Single Fiber Studies

Peter Bruecken
Leighton Huch
Samantha Molsberry

Summer 2009

Abstract

In order to better design light producing and collecting fibers for the Forward Calorimeter at CERN (HF), single quartz-core fibers were cut and prepared for testing. The fibers had their cladding and sheath removed and had p-Terphenyl (ptp) deposited on the quartz core. The ptp is a known ultra violet light absorber and visible light emitter in the violet range. Since the light detectors in the calorimeters are more sensitive to the violet than the ultra violet, this property makes ptp a good producer of light for HF. This act of wave shifting could make ptp a good candidate for getting light into the fibers so it can be detected by the electronic detecting instruments.

Procedure

To prepare a fiber, Leighton cleaved the fiber into a 40 cm length. This length allowed the fibers to fit into the vacuum pump for further processing. During the cleaving process, Leighton measured and clamped the fibers into the cleaver. Leighton then stretched the fiber to create tension, and scratched the fiber with a diamond blade to create a small nick in the bottom of the fiber. Leighton then pushed a cushioned lever against the fiber, which snapped the fiber, giving it a clean, straight cut. A good cleave was necessary to let light travel straight and uninterrupted through the fiber end, so the light can be accurately transferred into the spectroscope via its fibers. Leighton then inspected each end and re-cleaved if necessary.

Leighton and Sam then classified the fibers into six types, with three of each fiber being created and tested. The following table lists the types and descriptions:

Type	Description
1	middle 20 cm of plastic cladding removed
2	the middle 1 cm removed
3	the middle 5 cm removed
4	middle 1 cm of cladding still intact, while 1 cm on either side was removed
5	every other centimeter of cladding removed for the middle 11 cm
6	every other centimeter of cladding removed for the middle 21 cm

The fibers were grouped into three sets, A, B and C to test for conformity. These groups were kept separated throughout the burning, testing, and deposition processes. On the computer, fibers were kept distinct in files through the file names. The files were saved by Type/A or B or C

/State/STROBEorMERCURY.MasterorSlave, with possible states being unburned, burned, and PTP (ex: 1AunburnedSTROBE.Master).

Leighton ran base tests on each fiber after it had been measured and cut to ensure that the cut allowed light to travel from the fiber into the test fiber. The tests consisted of a strobe test and a mercury light test. The strobe test sent light into one end of the fiber and measured the light that passed through the fiber. The Mercury light test sent a constant mercury light source onto the outside of the fiber and measured the light that came through both ends, which were attached to the two channels of the spectrometer.

Running strobe test

The strobe test was performed by splitting the strobe source from the Ocean Optics PX-2 pulsed Xenon light source. The source was split using a bifurcated cable and attaching the test fiber from one end of the cable and a control fiber on the other end. The light was measured by sending it into an Ocean Optics SD2000 digital spectrometer. Since all test fibers were run with the same control fiber in one channel, the consistency of the strobe could be measured.

Preparing for Strobe Test

After the fibers were prepared, they were flushed with isopropanol, particularly on the ends, to remove as much oil and dirt as possible. Leighton and Sam applied optic jelly to the ends of the cables to ensure maximum optical transfer at the junction. The screws and fiber ends were then screwed into the ends of the cables. Once screwed in, Leighton and Sam ensured the connection yielded the strongest spectra by observing the spectra while moving the fiber in the junction.

The mercury test entailed holding a mercury light over the middle portion of the fiber and recording the absorbed spectrum on both ends of the fiber, which should match the mercury spectrum. This allowed us to see how much of the light was absorbed and retained by the fiber. The fiber was laid in an aluminum channel and the light was kept flat and even by the sides of the aluminum tray.

Mercury Testing

Once the base tests were recorded, Sam marked and burned the cladding and sheath off of the fibers according to type. A Bunsen burner was sufficient for types one and three, but for all other fiber types, a blowtorch was necessary to burn the shorter parts.

After they removed the cladding, both Sam and Leighton cleaned the fibers. To clean the fibers, we first washed them off with acetone in order to remove any large pieces of burned plastic hanging off and remove any other marks. Next, small squares of Scotch-Brite pads were cut and used to eliminate any remaining small pieces of plastic or dirt by gently twisting and pulling the fibers up against the pads. They rewashed the fibers with acetone to help reduce oils and fingerprints and inspected them to ensure that they had not been scratched and had all possible dirt and plastic removed.

Cleaning the fibers

Next, Sam and Leighton retested the fibers. This time, the lights had to be turned off during testing as the fibers registered both the lights we used for testing and the fluorescent lights in the room. Both the strobe and mercury tests were run as described above, using an integration time of 1000 ms.

Next, the fibers were prepared for p-terphenyl (PTP) deposition, which was performed by Ms. Truesdell, Mr. Bruecken, and Sarah Mascher at the University of Iowa. The fibers were flushed with ethanol again, and laid in an aluminum frame built by Mr. Bruecken. When placed in the frame, it was important to make sure that the burned part of the fibers lay on the legs or within the legs of the frame so

that the fibers wouldn't break. Clamps were then applied to hold the frame together and the frame and fibers were flushed once more with ethanol. The fibers were then placed in the vacuum chamber and coated with PTP. The fibers were coated on one side, and then the frame was flipped over and the fibers were coated again, ensuring that the fibers were evenly coated. Once the fibers were taken out of the vacuum chamber, they were inspected under a microscope to check that there were no significant PTP build ups or spots without PTP.

Once the fibers had been inspected, Sam and Leighton ran strobe and mercury light tests on them again. The above procedure was used once more except that on the mercury tests, the best integration time proved to be 50 milli-seconds. At this integration time, the readings were still saturated (which should be avoided as much as possible as it damages the spectrometer and also lends somewhat inconclusive data), but amply showed the effects of PTP on the fibers. Mr. Bruecken ramped the integration time down until all samples showed less than saturation. This time proved to be 50 ms so the ratio of the integration times was 20:1. To account for this, when the data was graphed, all non-ptp data was divided by a factor of 20.

