7-hole Laser Cathode Alignment

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Summary:

The 7-hole iris aperture is used to verify correct drive laser trajectory onto the cathode using the electron beam. Centering the beam orbit through the solenoid magnet is essential to prevent undesired steering and blowup of the beam. With a radially symmetric laser it's possible to confirm that changes to focusing don't adversely impact downstream steering or focus.

Shift goal:

The 7-hole alignment is generally performed following any significant work on the drive laser system which could affect the alignment. This procedure is intended to verify the proper solenoid alignment of the beam by steering the drive laser on the cathode. For FACET-II this procedure has also been used to optimize QE/charge by maximizing drive laser overlap with the previously laser cleaned surface.

Beam time needed:

2 hrs (extremely invasive)

Shift personnel needed:

Expert FACET-II physicist support only.

Diagnostics needed:

CATHODEF camera

VCCF Camera

PR 10241 camera

BPM02 TMIT

Shift plan:

1. Make sure Schottky phase is setup normally, so some charge is observable, and the laser is clearly visible on VCCF and CATHODEF cameras. The bunch charge feedback must remain OFF for this procedure.
2. Insert PR10241 and open striptools of the following signals:
    a. BPM02 TMIT
    b. VCCF X, Y, and SUM signals
    c. X/Y motor positions for M2 and M3 motors
    d. Laser power meter
    e. Solenoid strength

3. Additionally have profile monitors open for VCCF, CATHODEF, and PR 10241. Log each of these screens as an initial baseline.
4. Insert the P-arm shutter and move the iris control wheel to the 7-hole position. After the motor reaches its position, unshutters the P-arm and look at VCCF.
    a. Note: the iris aperture is determined by the iris motor angle, and this motor suffers from some lash which needs to be corrected manually
    b. After moving to a new iris position take note of the edge positions of the new aperture, and adjust the motor angle slightly to have them agree with the previous edges from your initial baseline
    c. This is most essential after returning to the 5.5 mm aperture after 7-hole is done
5. Increase the solenoid strength slightly so that the beam starts to flower outward and multiple "petals" are visible, as in Figure 1.

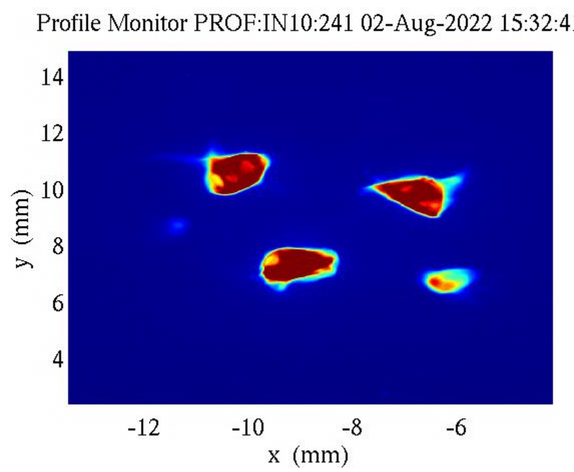


Figure 1

6. Save initial images of all three screens as a baseline with the7-hole aperture.
7. Begin making moves to M2 in the axis which seems most misaligned based on the current PR10241 position. For the example in Figure 1 it appears that the center of the beam and 4 petals are visible, suggesting 2 other petals are on the lower left. You'd try to steer so those petals are visible.
    a. Note that X and Y aren't strictly decoupled with these motors in terms of how they translate to the beam position
8. Make small, iterative moves in the same axis between M2 and M3 in opposite directions to improve the overall shape of the 7 petals (e.g., M2 up one, M3 down one). It should eventually be possible to see all 7 spots on PR10241 symmetrically around the center.
    a. Small steps are necessary to not get lost. As a first pass 0.05 mm motor jumps usually works, and smaller steps of 0.02 mm or 0.01 mm after closing in on a good solution.
    b. Monitor the charge and other screens while making these steps to see how they evolve.

