An Optica Sponsored Webinar:

The Harsh Realities of Testing Ruggedized Fiber Assemblies

Presented by Chris Heisler

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The content in this Presentation was presented by OptoTest in an Optica Sponsored Webinar "**The Harsh Realities of Testing Ruggedized Fiber Assemblies**." For further clarification of topics that may lack context or not be clear in this post.

Watch the Webinar Here.

This content in this post applies to testing military grade connector systems such as MIL-PRF-28876 and MIL-DTL-38999 series connectors, as well as commercial graded connector systems like the Senko™ series IP Plus and IP-9 hardened assemblies.

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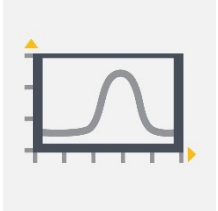
OptoTest Overview

- Designing fiber optic test equipment for over 15 years
- Tailor test equipment to the needs of the customer
- Partner with industry innovators to develop adapters/solutions for the newest optical connectors and components
- We take pride in simplifying the test and measurement process for our customers to help increase efficiency
- Dedicated to producing reliable, responsive, and accurate test equipment
- Our products are designed and manufactured in the USA
- We are ISO 9001:2015 compliant



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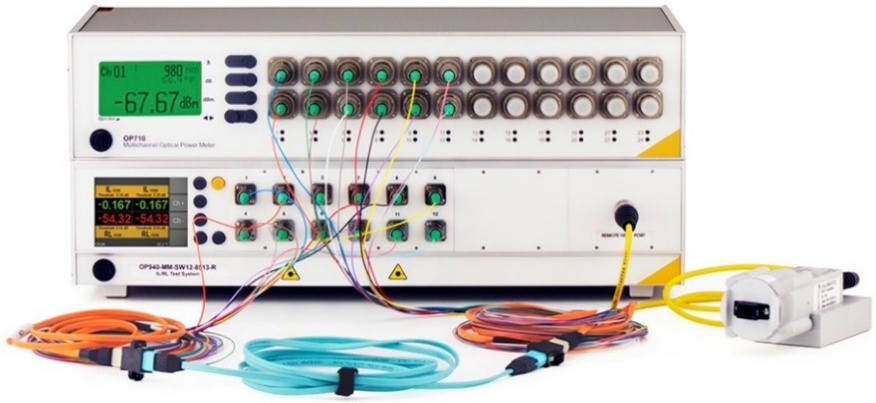
Webinar Overview

In this webinar we will look at:

- What is a ruggedized assembly?
- Equipment options for IL and RL testing of ruggedized assemblies
- Complexities associated with ruggedized assemblies
- Cabling setups for testing ruggedized assemblies
- Multimode launch condition concerns
- Vibration and shock testing



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What is a Ruggedized Assembly?

- For the purpose of this presentation, ruggedized assemblies are:
  - Hardened assemblies that, many times, will have rigid cabling.
  - Assemblies terminated where at least one end of the cable is connectorized with a large weather-proof, or vibration/shock proof connector.
  - Typically, assemblies with no available optical power meter adapter for one or all of the connectors.
  - Connectors use 2.5mm, 1.6mm, 1.25mm and MPO ferrules.

