Technology Enhancements

for the

UW-Developed CLARREO IR Pathfinder Instrument

to

Improve Performance and Reduce Program Risks

Year-1 Progress Report

NNX17AI70G

Submitted to

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Introduction

This is a progress report for Year-1 of NASA Grant NNX17AI70G to the University of Wisconsin Space Science and Engineering Center to conduct two technology enhancements to improve the performance and reduce program risks for the UW-developed CLARREO IR Pathfinder instrument. The two tasks include: A) Integrate the Harvard University developed QCL into the IR Pathfinder optical system in a flight-like configuration and measure blackbody emissivity and instrument line shape; and B) Demonstrate enhanced blackbody emissivity out to 50 microns by doping Aeroglaze Z306 paint with Graphene nano-platelets.

Since the start of this grant in March of 2017 we have made significant progress on both tasks and we are on target for a successful completion at the end of Year-2.

Progress Details

The progress status for each task is provided below.

Task A. Integrate the Harvard University developed QCL into the IR Pathfinder optical system in a flight-like configuration and measure blackbody emissivity and instrument line shape

A-1. *Using the current configuration, investigate the measured blackbody reflectivity sensitivity with laser injection position and angle. Identify optimal position and angle.*

While in the initial “brute force” configuration, the QCL was injected into the CLARREO IR Instrument Blackbody at various positions to investigate the signal level returned to the Absolute Radiance Interferometer (ARI), and the level of sensitivity to change in injection position. Figure 1 shows the “brute force” configuration of laser injection and how alignment was obtained for the non-visible QCL, by using a surrogate HeNe laser with identical kinematic registration. Figure 2 shows the signal level measured by the interferometer for various injection positions, indicating a well defined flat peak at the apex. This result shows that the best injection position to measure a signal related to cavity emissivity is at the apex, and that this signal is somewhat insensitive to injection position change.

A-2. *Using the new mounting hardware, integrate and align the QCL to the Prototype instrument (this will involve drilling a hole through the periscope mirror at the vendor and getting it recoated).*

The new mounting hardware for placing the QCL in the flight-like configuration is in hand, has been fit checked, and is ready for assembly. The hole has been drilled in the Periscope Mirror and the mirror has been recoated. The next step is the actual integration and alignment of the QCL. It should be noted that this step will be greatly facilitated by the (visible) surrogate NeNe laser assembly that was aligned with and kinematically registered in identical fashion as the QCL laser assembly. Figure 3 shows the flight-like configuration of the ARI instrument, including the Periscope Mirror with the hole that will replace the original solid mirror.

