QCLS DUAL SPECTROMETER ALIGMENT PROCEDURE

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Abbreviations

QC:	Quantum-cascade
QCLS:	QCL spectrometer system
LHH:	Laser house
SPG:	Stable pulse generator
MO:	Microscope (Schwarzschild) objective
MOM:	Microscope objective mount
PN:	Pulse normalization beam
LL	Line lock beam
M:	Main (sample) beam
MCT:	Mercury cadmium telluride (HgCdTe) dual detector
EBG:	Electronic background

This procedure assumes that all optical components have been properly placed and pre-aligned with laser simulators. It includes all the steps necessary to re-align the DUAL spectrometer after one or the two LHH have been replaced, either for laser replacement or LHH repair. There are 3 major alignment steps embedded in this procedure: A) LHH pre-alignment with eyepiece; B) MOM alignment; C) Downstream (final steering) mirror alignment.

1. Go to STEP 19 if the LHHs have been properly pre-aligned with eyepiece but MOMs have not been aligned yet. MOM alignment should be assess/revisited prior missions and after QCLS shipping.
2. Go to STEP 32 if LHHs and MOMs have been properly aligned but the downstream mirrors require some tweaking. QCLS DUAL typically requires some downstream alignment every third flight on the GV (HIAPER).
3. QCLS system must be OFF at this point. A) Verify that QC-lasers are tightly screwed/secured on their *base blocks*. Do not overtight QC-laser/ribbon cable related screws. If necessary, rectify LED positioning. The **LED should not be near touching the QC-laser** but it must be extended enough to provide sufficient illumination for LHH alignment. Tightly attach the SPG to the LHH. Verify that the *Mini DIP TTL delayed pulse generator* (blue chip) is secured in its socket. Replace LHH top cover (re-assemble the whole black anodized sheet metal cover if necessary).
4. Attach bottom brackets to the LHH-SPG ensemble by pre-tighten the four 4-40 side nuts **before** placing the LHH-SPG on its pedestal.
5. Remove the DUAL spectrometer lid. This may imply disconnecting the boiled LN2 at the MCT dewar T and unplugging the lid heater/thermistor cable.
6. Unlock the horizontal (H), vertical (V) and focus (F) MOM adjusters by releasing the locking screws on top of each brass cup. Reset the MOM adjusters to their middle,

nearly neutral positions. Release the *MOM lock* (screw + locking nut) only if the MOM adjuster run seems short and tighten it after resetting the adjuster positions.

7. Secure LHH-SPG on its pedestal by tightening the vertical 4-40 x 3/8" screws.
8. Once the LHH-SPG is secured on its pedestal, sequentially re-connect: A) IN/OUT coolant lines; B) SPG-LHH ribbon cable; C) Daisy-chained coaxial SMA trigger cables; D) Lemo-8 connector.
9. QC-lasers must be OFF and SPG LEDs must be ON for laser pre-alignment with eyepiece. Follow *QCLS manual operation procedure*: A) Close pump valve, unplug pump outlet, and plug inlets; B) Turn QCLS ON; C) Verify chiller operation, normal coolant flow, and pump startup; D) Turn pump OFF and vent it; E) Stop Wakeup instances; F) Wait until QC-lasers are power ON and turn them OFF; G) Close TDW Wintel instances; H) Verify that pressure controllers are disabled and temperature controllers enabled.
10. Wear nitrile gloves (both hands).
11. Carefully position the eyepiece base into the pinhole OUT cavity. **Careless operation may result in scratching/smudging of beam splitter**. The eyepiece mirror is oriented towards the QC-laser side.
12. **LHHs must be pre-aligned one at a time**. Using a clean ruled card, block light from LED A if aligning B and vice versa. The room must be dark or near dark for alignment. Cover yourself and the spectrometer with a black (optical) blanket if the environment is too bright for the room to be dark.
13. **[LHH horizontal pre-alignment]** Unlock the LHH bracket top screws. Slowly move (scan) the LHH in the horizontal. Stop and lock 2 (diagonal) LHH bracket top screws when the LED light is at its brightest position as seen on the eyepiece.
14. **[LHH focus pre-alignment]** Unlock the LHH bracket side nuts. Slowly move (scan) the LHH in the focal direction. Stop and lock 2 (diagonal) LHH bracket side nuts when the QC-laser (or base block) image reaches its best focus.
15. Sequentially repeat steps 13 and 14 until the QC-laser image is properly focused on the eyepiece, i.e. the magnified image of the QC-laser on the eyepiece is as clear as you can obtain. Insure that you are re-aligning for the actual QC-laser not for its gold wire pads. The QC-laser image must be nearly centered on the eyepiece.
16. Tightly lock all the LHH bracket screws/nuts. Repeat STEPS 12-15 if laser image gets blurred or lost.
17. Refine laser image/focusing by sequentially adjusting H, V and F MOM adjusters. Repeat the H-V-F adjustment sequence until the magnified image of the QC-laser on the eyepiece is as clear as possible.
18. Carefully remove eyepiece from the pinhole OUT cavity.
19. Wear nitrile gloves (both hands). Verify normal coolant flow and chiller operation. Open TDL Wintel DUAL and turn DUAL QC-lasers ON. Keep power to CO_2 QC-laser OFF and TDL Wintel CO_2 closed. Keep pump OFF and pressure controllers disabled.
20. Block light from both QC-lasers by interposing ruled cards in between MOs and LHHs.
21. **[Trace laser alignment]** Carefully lay a ruled card against mirror M-2. Turn ON trace laser A. Carefully interpose the pinhole into the optical path (pinhole IN) by firmly holding the pinhole holder until you reach the end of the hinge run. **The**