plug

receptacle

Mil/Aero

IP Series connectors courtesy of
Senko Advanced Components

Commercial

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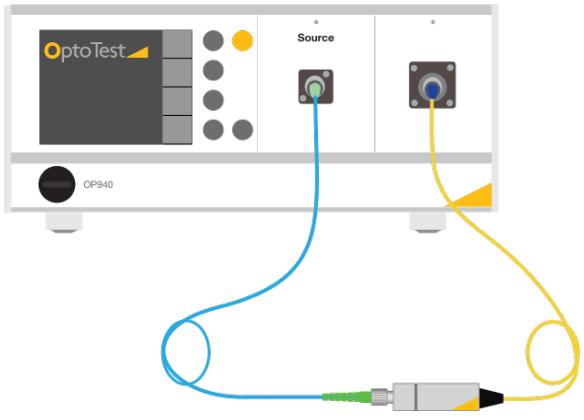
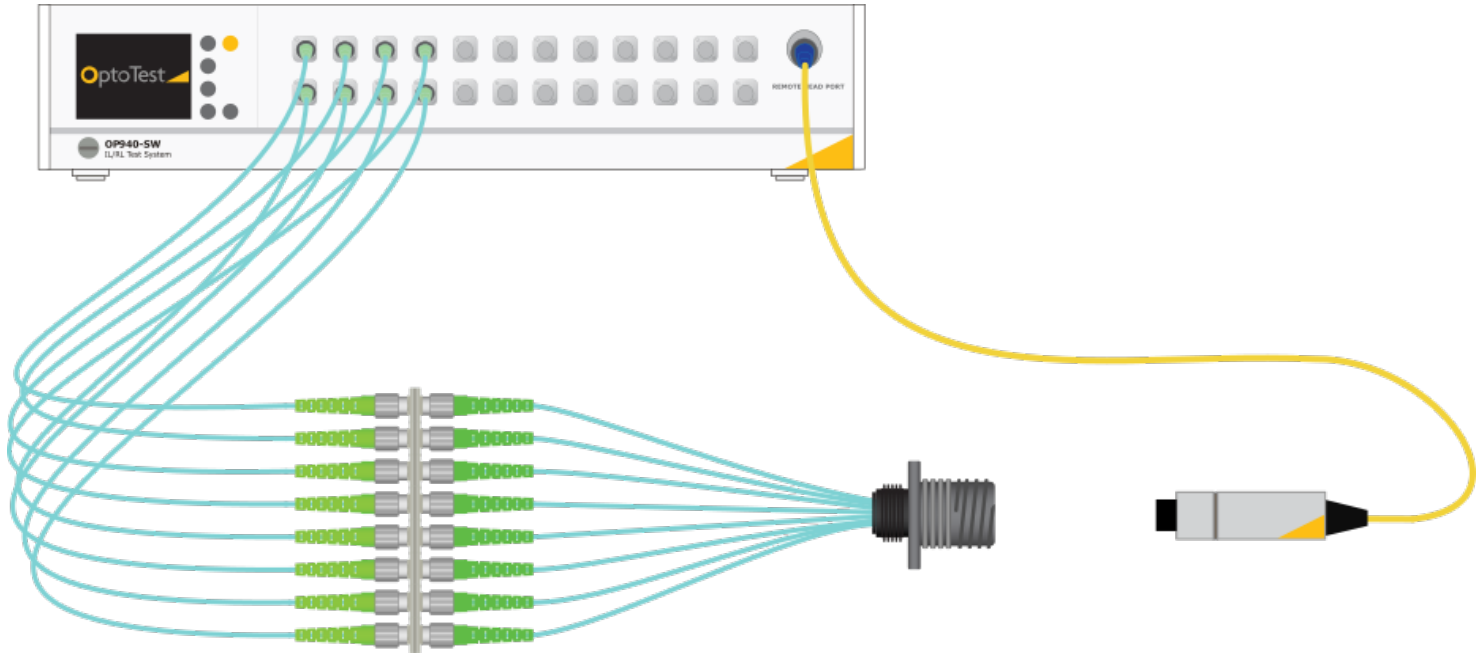
Insertion Loss and Return Loss Meter

- Different configurations:

