EFFECTS OF HIGHER POWER LEVELS ON OPTICAL CONNECTORS, SPLICES, AND RELATED COMPONENTS

D.N. Ridgway
OFS
2000 N. E. Expressway, Norcross, GA 30071
770-798-2772, dridgway@ofsoptics.com

Introduction

Raman amplifiers are expected to achieve optical power levels in excess of +30dBm. This represents a four to eight-fold increase in power level over systems presently being deployed. At these power levels, there is increased risk of performance degradation from damage to transmitting components that include connectors, splices, and attenuators. To evaluate the effects of higher power levels, a test facility was upgraded to provide +30dBm of optical power using a Raman amplifier. Connectors, splices, and attenuators were evaluated at power levels of +30dBm for short-term stability, mating durability, disconnecting/reconnecting under power, and long-term stability. Evaluations were made at 1535 and 1560 nm to simulate the range of wavelengths used in current C-band systems. Most evaluations were made at the 1535 nm wavelength where the fiber mode-field radius is smallest and the power density the highest for current operating systems. Components evaluated include the STII, SC, and LC connectors, the Rotary Mechanical Splice, and two different LC attenuator designs.

Sample Selections

The jumper assemblies selected for this study were chosen to represent connector types that have been or are currently being used in large quantities throughout the telecommunications industry. The fiber in each jumper is a singlemode, depressed-clad type. The STII connector has been used for many years and many remain in active use. The SC connector is another current design widely used in existing applications. The LC connector is a small form factor connector planned for use in many new applications.

Many systems being deployed require the use of attenuation. Two types of attenuators currently used are fiber-based or lensed-based attenuators. Since attenuators are used to reduce transmitted power, it is necessary to understand what effects higher power levels will have on the attenuator performance.

Rotary splices were selected for evaluation because they are embedded in many current long-haul systems. As these systems are upgraded, these splices may be exposed to higher levels of optical power. How they perform under these more stringent conditions is important to reliability.

All samples evaluated are standard products manufactured to Telcordia GR-326-CORE[1] for connectors, Telcordia GR-765-CORE[2] for splices, and Telcordia GR-910-CORE[3] for attenuators. No special sampling was done in the selection of test samples. Each sample was tested as if it had been received at a field location. This means that no sample was tested for performance before the evaluation began. Additionally, the connectors tested in series were the same connector series used in every test condition. No samples were changed during the test.

Test Facilty

The test facility used for this study is shown in Figure 1. The facility includes a tunable wavelength laser source, an erbium-doped fiber amplifier, a Raman amplifier, a variable attenuator, a HP Multimeter, a HP 40dB attenuator for the optical receiver head, and an environmental chamber. This facility provides +1 watt (30.7dBm) of optical power.