In addition to the regular tests, Leighton and Sam performed an additional round of testing on fibers 1C and 6C. During these tests, the fiber was exposed to one centimeter of mercury light at a time. This was accomplished by having Mr. Bruecken make special metal plates to fit over the UV light, with a one centimeter wide hole cut into one of the plates to allow light to pass through. Once the fibers had been attached to the slave and master channels, the ends of these channels were taped down to ensure that they would not move. Next, a ruler was used to mark off each centimeter on the aluminum tray, starting two centimeters back from the burned portion of the fiber to allow for the width of the light prior to the hole in the plate. The lights were then turned off, and the fiber was then exposed to the UV light one centimeter at a time. At each centimeter, there was a pause to allow the spectrometer to pick up the change in the

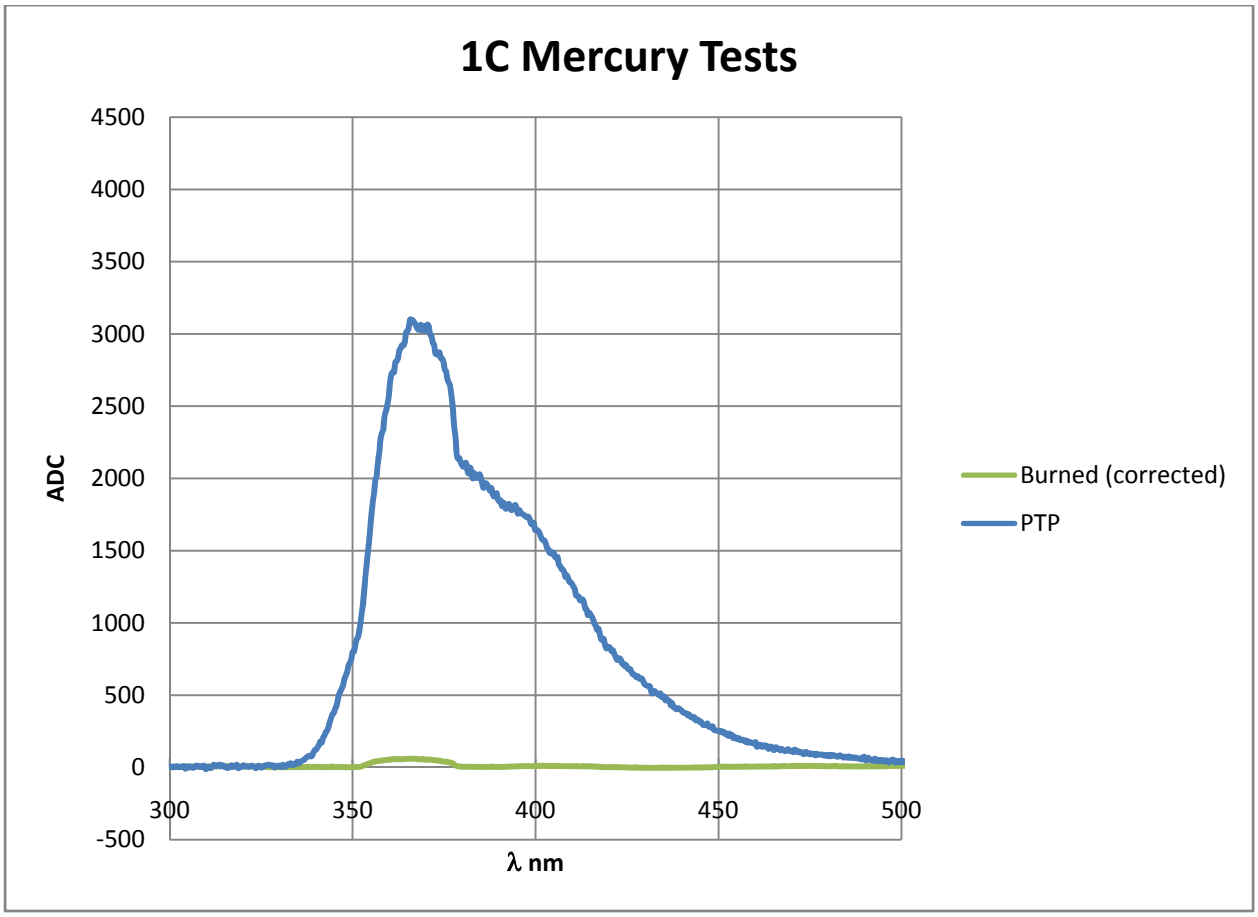
PTP deposition in the vacuum chamber

area of light exposure before the data was saved. This test was run on the fibers in the stage after burning and cleaning (1000 milli-second integration time), and again after PTP deposition (50 milli-second integration time).

