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PZ Fiber Loss Measurements at LLNL and Plan to Confirm Results at CEA/Thomson

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Objective

To confirm the slow-axis loss of less than 0.1 dB/m for the PZ fiber manufactured for LLNL by 3M and to provide samples of the fiber to CEA/Thomson that will permit them to readily verify this result.

Problem

CEA/Thomson measured a 1.2 dB/m slow-axis loss of the sample of PZ fiber that was sent to them by LLNL. This greatly exceeds the <0.03 dB/m loss measured by LLNL for this fiber. The CEA/Thomson measurement was done by a cutback method on bare fiber without connectors. Since numerous measurements at LLNL have been consistent with a slow-axis loss <0.1 dB/m, we suspect a measurement problem at CEA/Thomson. One possibility is damage to the fiber during cleaving that is not visually apparent.

There is also the possibility that the fiber sample sent to CEA/Thomson might have had an unusually high loss. It was taken from the original shipment to LLNL of 500 m of PZ fiber from 3M in the second half of 1998. A total of approximately 4000 m of this fiber was produced from the same pre-form at that time. LLNL procured the remaining 3500 m in late 1999.

Approach

The slow-axis attenuation of two, 2-meter, Hytrel-tubing jacketed, PZ fiber jumpers with Diamond, FC/APC connectors at each end will be measured at LLNL. After receipt of the jumpers, CEA/Thomson can then inject 1053 nm light into one of the jumpers polarized along the slow-axis. The output of this jumper then serves as the source light for measurement of the insertion loss of the second jumper. This method eliminates the uncertainties associated with cleaving fiber in cutback measurements.

Jumpers with 900 micron, Hytrel-tubing jackets exhibit considerable lower bend loss sensitivity than jumpers with 3 mm jacketing. This reduces the uncertainties associated with fiber bending during the measurements.

The two jumpers will be made with fiber from the 1999, 3M shipment of PZ fiber to LLNL. In addition to the two jumpers, a 10 m length of bare fiber from this shipment will also be sent. This will permit CEA/Thomson to perform direct, cutback type measurements on fiber whose loss has been independently verified.

CEA/Thomson will send LLNL a 5 m sample from the fiber originally sent to them by LLNL (fiber from the 1998 3M shipment). LLNL will use it to make a jumper with connectors. LLNL will measure the slow-axis loss of this jumper for comparison with the CEA/Thomson measurement and the loss of jumpers made from the 1999 3M shipment.

Summary of LLNL Results

The insertion loss of each of the 2-meter jumpers was measured to be <0.35 dB. This insertion loss was the sum of the slow-axis loss of the fiber itself plus the loss of one connector pair. A typical connector pair loss is ~0.2 dB. We thus conclude that the slow-axis fiber loss for each of the jumpers is <0.1 dB/m.

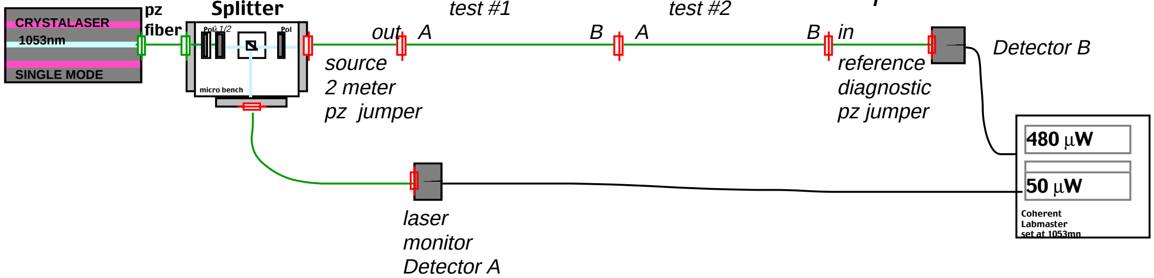
LLNL Measurement Technique

The set-up used at LLNL for measuring the slow-axis loss of the PZ fiber jumpers is shown below. The CW, 1053 nm source laser was coupled into a PZ fiber that was connected to a bulk splitter assembly. This assembly provided a nominally 10% tap to monitor the laser output. A 90% tap was delivered into another PZ fiber labeled *source 2 meter pz jumper* in the figure. This jumper provided the input through FC/APC connectors to the sample PZ fiber jumpers being measured. Similarly, the output of the sample being measured was coupled into a power meter through the FC/APC connector of another PZ fiber labeled *reference diagnostic pz jumper* in the figure. By using connectors between the samples and PZ fiber from the source and into the power meter, we are able to minimize the uncertainties associated with coupling light into the sample and into the detector.

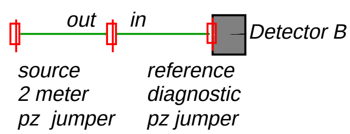
The two sample jumpers are labeled *jumper under test #1* and *jumper under test #2* in the figure. We measured insertion loss of the test jumpers into this optical circuit both individually and together. Measurements were made for both orientations of each jumper in all the configurations, and both orders when together. There were thus a total of 12 measurements as indicated in the table below.