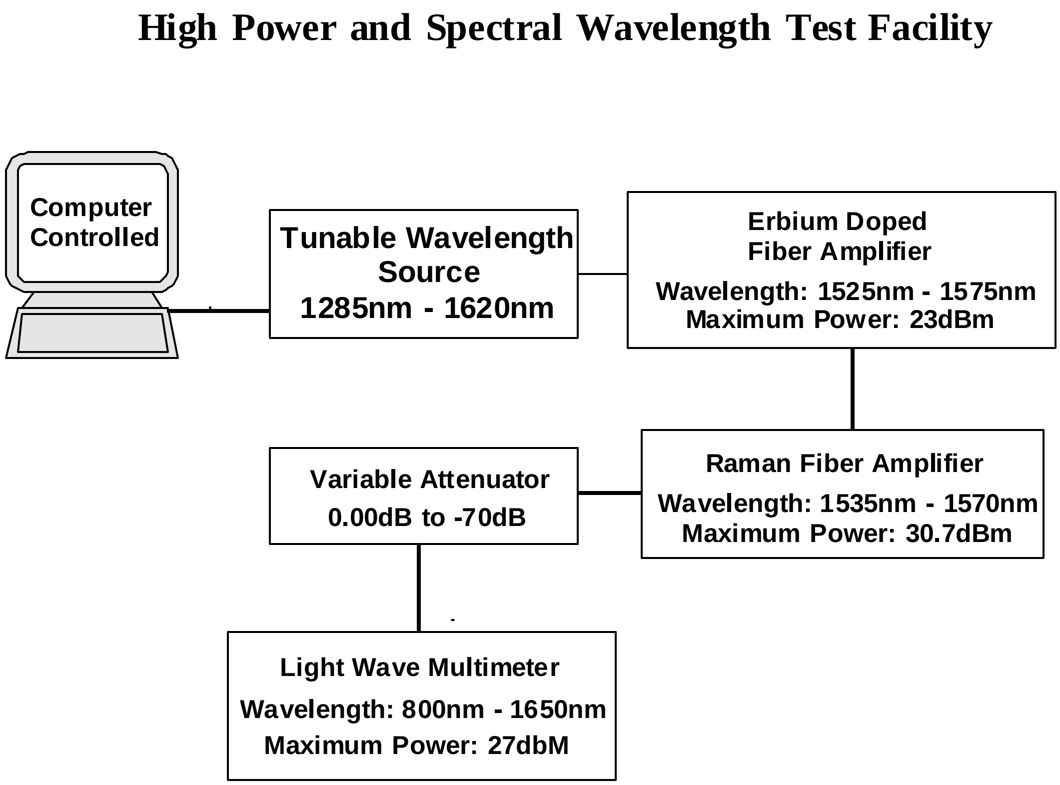
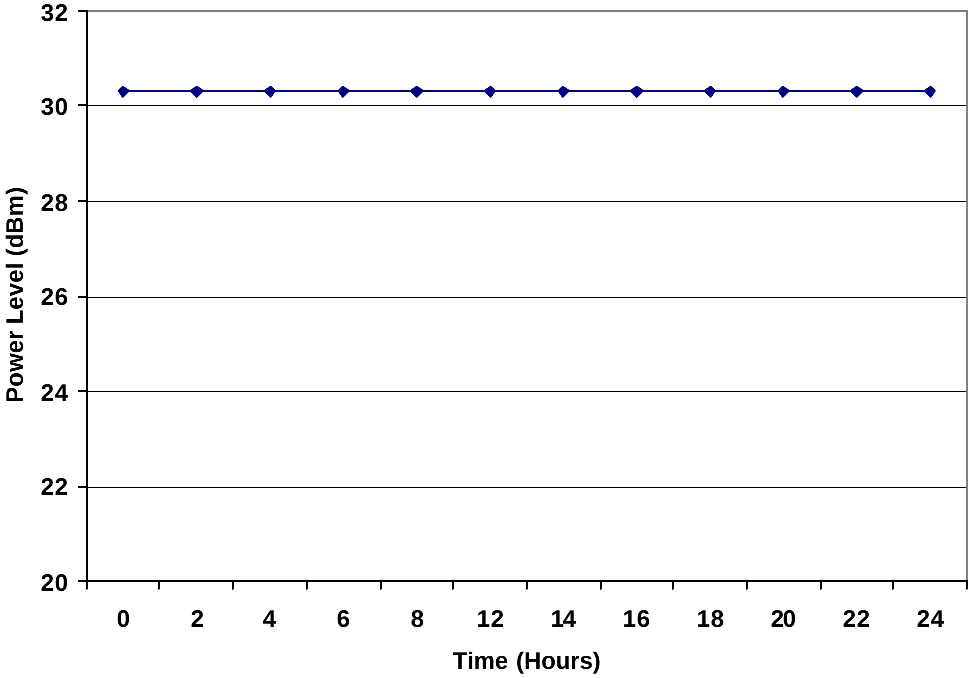

High Power and Spectral Wavelength Test Facility

Figure 1.