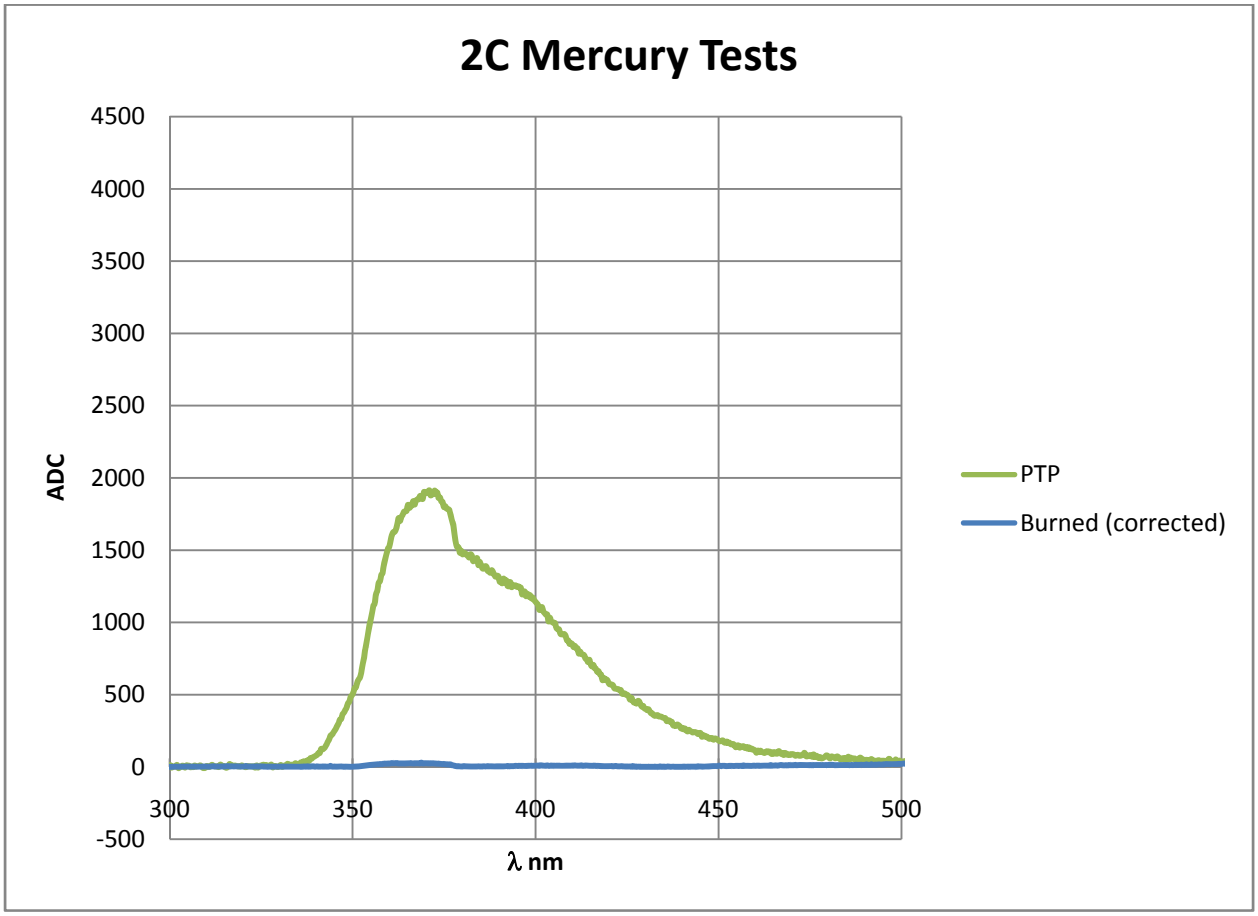
Sam then formatted all of the data into spreadsheets and graphed the results using Microsoft Excel. To account for the differing integration times used during testing, all of the data for the burned and cleaned only fibers was divided by twenty. For each fiber, a graph was made comparing the pre-PTP slave and master channel data with the post-PTP slave and master channel data from the mercury tests. In addition, graphs were made depicting the results of the one centimeter testing in the same manner for each individual centimeter. Also, attenuation graphs were then made to show the relationships between particular points on the fiber for both fibers 1C and 6C using data from the one centimeter testing, but this time the pre-PTP data was divided by two. Furthermore, the average attenuation for each centimeter on both fibers was found between the wavelengths of 300 nm and 500 nm, and a graph was made comparing the two.

The results of the third set (C) key points are discussed below. To make the graphs, Mr. Bruecken summed the channels of the spectrometer since the total light came from both ends. The non-ptp runs were divided by 20 to correct for the integration times (1000 ms / 50 ms).