pinhole holder spring is strong enough near the end of its run to abruptly close/open the pinhole hinge. This may result in dislocation of the pinhole. Align trace laser A so to obtain the brightest/clearest image on the ruled card. Turn trace laser B ON and align it as for trace laser A. Remove pinhole from optical path (pinhole OUT).

22. **[PN beam pre-alignment]** Block LL trace laser beams by interposing a ruled card between mirrors LL-1 and LL-2. Carefully loosen locks on the mirror PN-6 adjusters if they are too tight for smooth alignment. Visually pre-position the trace laser PN beam onto MCT B using mirror PN-6. Go to Field 2 (PN) on TDL Wintel and set its update/display/ frequency to 10 Hz by simultaneously pressing *[Ctrl Q]* only once (if the frequency becomes 100 Hz or higher, sequentially press *[Ctrl O]* and then *[Ctrl Q]*). Align PN-6 until the DC level is maximized.
23. **[EBG]** Ruled cards must prevent QCL-laser light to reach the MCT. Save EBG spectrum (mouse right click on *ebg*).
24. **[MOM pre-alignment]** Remove blocking card from QC-laser A. If light intensity seems to be low, verify that some light is reaching the MCT by repetitively chopping the beam between MOM and LHH. Usually an average intensity of ≥ 0.1 mV (EBG subtracted) should be enough as starting point. If the PN A intensity is undistinguishable from noise go to STEP 25. Otherwise optimize the MOM position by sequential H-V-F adjustment until the intensity is high enough for interposing the pinhole. Block QC-laser A and unblock QC-laser B. Repeat alignment/searching procedure for QC-laser B. Slowly and stepwise release the *MOM lock* (compensating for any intensity loss with H-V-F adjustment) if one or various MOM adjusters has a short run. If the PN B intensity is undistinguishable from noise go to STEP 25, otherwise unblock QC-laser A and go to STEP 26.
25. If QC-laser intensity is undistinguishable from noise be prepared to keep track of any MOM adjuster tweaking of 1/16 of a turn or smaller. Slowly scan MOM H until the some light reaches the MCT. If this is not achieved, come back to the original MOM H position, and sequentially repeat the searching procedure for MOM V and MOM F. If none of the searches is successful, turn QC-lasers OFF and go back to STEP 11, otherwise go to STEP 26.
26. **[MOM alignment]** If pinhole OUT intensities of QC-lasers A and B are high enough, interpose the pinhole into optical path, otherwise go to STEP 28. If the pinhole IN intensities are high enough, block QC-laser B and optimize MOM A alignment (H-V-F sequence until maximum intensity). Unblock QC-laser B, block QC-laser A and optimize MOM B alignment. Unblock QC-laser A.
27. **[PN beam alignment]** Re-align PN-6 for maximum combined PN intensity and subsequently optimize alignment of MOM A and B. Carefully lock the MOM adjusters. This may require stepwise, sequential locking followed by tweaking of the MOM adjusters in order to avoid intensity loss. Go to STEP 29.
28. Amend MOM position if pinhole IN intensity is undistinguishable from noise by sequentially removing the pinhole, tweaking MOM F and interposing the pinhole until some pinhole-IN QC-laser light reaches the MCT. If tweaking MOM F is unsuccessful, repeat searching for MOM H and MOM V, always remembering to go back to the original F, H or V position if no improvement is obtained. Go back to

STEP 11 if no pinhole-IN QC-laser light reaches the MCT after this sequential search, otherwise go to STEP 27.