Short Term Stability

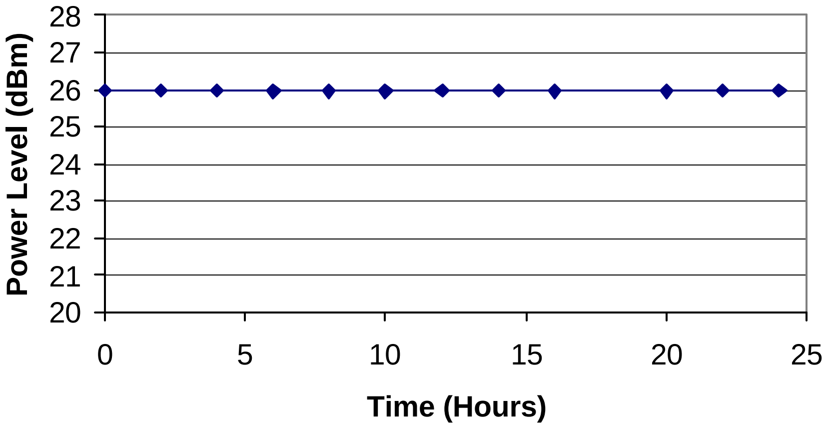
A series of four of each connector type and splice were exposed to power levels of +30dBm for 24 hours at the 1535nm wavelength. Power levels were monitored and recorded at specified time intervals, and a final reading was taken at the end of the test period. The STII, SC, and LC connectors and the Rotary Mechanical Splice showed no short-term change in power level that would indicate degradation in performance. Power levels remained constant over the 24-hour time period as shown for the LC connector in Figure 2.



LC Short-term Stability
Four Connections in Series at 1535nm and 30dBm.
Figure 2.

LC lens-based attenuators have been tested with satisfactory results up to power levels of 23dBm. These types of attenuators use a clear element to attenuate the signal.[4] LC lensed attenuators (0.5dB, 5dB,and 10dB) were exposed to +30dBm with varied results. The 0.5dB sample showed no significant change in performance. The 5dB and 10dB samples attenuation levels began to change above 25dBm. This change was caused by the element softening to the point that the connector ends began moving closer together. Further evaluation is needed to determine what levels of attenuation and what power levels above 23dBm, the LC lensed attenuator can be reliably used.

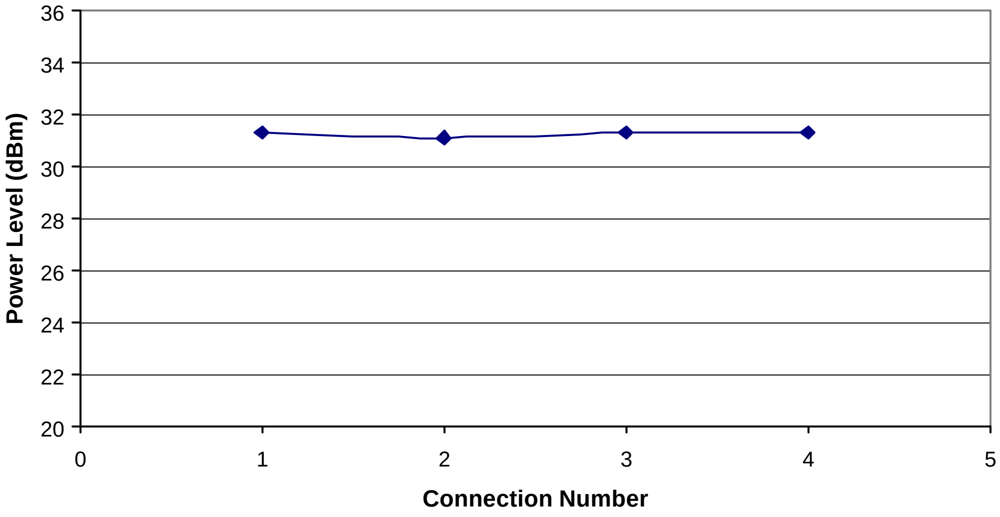
LC fiber-based attenuators of 5dB, 10dB, and 20dB were monitored for a 24-hour period at the 1535nm wavelength. No failures were observed, however, further study is needed to determine what long term effect these higher power levels may have on the attenuation level. Figure 3 shows the short-term stability for a 10dB LC fiber-based attenuator over a 24-hour period.



LC Fiber based Attenuator
Figure 3.