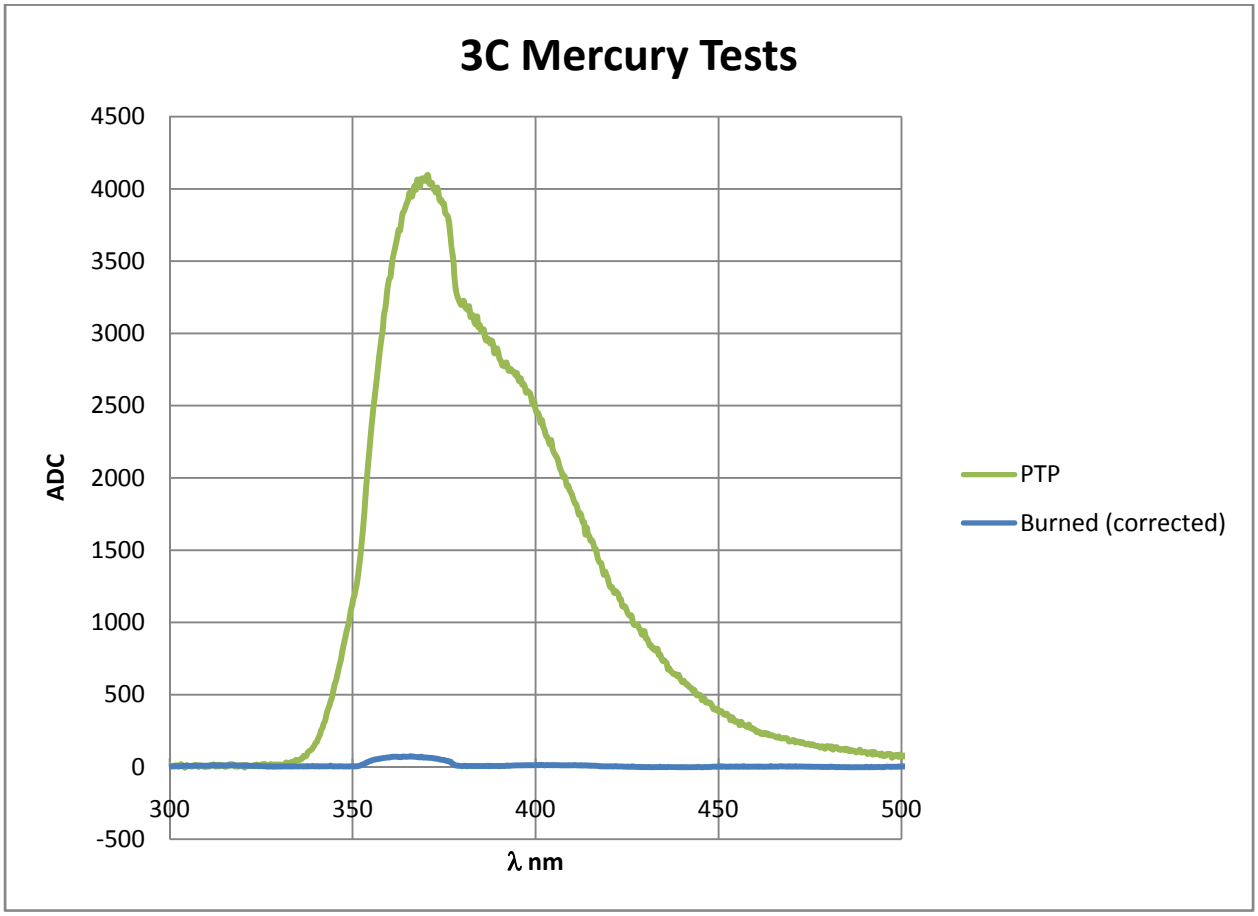
Results



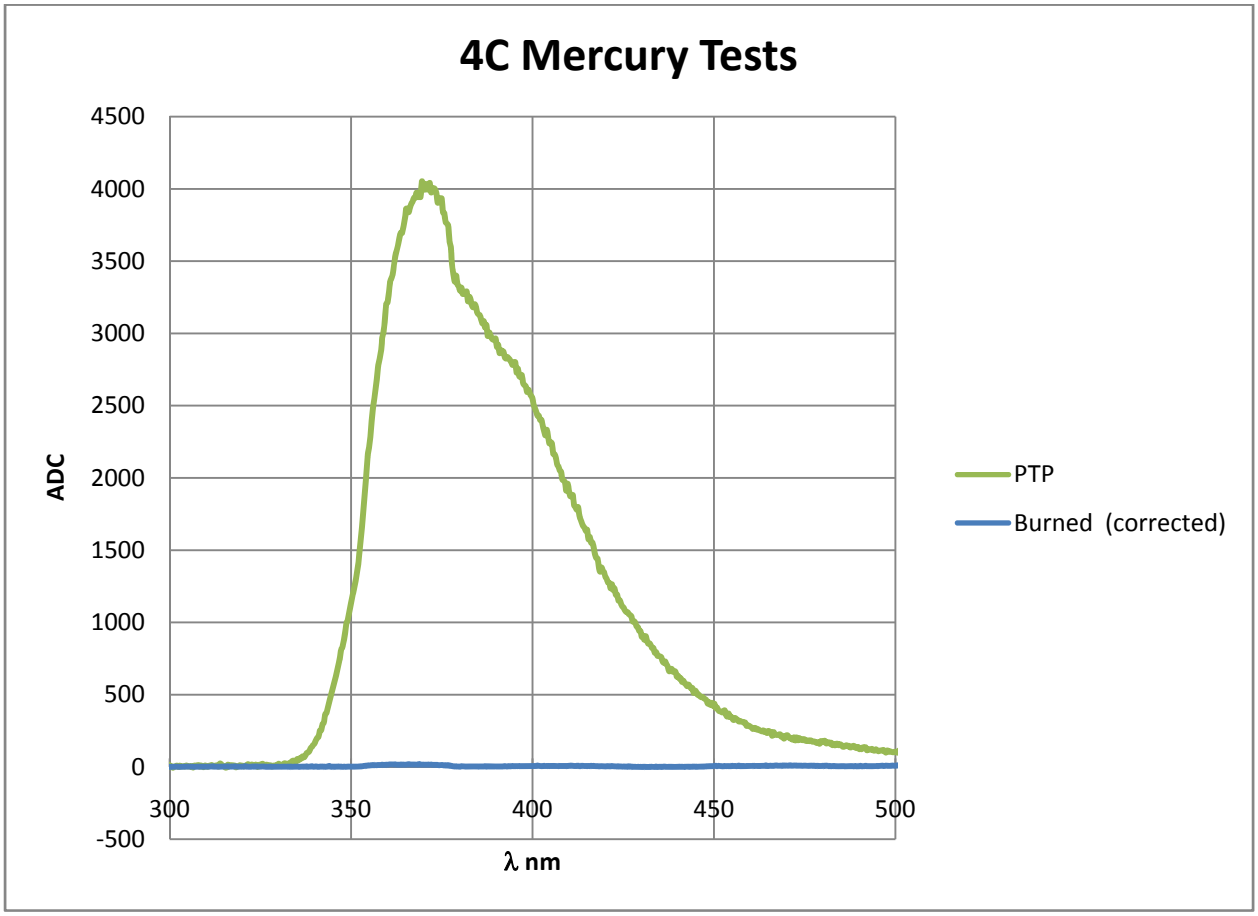
The above graph depicts the relationship for fiber 1C's pre- and post-PTP mercury light tests. Burned refers to the test results before PTP deposition, while PTP refers to the test results after PTP deposition. Clearly, the addition of PTP enhances the light production in this range. This was the set that had the entire middle 20 cm of cladding removed. The thought was that the middle of the range would be lost as the ptp cladding has a higher index of refraction than the quartz and the light produced in the middle would not make it to the end of the fiber.