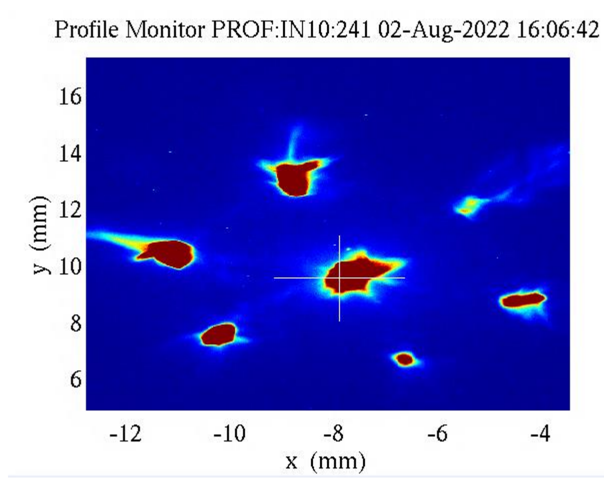


Figure 2

9. Repeat the same style of walk for the other axis with M2 and M3 as needed to observe all 7 beam petals as much as possible, as in Figure 2.
10. Successive iterations between both planes by walking the M2/M3 motors in opposing directions may be necessary to get all 7 petals visible. Repeat this process until the petals are as symmetric, uniform, and even as possible (do not expect perfection).

11. After all the petals are visible and made as even as possible it's time to check the solenoid alignment. Start by changing the solenoid so that the beam on PR10241 is as focused into a single spot as possible and get a beam marker (BM) of that position.
    a. It's sometimes difficult to get a BM of the center spot, which is what we want. If the profmon intensity isn't uniformly distributed you may need to just use the BM as a visual reference or use a post-it note.
12. Gradually increase the solenoid strength while watching how the beam petals evolve. Ideally you would see that the center spot doesn't translate as the solenoid over focuses the beam, and each petal projects out at the same rate.

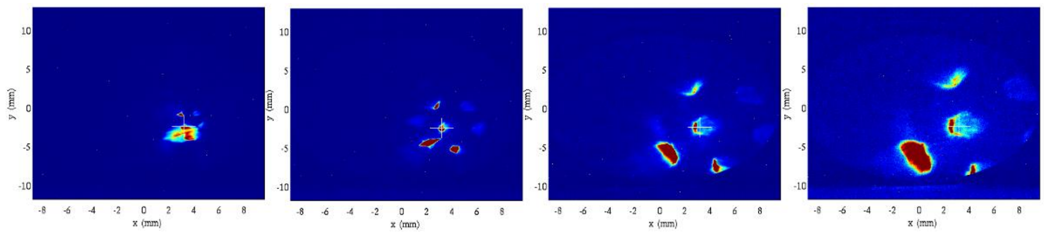


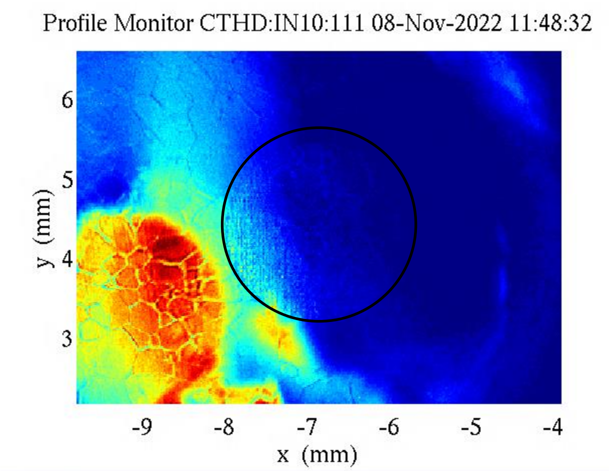
Figure 3

13. If you're satisfied with the proper focus, document everything and proceed to step 15. Particularly make sure you have a VCCF reference.
14. If you're not satisfied with the focus, you need to go back to step 10 and re-iterate the steering of the mirrors until you can get the focus to work.
    a. At the end of this process it's the PR10241 screen and how it responds to changes in solenoid or gun RF phase that are most important.
    b. If the spot on PR10241 doesn't appear to be converging on seven spots which symmetrically focus with the solenoid it may be necessary to try walking a pair of motors pretty far in one plane to see the effect it has. See notes below.
    c. It helps to also monitor the laser profile on VCCF and especially CATHODEF. See notes below.
15. When you're finally satisfied with the laser steering, set the solenoid back to its nominal value, shutter the P-arm, and move the iris wheel back to the 5.5 mm iris.
    a. You will likely need to minorly adjust the motor angle so that the 5.5 mm laser spot edges are in the same spot as the edges of the 7-hole aperture on VCCF due to motor lash.
16. If your alignment is good, you should find that the orbit through the first BPM(s) hasn't change significantly from canonical orbits. If the orbit is very different you may want to consider revisiting this procedure.
17. Verify QE, steering, and emittance measurements. The process is complete!
    a. If the QE seems much lower after performing 7-hole alignment, verify that the laser spot is still overlapping the cleaned spot of the cathode reasonably well. See notes below.
    b. This process can also be used to get marginal gains in charge by re-optimizing the overlap of the laser spot with the cleaned area.