Mating Durability

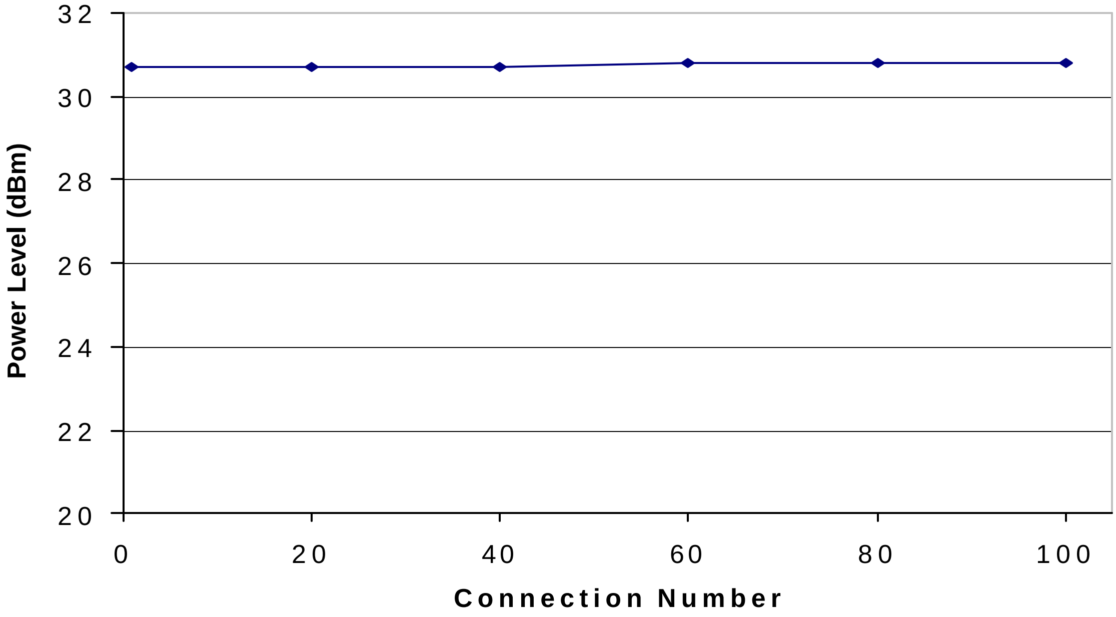
Mating durability tests were done for each connector type at each wavelength. During this test a connection was disconnected and reconnected five times after the power level was reduced to +15dBm or less. The connectors were not cleaned between reconnections in order to simulate what might happen in a field environment where a connection is frequently disconnected and then reconnected right away. The power level was then raised to the +30 dBm level and allowed to dwell for a five-minute period to provide opportunity for any possible short-term failures. No failures or changes in performance were observed. Figure 4 shows the mating-durability results for the STII connector.



STII Connector, Limited Mating-Durability
Figure 4.

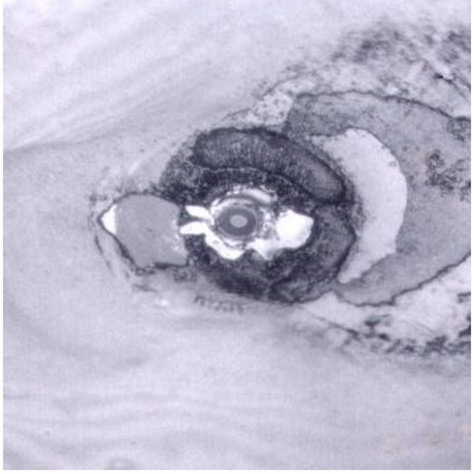
High Power Connections

The possibility of a connector being disconnected while transmitting high optical power is a concern. Tests were conducted to establish the power level at which a connection could be disconnected and reconnected without end-face damage. SC and LC connectors were disconnected and reconnected at power levels of +30dBm. After twenty repetitions the power level was lowered to below 15dBm and the connectors cleaned. This was done to remove any contaminates that might have been generated during the matings. The power level was then restored to +30dBm and another twenty repetitions were performed. This process was continued until the connector under test was mated 100 times. Figure 5 shows typical performance of an LC connector mated 100 times at +30dBm and 1560nm.



LC Connector Mated 100 times
Figure 5

During the high-power connection study it was noticed that well guided connectors like the SC and LC are less likely to be damaged during the connection process. Less well guided connectors like the FC and STII present more opportunity for ferrule contact with the coupling during insertion causing damage to the fiber end. Figure 6 shows damage to a fiber end incurred while inserting an STII connector into the coupling.