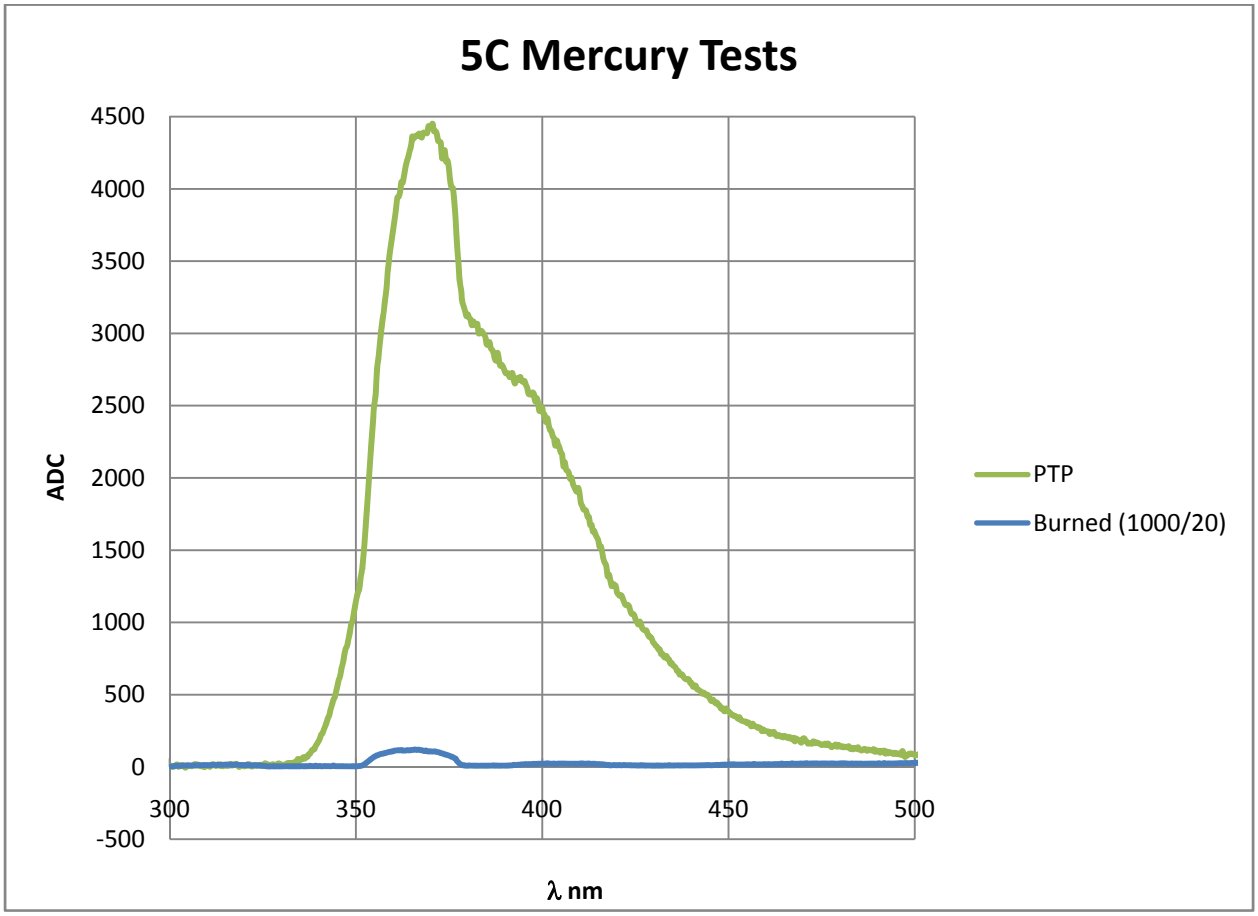
The above graph shows the results of fiber 2C's pre- and post-PTP mercury tests. Burned refers to the test results before PTP deposition, while PTP refers to the test results after PTP deposition. Again, the PTP has had the effect of enhancing the signal. 2C only had the middle 1 cm of cladding removed so the active area is down by 95% compared to 1C. It seemed less of the captured light escaped once captured due to the intact cladding. The overall performance of this fiber was down from 1C but not down by a factor of 20! This graph had a significantly lower base signal before PTP deposition.