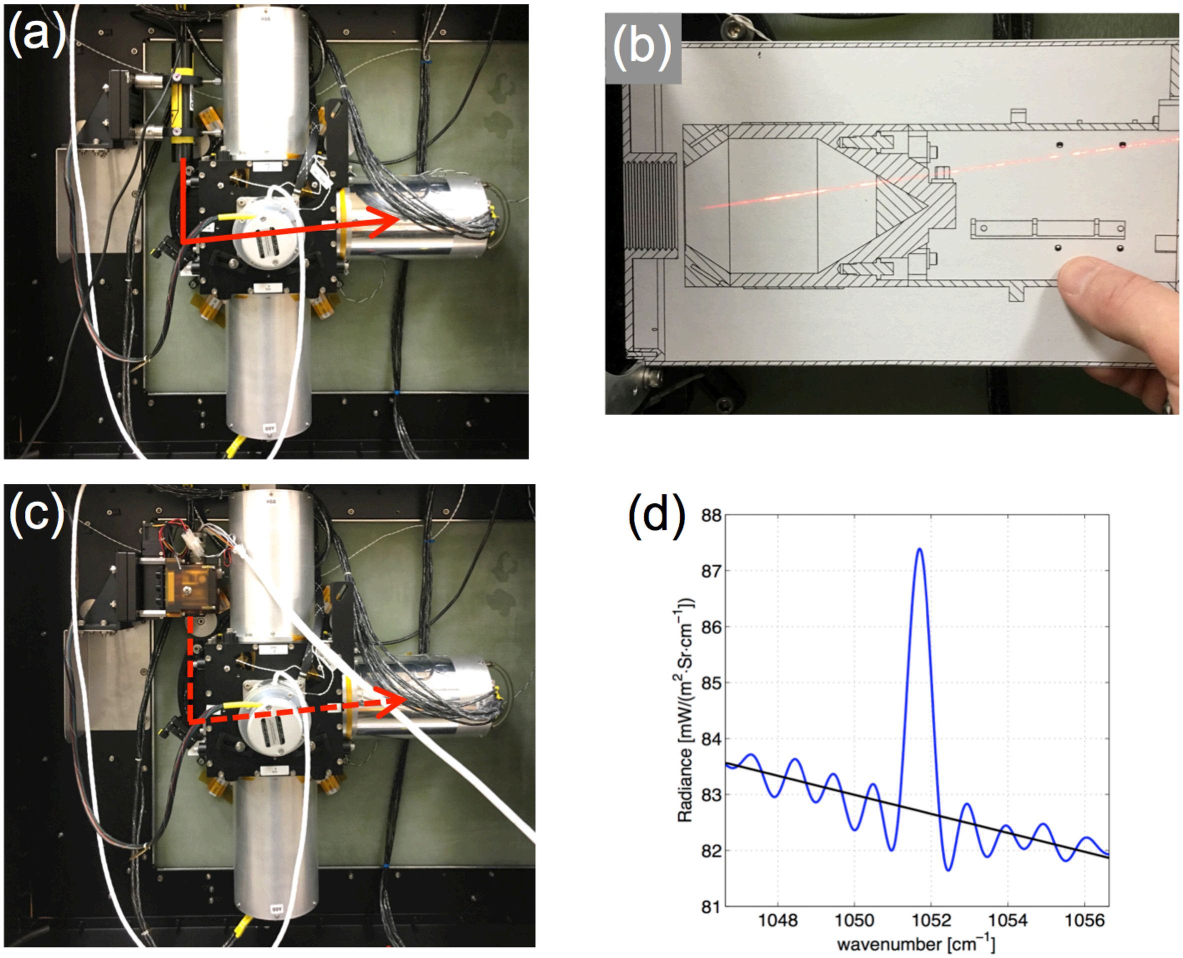

Figure 1. "Brute Force" configuration for direct injection of the QCL laser: a) surrogate HeNe laser used for alignment of the system; b) planar blackbody target indicated laser placement; c) QCL laser registered identically as the HeNe; d) resulting FTS signal.

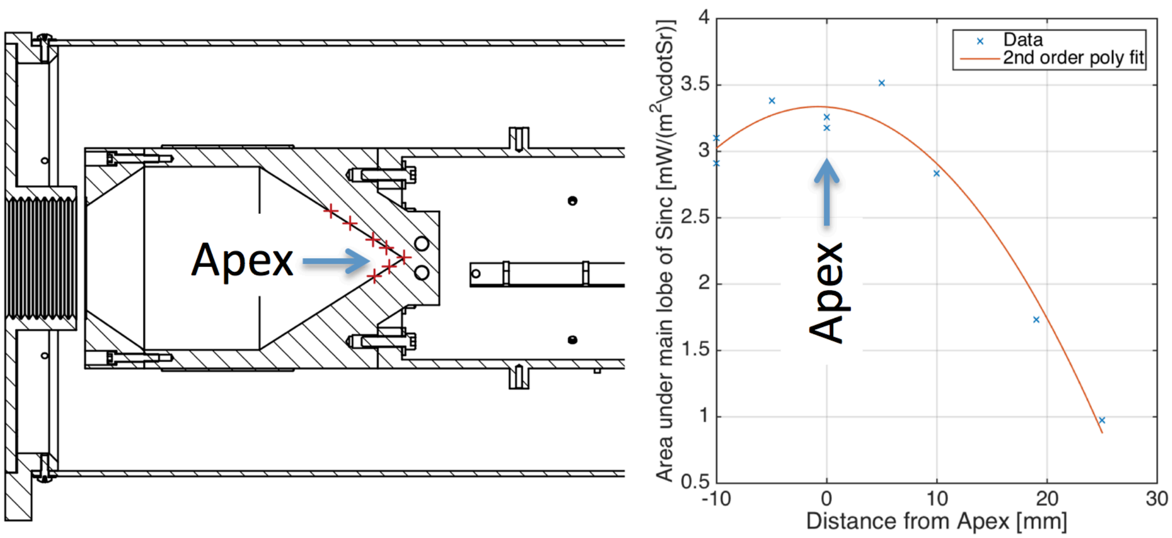

Figure 2 Direct QCL injection measurements of the blackbody reflected signal as a function of laser position within the cavity apex region.