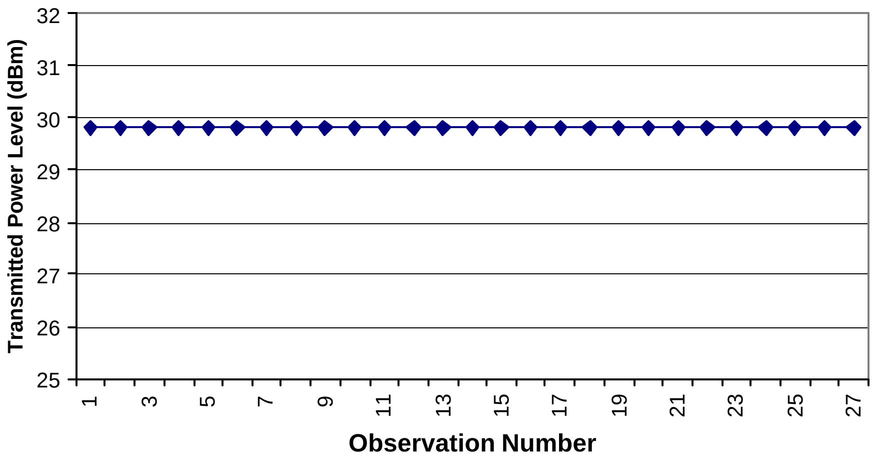
STII Fiber End Damage
Figure 6.

Long Term Stability

A major concern for connectors, splices, and attenuators is long-term performance. Four long-term tests have been done using test cycles found in Telcordia GR-326-Core[1] to test for different environmental conditions. These long-term tests include a thermal-aging test, a thermal-cycle test, a humidity-aging test, and a humidity/condensation test cycle. A Thermotron, Programmable Temperature Chamber, Model SM5.5C was used for these tests. The long-term stability tests have been completed for the LC connector.

Thermal-Aging Test

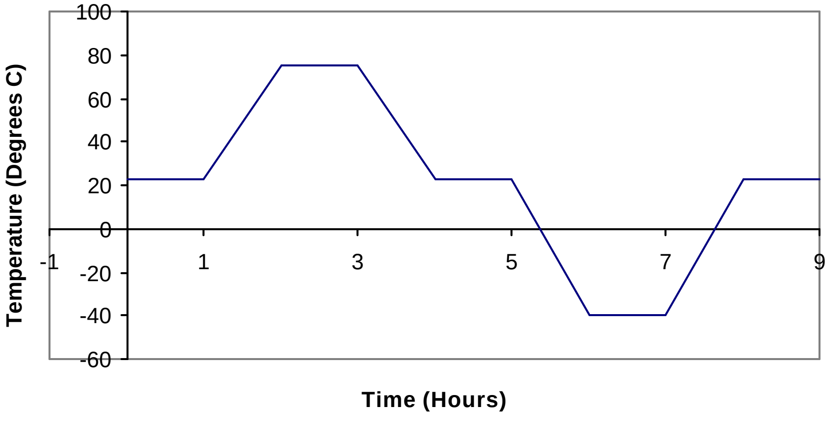
The thermal-aging test was done at 85°C with uncontrolled humidity for 168 hours (7 days). The four connectors in series were monitored for any change in power level during this time period. Any significant change in power level would indicate a change in the connector performance. During the seven-day period no change in power level was detected. Figure 7 shows the results of the four LC connectors in series during the thermal-aging test.



LC Connectors in Series
Thermal Aging Test
Figure 7

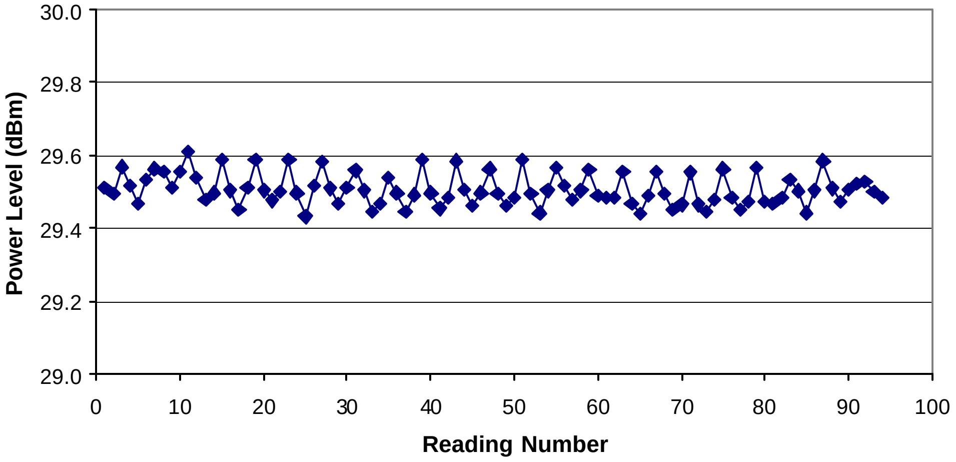
Thermal-Cycle Test

The thermal-cycle test exposes the connectors under test to extreme temperature variations with uncontrolled humidity. The thermal-cycle used for this study is shown in Figure 8.