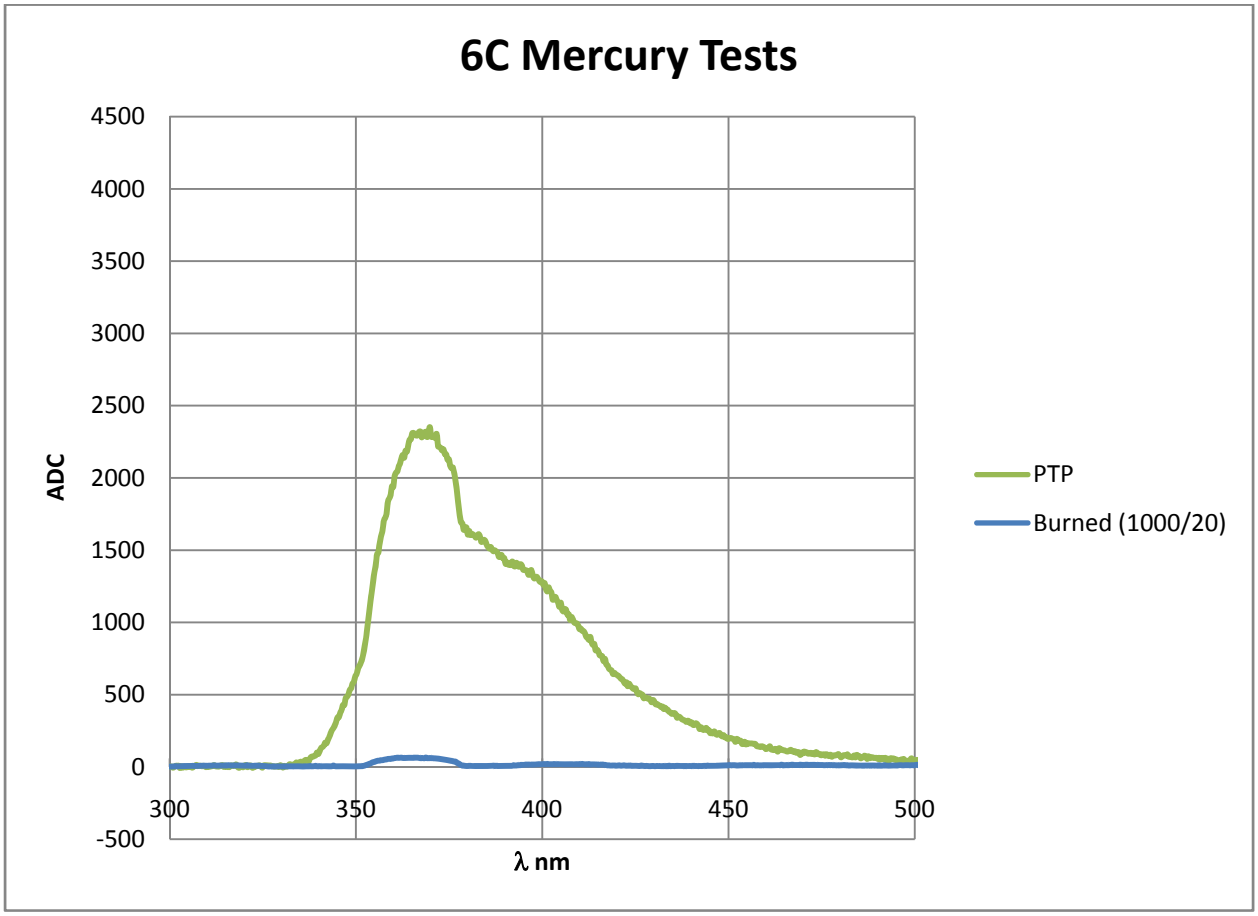
The above graph shows the results of fiber 3C's pre- and post-PTP mercury tests. Burned refers to the test results before PTP deposition, while PTP refers to the test results after PTP deposition. Again, the PTP has had the effect of enhancing the signal. 3C only had the middle 5 cm of cladding removed so the active area is down by 75% compared to 1C. It seemed less of the captured light escaped once captured due to the intact cladding. The overall performance of this fiber was up about 33% from 1C despite only 25% of the area was covered. There seems to be a middle ground between 20 cm and 5 cm of active area that captures more light.



The above graph shows the results of fiber 4C's pre- and post-PTP mercury tests. Burned refers to the test results before PTP deposition, while PTP refers to the test results after PTP deposition. Again, the PTP has had the effect of enhancing the signal. 4C only had 2 alternating cm of cladding removed so the active area is down by a factor of 90% compared to 1C. It seemed less of the captured light escaped once captured due to the intact cladding. The overall performance of this fiber, again, was up about 33% from 1C, about the same as the previous graph. This graph indicates that 2 cm can enhance as much as 20 cm if configured differently. This graph had a significantly lower base signal for some reason.