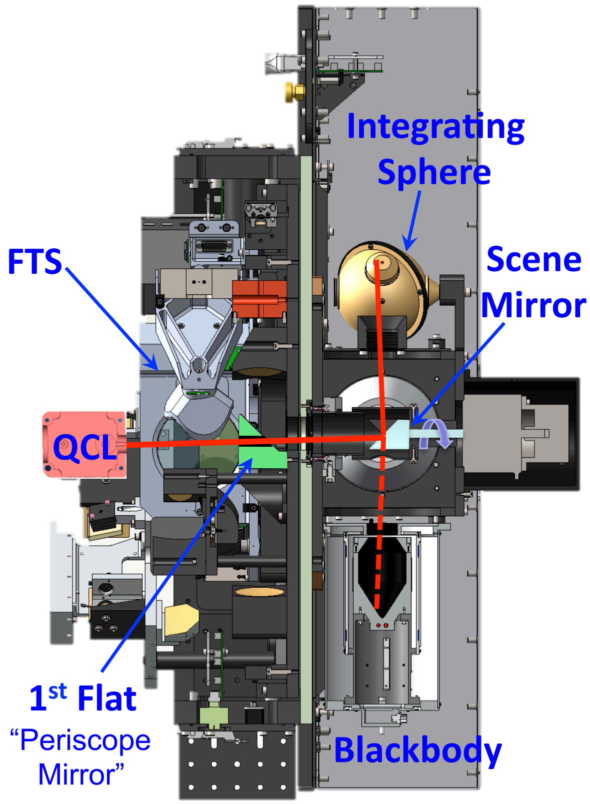

Figure 3. Flight-like configuration of the QCL passing through the "Periscope Mirror" to the Scene Mirror that is repositioned to view either the Blackbody or the On-Orbit Absolute Radiance Standard to make emissivity measurements; or the Integrating Sphere to make Instrument Line Shape measurements.

A-3. *Conduct initial instrument line shape and cavity emissivity testing and compare with preliminary results (obtained in (1) above).*

This step will start in March 2018

A-4 *Conduct more comprehensive instrument line shape tests.*

This step will follow the above.

A-5 *Conduct more comprehensive emissivity comparison tests with both the ABB and OARS.*

This step will follow the above.

A-6 *Write up results.*

This step will follow the above.

Task B. Demonstrate enhanced blackbody emissivity out to 50 microns by doping Aeroglaze Z306 paint with Graphene nano-platelets.

B-1. Fabricate paint witness samples and fixtures to hold them, mimicking the cavity cone geometry.

Witness samples and holding fixtures have been fabricated, assembled, cleaned, and ready for use.

B-2. Characterize the wet paint viscosity and dry paint thickness relationship.

We have learned that dry paint thickness depends on viscosity of the wet paint, as expected, but it also depends on application technique and temperature and humidity conditions at the time of spraying. Achieving the recommended viscosity allows the paint to be optimally sprayed in a way that will apply a wet coat of reasonable thickness (about 1 mil) that will not run – but there is variability in the resulting thickness. We have now added to our procedure a mass measurement of the wet paint as applied to witness samples and have characterized the dry paint thickness, based on this measurement. This has been done with the as-received paint and the paint that is doped with 2% by dry mass.

B-3. Prepare and spray paint cavities, and witness samples, including controlled humidity cure.

We encountered significant problems dispersing the graphene nanoplatelets into the Aeroglaze Z306 paint. Our early attempts followed the recommendations of both the manufacturer of the graphene, NanoIntegris, and our local nano-technology expert, Professor Mike Arnold of the UW Materials Science Department. Those recommendations were to first disperse the graphene in the Aeroglaze Z306 thinner, using an open bath sonicator for dispersion, then add this mixture to the paint; then mix; then further sonicate. Following this procedure, we were unable to complete the first step of dispersing the graphene into the thinner, we instead grew exotic shapes of aggregated graphene that increased in size over time.