Thermal Cycle
Figure 8

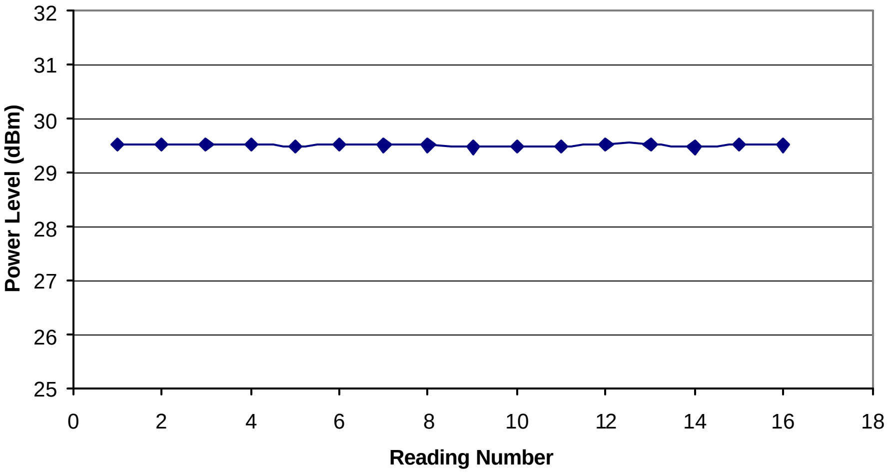
The power level was monitored throughout the test for changes in power level. Figure 9 shows the result for the four LC connectors in series during the thermal-cycle. The power level change observed is within normal expected changes for this type of test. Comparing the level before the test with the level at the end of the test indicates that no damage occurred that would affect performance.



Four LC Connectors in Series
Thermal-Cycling Test
Figure 9

Humidity-Aging Test

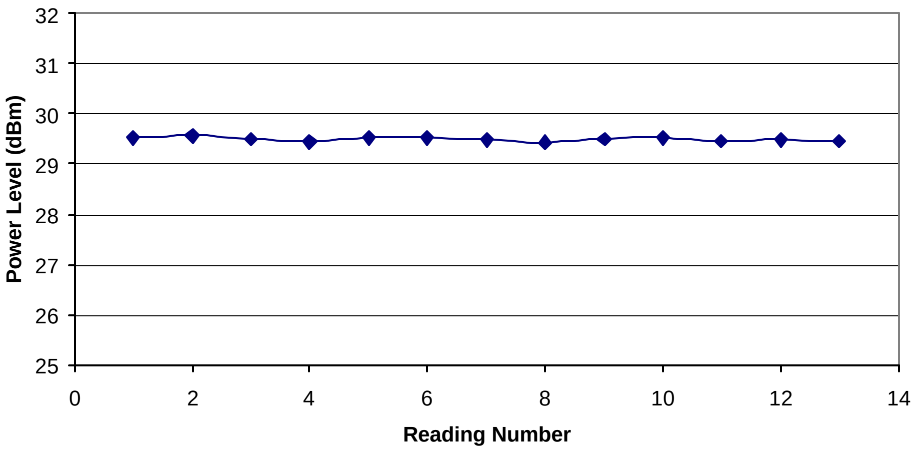
The same series of LC connectors was then subjected to a humidity-aging test. The samples under test stood at 75°C and 95% humidity for a period of 168 hours (7 days). The optical power level was monitored before, during and after the test with no change in optical power level observed. Figure 10 shows the results for the four LC connectors in series during the humidity-aging test.