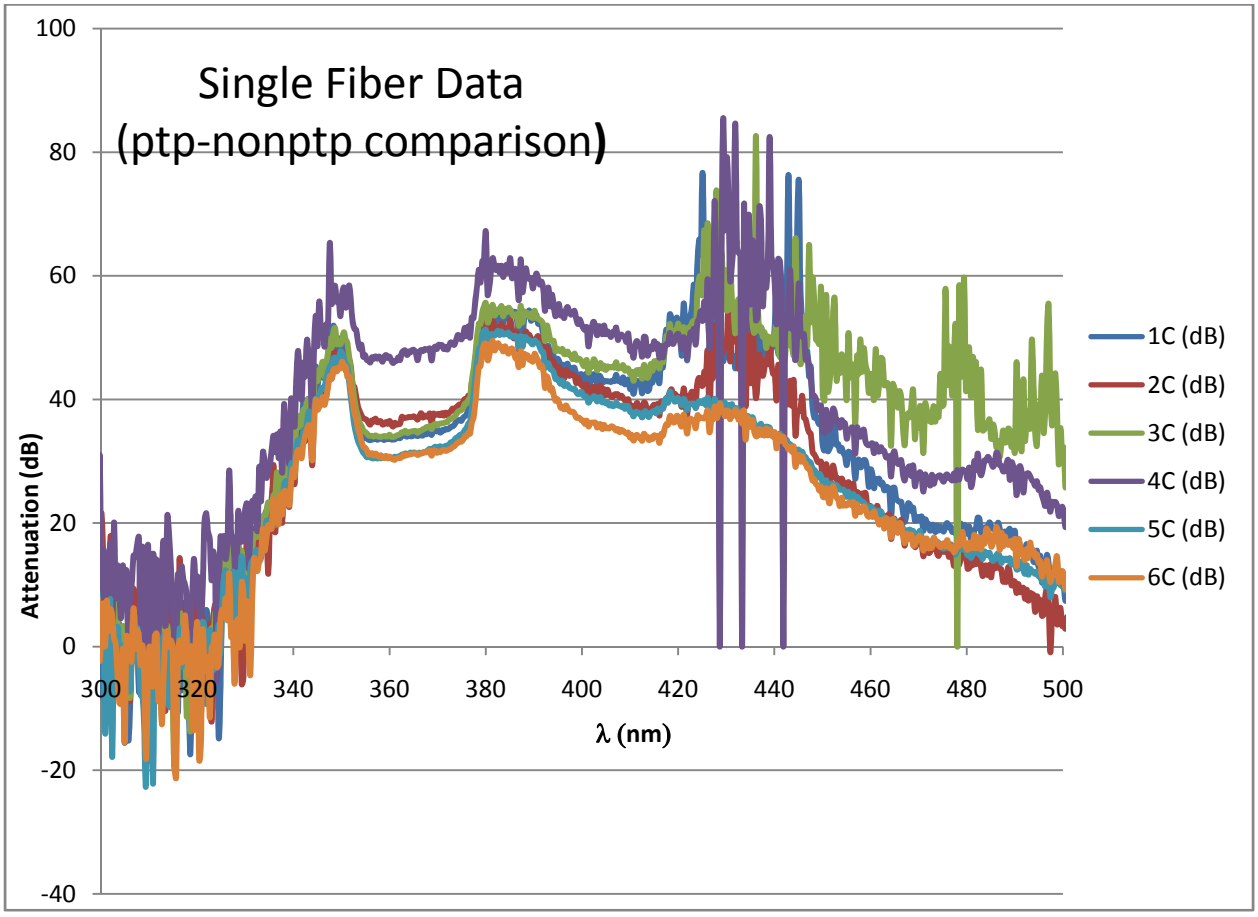


The above graph shows the results of fiber 5C's pre- and post-PTP mercury tests. Burned refers to the test results before PTP deposition, while PTP refers to the test results after PTP deposition. Again, the PTP has had the effect of enhancing the signal. 5C had six one-cm of cladding removed with five one-cm cladded sections between each so the active area is down by a factor of 70% compared to 1C. It seemed less of the captured light escaped once captured due to the intact cladding. The overall performance of this fiber, again, was up about 33% from 1C. This chart indicates that 2 cm can enhance as much as 20 cm if configured differently.



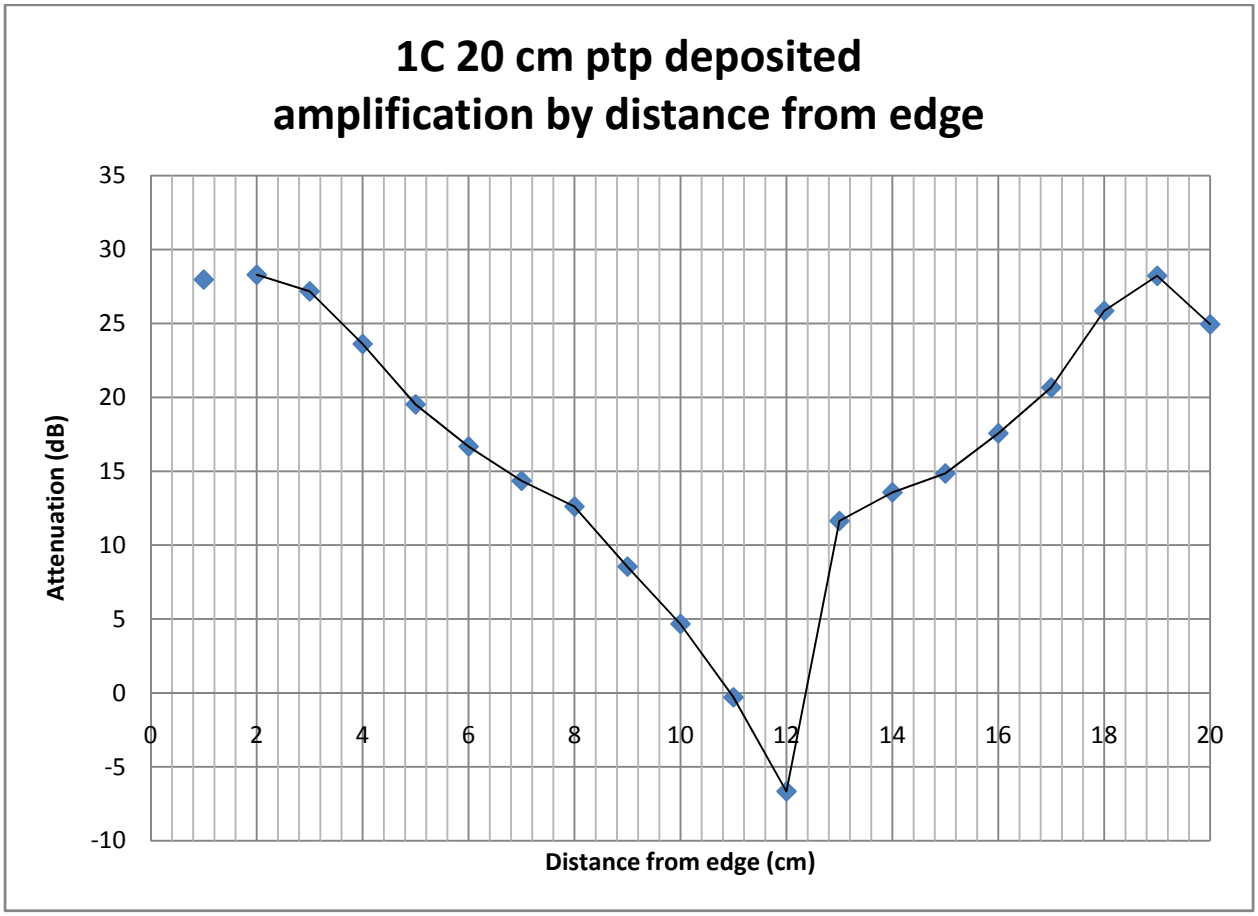
The above graph shows the results of fiber 6C's pre- and post-PTP mercury tests. Burned refers to the test results before PTP deposition, while PTP refers to the test results after PTP deposition. Again, the PTP has had the effect of enhancing the signal. 6C had eleven-one cm of cladding removed with 10 one-cm sections between them so the active area is down by a factor of 45% compared to 1C. It seemed this configuration also lost much of the captured light due to the ptp gaps. The overall performance of this fiber was down about 25% from 1C. This chart indicates that the one-cm gaps must be carefully configured to maximize light enhancement.