Simplex



Multichannel



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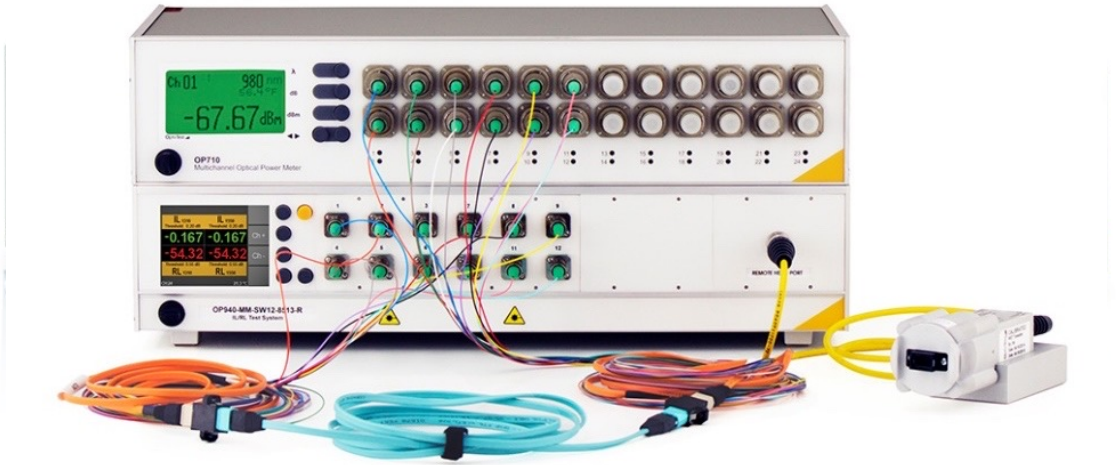
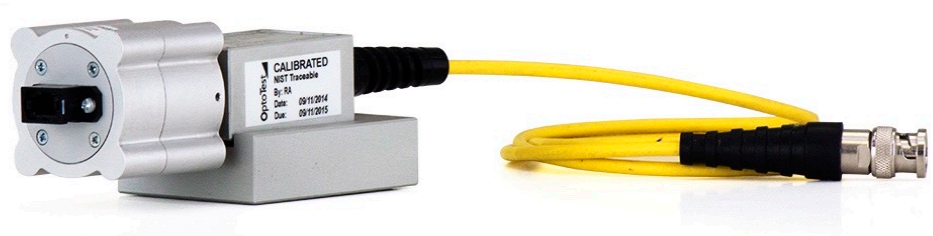
Equipment Selection

Optical Power Meter

- Multichannel Power Meter
  - Allows for discerning polarity in certain cases.



- Integrating Sphere / Large Area Detector
  - Allows for large wide aperture connectors in most cases.
  - Cannot discern polarity.