Four LC Connectors in Series
Humidity-Aging Test
Figure 10

Humidity/Condensation Cycling Test

The humidity/condensation cycling test was done to subject the four serial connectors to situations where the connectors might see water in the connection path. Under certain conditions the water might freeze and cause connector damage and transmission failure. The samples were cycled from -10°C to +65°C and 90% to 100% relative humidity at certain temperatures during the test. The cycle ran for 168 hours (7 days). The optical power level was monitored before, during and after testing and is shown in Figure 11. No changes were observed.



Four LC Connectors in Series
Humidity/Condensation Cycling Test
Figure 11

After Test Connector Evaluation

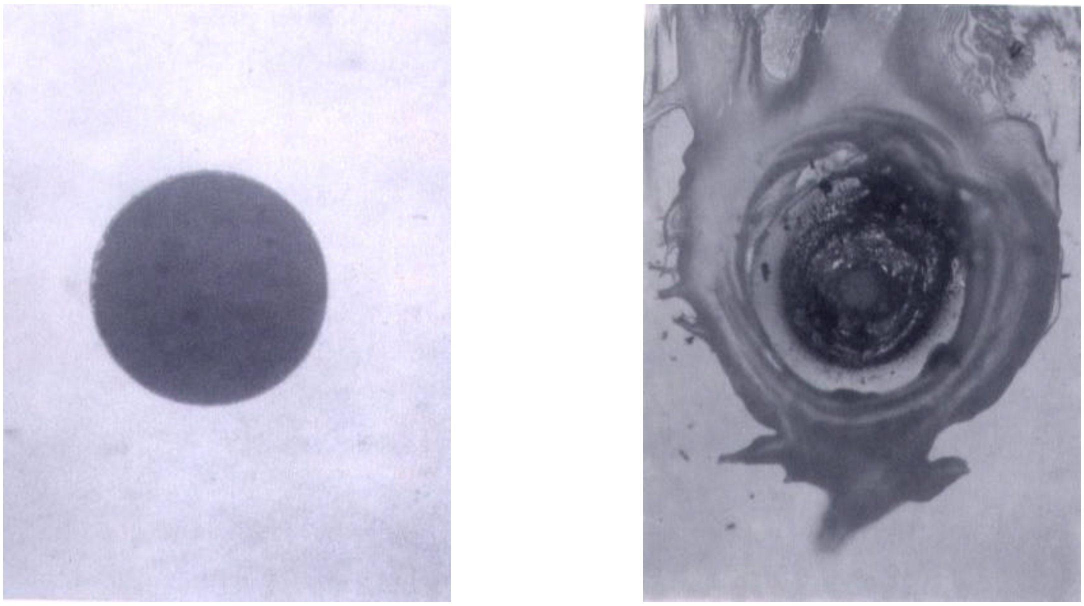
The LC connector samples used throughout these tests were evaluated individually for insertion and return loss. All four samples showed no significant of degradation in expected performance. The individual connector sample evaluations are shown in Table 1.

Jumper #	Insertion Loss (dB) 2 Connections	Return Loss (dB)
1	.21	54
2	.29	57
3	.27	56
4	.33	60

LC Connector Samples After Test Series
Table 1.

Cleaning

Connectors or splices should never be cleaned with high optical power present. Response to cleaning was tested using a Cletop cleaner, a dry wipe, and an alcohol wet wipe. The use of any of these cleaning methods at optical power levels higher than 15 dBm can cause fiber interface damage at the 1535 and 1560 nm wavelength. It appears that any combustible material cleaning can ignite at these power levels and cause the fiber end to become pitted. Figure 12 shows a connector that was cleaned at 20 dBm and 1535 nm.



Before **After**

Fiber End Damage Due to Cleaning Under Power
Figure 11

Conclusions

Connectors, a mechanical splice, and attenuators have been evaluated for performance at optical power levels of 1watt (+30dBm). Results show that these connectors and splices can be used in system applications with no observed performance penalty. Guided connectors are less likely to be damaged during insertion into the coupling and can be disconnected and reconnected at the 1-watt power level. Fiber-based attenuators can be used at these power levels, however, further evaluations are needed to determine long term performance effects. Lens-based attenuators should be used where system power levels will not exceed 25dBm. When components are cleaned, care should be taken to insure that the optical power level has been lowered to a safe cleaning level at or below 15dBM.

Long-term studies are planned for the STII, the SC connector as well as the Rotary mechanical splice and fiber-based attenuator. These results will be published later.

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