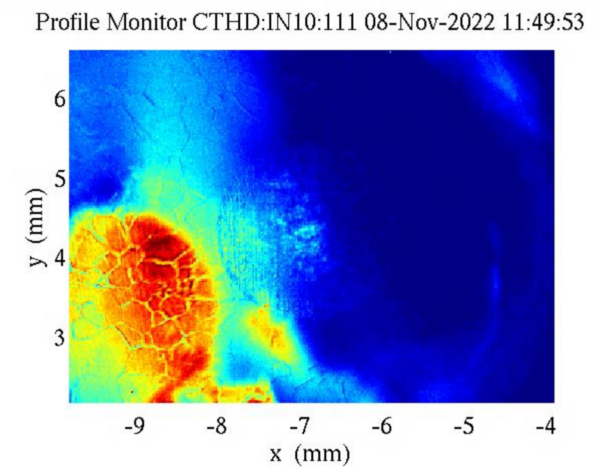
Many helpful observations to consider:

Familiarize yourself with what the cleaned area of the cathode looks like. This can be seen by inserting the Faraday cup with PR10241 out and turning on the target lamp. Variable *Figure 4* resolution can be found by gained by adjusting the lamp brightness. With the laser shuttered it should be possible to see the perimeter of the cleaned area, and the texture of the cathode surface.

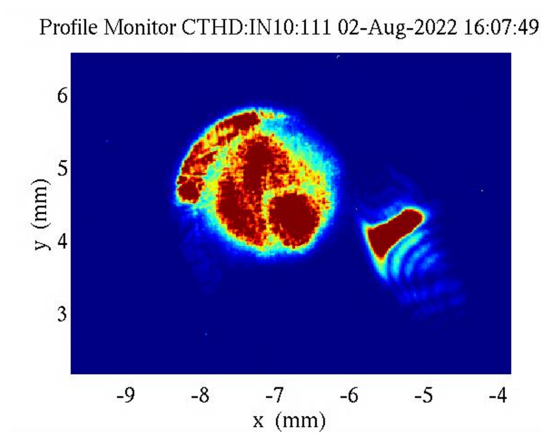
Cathodef with the laser



Cathodef with the laser



When the 5.5 mm iris laser is returned to the CATHODEF camera ideally you won't see additional light outside of the cleaned area. If you do, even if the 7-hole alignment with beam seemed reasonable, it's often possible to recover some QE (i.e., laser power) by iteratively adjusting the position to maximize overlap of the laser spot with the cross hatched pattern of the cleaned area.



Knowing where this cleaned profile is while you have the 7-hole aperture up will make it easier to perform the alignment procedure above while considering the QE preservation.

Sometimes it's possible to see the edge of the cleaned area even without the profile monitor lamp on because the reflectivity outside is different. In some cases it's even possible to see reflections of the drive laser well outside of the laser profile, including diffraction patterns. Reflections like the one to the right are a good indication that some laser power is not making it onto the cathode and additional steering would be of benefit.

Due to the geometry of the CATHODEF camera relative to the actual cathode it can be possible to get the laser cleanly to the cathode with good intensity, but the CATHODEF screen itself may appear clipped. Clipping on CATHODEF could be due to laser clipping upstream of the cathode (which would result in significant charge loss without observed power meter loss), or due to clipping on the *outgoing* reflection off the cathode, towards the camera. Don't let clipping on the CARHODEF camera be an indicator of a problem if you're still able to see all the petals on PR10241. If, however, you observe clipping *and* missing petals it's a good sign the alignment is off and you either need to walk the M2/M3 mirrors back, or move them much farther.

Sometimes it's necessary to make surprisingly large moves with the motors. It's important to have the motor readbacks on a stripchart so you can see how much you're moving them, and have the visual aid to walk them back if things get hairy. Having the BPM TMIT on the same plot allows you to more easily walk the mirrors back to any "good" times, where the charge was greater.

A significant part of this process is moving the mirrors in order to have a good feel for how the laser position effects the beam shape and charge coming off the cathode. It's an explorative process which takes some time and patience in order to be successful.