As a next step we added the graphene directly to the paint, mixed, then pulse-sonicated this solution with an immersion sonicator. We finally arrived at a process that led to nicely dispersed and dis-aggregated graphene. Because we felt we finally obtained the desired paint mixture, this batch was used immediately to paint test samples, by hand, before any graphene aggregation and/or settling could occur. At this point the logistics were quite difficult because we had limited use of equipment in a lab across campus for the graphene dispersion, and then the paint had to be quickly returned to SSEC for painting. The resulting paint job looked excellent, but ended up under the desired thickness – due to our complicated logistics and limited access to the immersion sonicator to make additional doped paint batches. Paint thickness is something we understand how to control in the future with the spray process we have developed, and we have brought an immersion sonicator to our painting lab – now setting us up for successful painting outcomes.

B-4. Evaluate the witness samples: determine paint density, paint thickness, peel resistance, spectral emissivity out to 50 microns, take photo micrographs to evaluate structure, and measure thermal conductivity.

After the 7-day humidity cure, three of the hand-paint graphene-doped Aeroglaze samples were sent to Surface Optics for reflectivity testing from 2.5 to 50 microns. We also sent a sample of un-doped Z306 for comparison purposes. The results are presented in Figure 4, and show that we are under our target of 0.93 for emissivity, due primarily to the samples being under our desired paint thickness of 3 to 4 mil (as discussed above). Figure 5 shows how the emissivity changes with added paint thickness. Particularly at wavelengths from 24 to 50 microns, the emissivity increases with thickness for our three samples. The plot indicates our desired target emissivity when the paint thickness is between our desired paint thickness of 3 to 4 mil. The target emissivity is consistent with the 2011 Lorenzi CLARREO paint study conducted at LaRC.