From the preceeding results, there seemed to be a factor that needed some attention. We needed to compare the baseline data to the ptp data to compensate for different baselines. To accommodate this, we calculated the actual amplification of the light in decibels between the ptp data and baseline (non-ptp) data. Recall the spectrometer had different integration times to measure these signals and the baseline data was at l000 ms integration time and the ptp data was at 50 ms so the baseline data was divided by 50. The following chart is the attenuation of all six configurations:

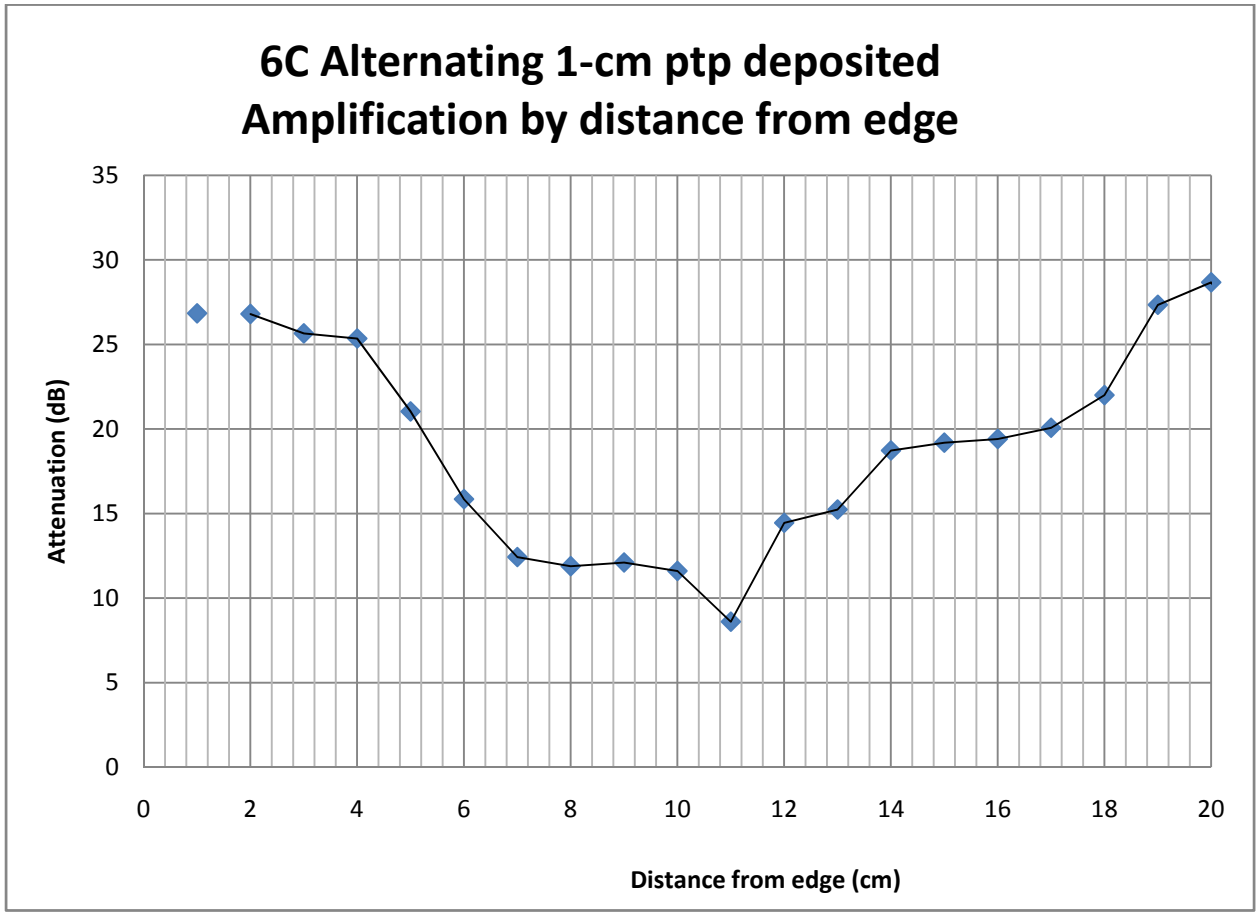


This graph indicates the margin of noise to be approximately ± 20 dB. As one can see, configurations 3C and 4C seem to have the best amplification of light from their baselines, particulary in the 400 to 500 nm range. 5C and 6C seem to have less than the 20 cm configuration.

This leaves the question of how the light is transmitted from the center of the ptp-treated area to the edge of the ptp treated area. As previously described, Sam and Leighton took data using a linear light source every 1 cm from the edge of the treated area. Mr. Bruecken sumed the ADC signals from 300 to 500 nm on both ends of the fiber. He calculated the attenuation and plotted it verses the distance from edge to edge.



This is the graph of amplification in dB vs. distance from edge for the 20 cm treated area. It seems the symetry of our fiber setup is a bit off but the graph appears to show that there is considerable fall off from about 3 to 4 cm widths. Perhaps this is our maximum fiber width that gives the best active area to fiber loss.



This graph shows the distribution of attenuation over the distance edge-to-edge for the 1 cm-staggered treatment. It appears to have higher signal than the bare 20 cm width but still suffers from loss in the center but to a lesser degree.

Conclusions

It appears from this study the ptp deposition has high promise for increasing light amplification in quartz fibers. The configuration of the ptp deposition seems to be very important. Ptp deposited quartz seems to loose their signal the longer the treated area. Even staggering the treated vs. untreated areas has increased overall signal strength. There are an infinite number of possibilities for configuration and more work is necessary to test them.