By measuring the fibers individually and together, we are able to calculate the insertion loss when one of them serves as the source to the other (the method that will be used by CEA/Thompson). By taking measurements for each orientation of each fiber, we are able to achieve some degree of statistical sampling of the connector losses.

configuration for power OUT



configuration for power IN



$$\text{Loss in dB} = 10 \log \frac{\text{power OUT}}{\text{power IN}}$$

cfg #	jumper configuration drawing	power IN (µW)	power OUT (µW)	total insertion loss (dB)	second jumper loss (dB)
1	out A #1 B A #2 B in	570	485	-0.701	-0.499
2	out A #1 B B #2 A in	570	509	-0.492	-0.289
3	out A #1 B in	570	544	-0.203	Not applicable
4	out B #1 A A #2 B in	570	426	-1.265	-0.276
5	out B #1 A B #2 A in	570	440	-1.124	-0.136
6	out B #1 A in	570	454	-0.988	Not applicable
7	out A #2 B A #1 B in	539	460	-0.688	-0.345
8	out A #2 B B #1 A in	539	463	-0.660	-0.316
9	out A #2 B in	539	498	-0.344	Not applicable
10	out B #2 A A #1 B in	579	530	-0.384	-0.339
11	out B #2 A B #1 A in	579	531	-0.376	-0.331
12	out B #2 A in	579	573	-0.045	Not applicable

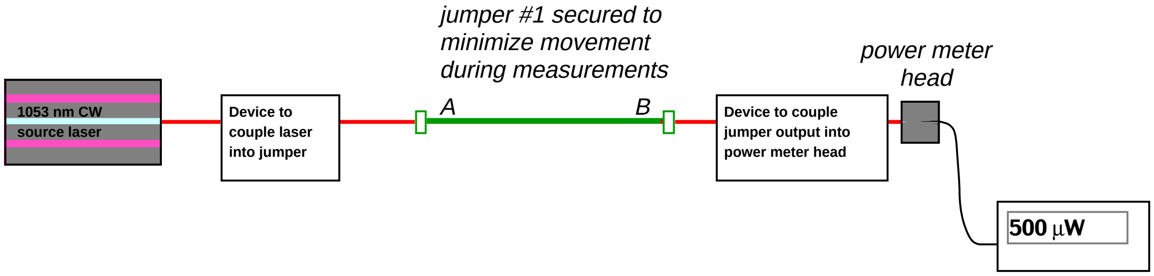
The values in the column labeled *total insertion loss* are the insertion losses of the individual or pair of sample fibers. The values in the column labeled *second jumper loss* are the insertion losses of the second sample fiber only when the first sample fiber remains in the circuit.

Since the individual jumper losses were determined on the second jumper, we always attempted to keep this jumper straight although modest bending did not affect the results significantly.

It is seen that the average of the four insertion losses for jumper #2 is 0.30 dB, and the average for the four insertion losses for jumper #1 is 0.33 dB. These losses include the loss of the fiber itself plus the loss of one connector pair when the jumper is inserted into the optical circuit. A typical connector pair has a loss of 0.2 dB. We thus calculate the slow-axis fiber loss of jumper #2 to be 0.05 dB/m, and that of jumper #1 to be 0.07 dB/m. These values are consistent with the earlier fiber loss measurements of 0.03 dB/m given measurement and connector loss uncertainties of the order of 0.1 dB.

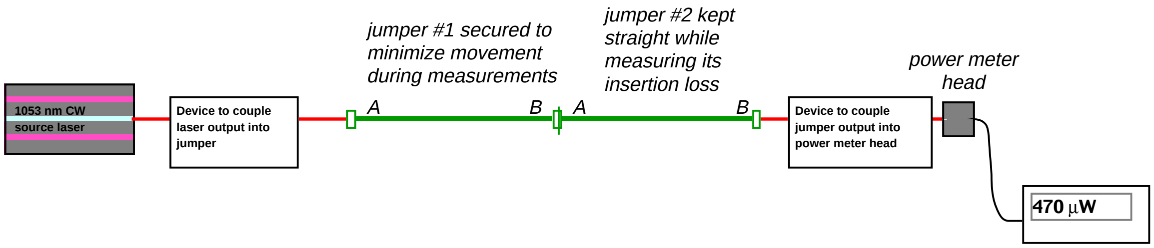
Recommendations for CEA/Thompson Measurements

As shown in the figure below, light from a CW, 1053 nm source laser should be coupled into one of the sample jumpers (designated #1 in the figure) by the most convenient approach available. It is preferable to launch the light predominantly with the slow-axis polarization, but the results should not be affected if there is a comparable component along the fast-axis because of the high fast-axis extinction by PZ fiber.



Secure jumper #1 in order to minimize its movement during the remainder of the measurement, particularly when delivering its output to the power meter head or connecting it to the other jumper. Then measure its output using some convenient method to couple the light into the power meter head.

Next connect the output of jumper #1 as shown in the figure below to one end of the other sample jumper (designated jumper #2 in the figure). While keeping jumper #2 as straight as possible in order to minimize bend loss effects, measure its output with the power meter. Care must be taken to assure the same alignment of the output of jumper #2 into the power meter head as had been used for jumper #1 because the reading can be spot size and position dependent.



If a tap is not used to monitor changes in the source laser power, repeat this procedure several times to either assure that the source laser is stable, or to statistically average the variations.

Repeat the last measurement while reversing the orientation of jumper #2. Two values of the insertion loss of the jumper #2 may then be calculated. One result is the fiber loss plus the loss of one of its connectors attached to jumper #2, and the other is the fiber loss plus the loss of the other connector attached to jumper #1.

Obtain two more insertion loss measurements of jumper #2 by repeating the above with jumper #1 reversed in orientation. Then obtain four insertion loss measurements of jumper #1 by reversing the positions of the two jumpers.

The insertion loss measurements of each of the jumpers may then be compared to the corresponding measurements obtained at LLNL.