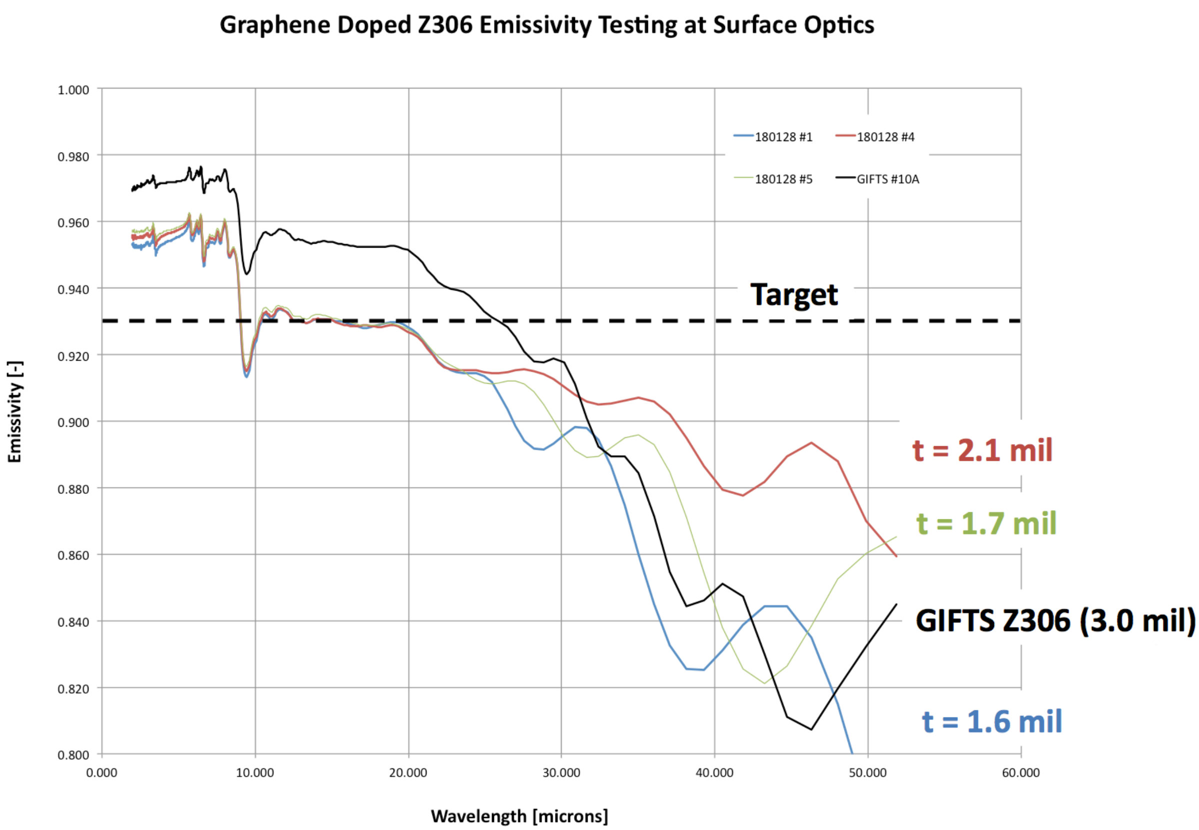

Figure 4. Emissivity results from three different samples of Aeroglaze Z306 doped with graphene compared with a sample of Z306 only. As can be seen the target emissivity is improved with thickness of doped paint in the desired range beyond 24 microns. The depression in emissivity of the Z306 sample up to 24 microns is expected to improve when the desired paint thickness level is applied.

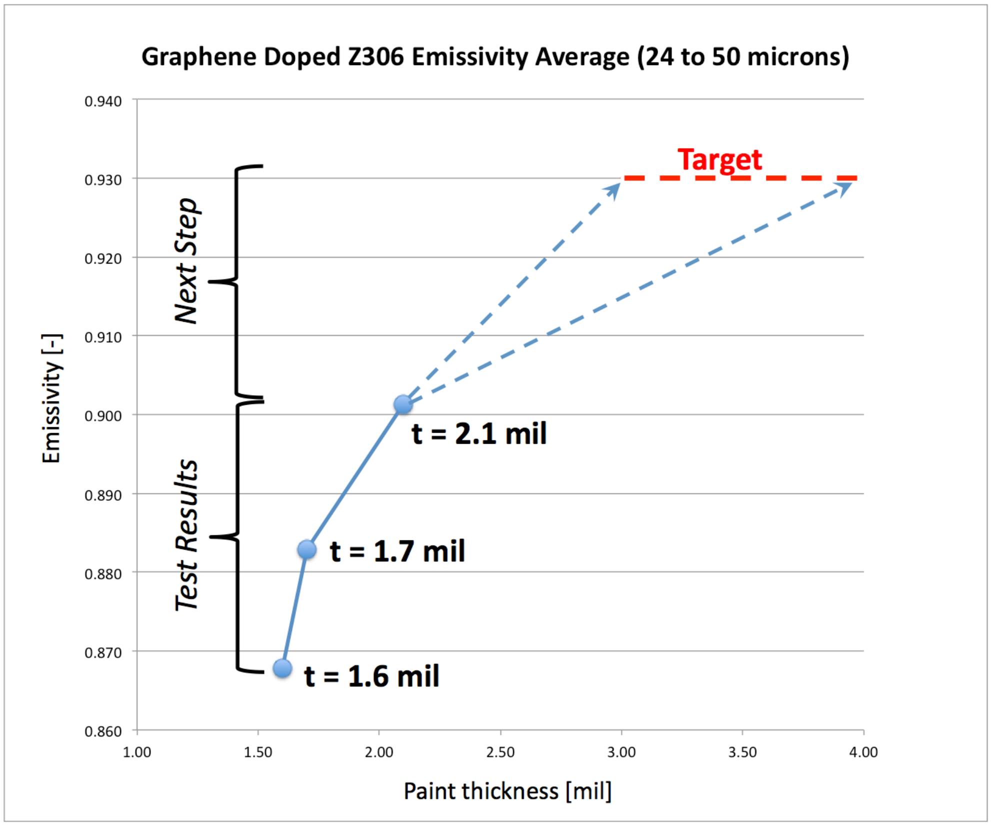

Figure 5. Improvement in emissivity with paint thickness at wavelengths from 24 to 50 microns. For these samples, limitations in our painting logistics limited us to a paint thickness of about 2 mil. Paint thickness from 3 to 4 mil are expected to bring our emissivity to above our target of 0.93.

B-5. Evaluate the cavity emissivity. Populate the cavity with thermistors and heaters, and integrate into an OARS assembly. Measure the spectral emissivity from 3.3 to 50 microns (to an uncertainty of < 0.001 3-sigma) using the UW Heated Halo technique (Gero, 2012).

This step will follow after we do a repeat of the above task, with cavities included in the painting.

B-6. Write-up results.

This step will follow the above.