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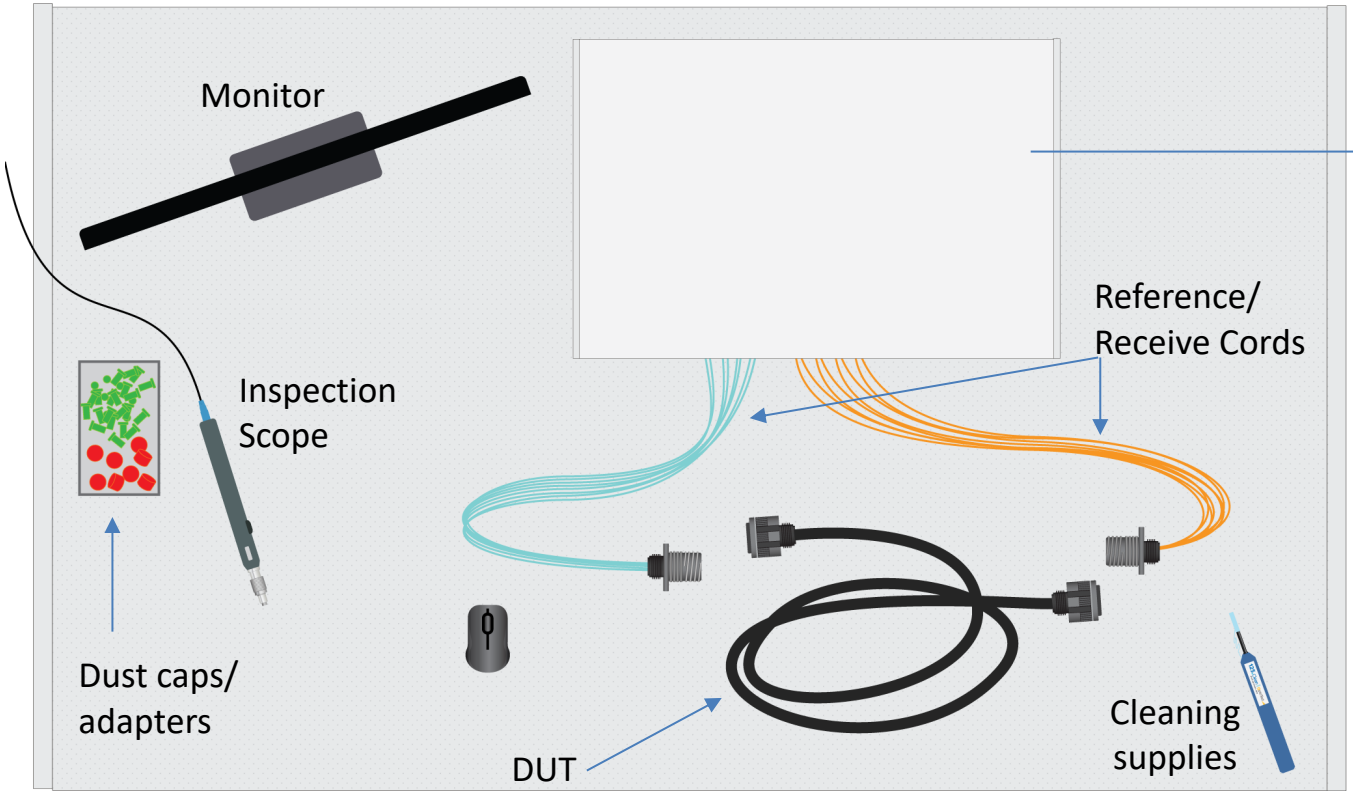
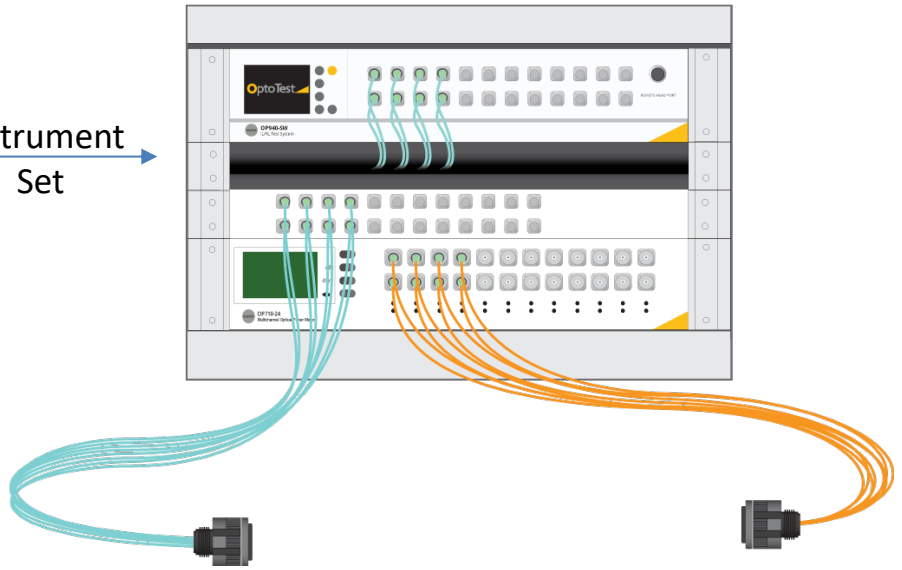
Workstation Organization

- Ruggedized assemblies can have many fibers and cables within an assembly.
- Assemblies are typically rigid or difficult to bend.
  - Ruggedized cabling typically has “memory” and when bent might return to their previous form.
- Handling the reference cords, DUTs, receive cords, etc. can get “clunky” when in constrained spaces.
- Keeping the workstation organized can help to minimize technician error.