29. Measure/record the PN pinhole IN and OUT light intensity levels for each QCL. Measure the spectral intensity of each spectrum from DC level to maximum. The pinhole ratio (IN/OUT) should be larger than 50%. Ratios of ≥ 65% are indicative of a very good alignment. Leave pinhole OUT. Sequentially revisit the alignment of PN-6 and MOM if at least one of the pinhole ratios is too low (≤ 50%) or the pinhole ratios are too dissimilar.
30. **[M beam alignment]** Turn the pump ON, enable the pressure controllers and open the pump valve following *QCLS manual operation procedure*. Wait for a few minutes. Go to Field 1 (M) on TDL Wintel and set its update/display/ frequency to 10 Hz by simultaneously pressing *[Ctrl Q]*. Carefully loosen locks on adjusters of mirrors M-3 and M-7 if they are too tight for smooth alignment. Repetitively adjust M-7 and M-3 until the combined M beam intensity is optimized. Activate pulse normalization and measure the intensity (DC-level referred) and the M/PN ratios at the spectra *turn-around point* for each QC-laser. TDL Wintel multiplies the measured ratios by 1000. The two M/PN ratios should be quite similar and ≥ 1.5 (i.e. ≥ 1500 on the screen). M/PN ratios of ≥ 1.8 are indicative of a very good alignment. Deactivate pulse normalization. Sequentially revisit the alignment of M-7, M-3+M7, (M-3+M4)+M-7, and the MOM if at least one of the M/PN ratios is too low (≤ 1.5) or the M/PN ratios are too dissimilar.
31. **[LL beam alignment]** Go to Field 4 (LL) on TDL Wintel and set its update/display/ frequency to 10 Hz (*[Ctrl Q]*). Loosen locks on adjusters of mirror LL-4 if they are too tight for smooth alignment. Adjust LL-4 until the combined LL beam intensity is maximized. Record maximum intensities referred to DC level.
32. **[Thermal stabilization]** The two LHHs and MOMs must be fully aligned and the PN, M, LL beams aligned prior thermal stabilization at this point. QC-lasers must be ON. Remove the sheet metal window at the detector side. Wear nitrile gloves (both hands). Carefully place Ge etalon on the pedestal of its holder. **The etalon facets must be oriented sideways**. Replace the detector-side metal window. Put the spectrometer lid ON, plug the lid heater/thermistor cable and reconnect the boiled LN2 tubing at the MCT dewar T. Allow for thermal stabilization (≥ 30 min).
33. **[Adjustment after temperature stabilization]** Set the update/display/ frequency of Fields 1 (M), 2 (PN) and 4 (LL) to 10 Hz. Remove the sheet metal window at the detector side. Optimize PN, LL and M intensities by tweaking the PN-6, LL-4, and M-3 and M-7 mirrors as described in STEPS 27, 30 and 31, respectively. Adjust the mirrors as fast as possible in order to minimize thermal perturbation, and tighten lock screws if they are too loose. Replace the detector-side metal window. Wait for a few minutes, set update/display/ frequencies to 1 Hz, and then record maximum (PN and LL) and turn-around-point (M) intensities referred to DC level.
34. **[Etalon spectra]** Go to Field 2 (PN) and set its update/display/ frequency to 10 Hz [Ctrl Q]. Remove the sheet metal window at the detector side. Interpose the Ge etalon into PN beam by placing it on its holder at the specified orientation. Rotate the etalon until the fringe contrast is maximized. Replace the sheet metal window. The etalon should be thermally equilibrated with the enclosure at this point, thus no phase shift should be observed. Go to of Field 1, set its update/display/ frequency to 1 Hz *[Ctrl*

O] and activate the *pulse normalization*. Switch from *Current Signal* to *Display Mode*. Fit the etalon spectra by pressing *[Ctrl E]* and answering *a* to the *Choose Laser* window question. Update the tuning rate on all fields by pressing *[Ctrl U]*. Save the etalon spectra by pressing *[Ctrl S]*. Record the spectra file name. Copy the etalon spectrum onto Field 3 by pressing *[Ctrl T]* and transferring *All the above* from *Field #1* onto *Field #3*. Remove the sheet metal window. Carefully remove the Ge etalon from the spectrometer, wrap it on optics paper and put it in its bag. Replace the sheet metal window. Switch from *Display Mode* to *Current Signal*.

35. The QCLS DUAL spectrometer should be ready for normal operation.