without feedbacks on. How fast we dither will be determined by the response of the magnets to small changes. But my guess is that we will do the following:

- Actively dither for about half a minute (feedbacks are off), completing an entire dithering cycle and obtaining a full set of correlation coefficients.
- Sit with feedbacks on for about a minute.
- Dither again, obtaining another full set of correlation coefficients.

This would mean we're dithering for 33% of the time, though some of that time we'd still have nominal beam, due to SCP delays. Remember, SCP causes a delay of 12 seconds per dithering cycle, so that during this time we're not actively dithering and we have nominal beam.

So, that's basically it. I'm going to write up the button macro pretty soon, and then it's just a matter of testing it during the February run and seeing how accurately we can determine the correlation coefficients.

Oh, and how much we dither by will be determined by the spotsize of our beam. We're worried about moving the centroid of our beam around and causing greater amounts of radiation to hit the 3DC2C collimator, damaging it. Dave gave me some simulated data that I used to show that moving a 2.8 mm spot size beam around by as much as 1 mm (in either x or y) would deposit less than 5 kW of energy – the upper limit of what was considered acceptable – on 3DC2C. If the beam is less than this size, then we have even more margin for error. However, I found that a 3 mm beam deposited 6 kW of energy on 3DC2C *even on center!* So, unless our beam has a 3 mm spotsize (in which case 3DC2C is in trouble even without moving the beam), we can easily move the beam by as much as ± 300 μm in x and y, it seems. Figure 3 illustrates all of this.