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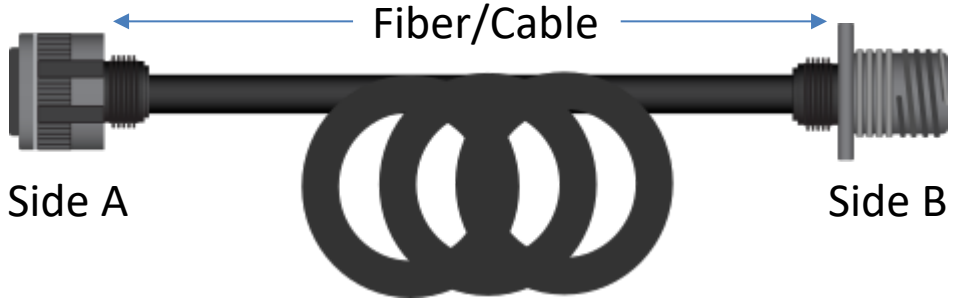
Selecting a Test Method

- Understanding what needs to be measured helps to define how to measure.
  - Does each connector need to be measured?
    - Connector Loss measurements.
  - Does the full assembly need to be measured?
    - Link loss measurements.

- The DUT structure and available equipment are factors as well.
  - Simplex or Multichannel source.
  - Simplex or Multichannel optical power meter set.

- Cable assemblies typically have three components that contribute to insertion loss and return loss.
  - Front connector (Side A).
  - Back connector (Side B).
  - Fiber (Link(s) from A to B).



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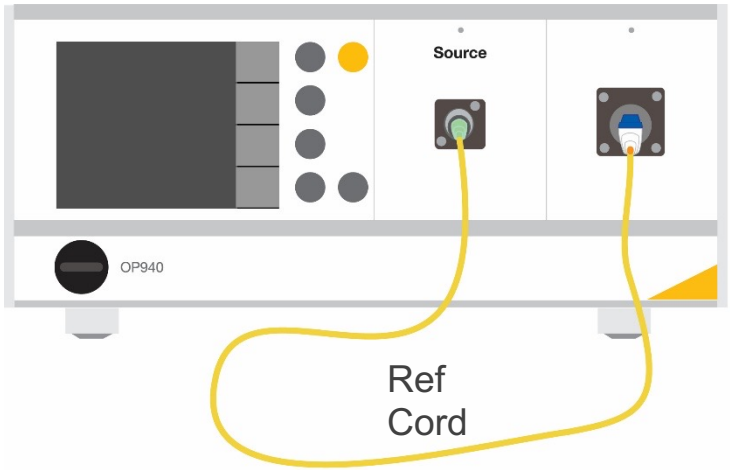
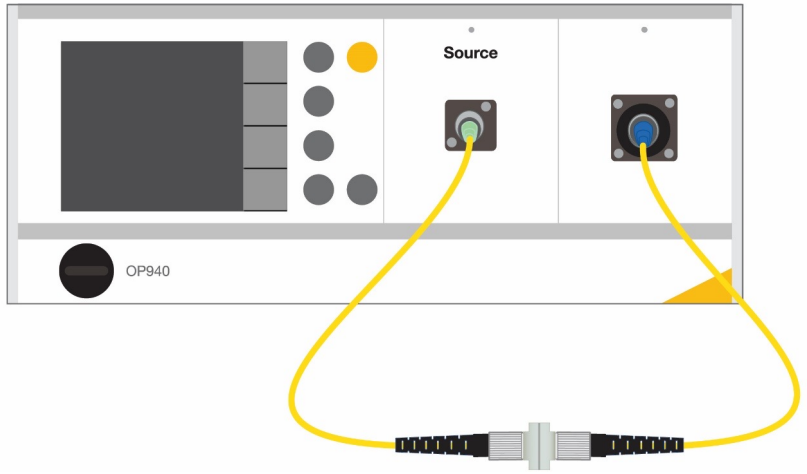
Connector Insertion Loss and Return Loss

- To accomplish this:
  - Power must be measured directly out of the reference connector during the reference step.
  - Power must be measured directly out of the Side B connector for measurement of side A.



Reference Setup



Measurement Setup

- IL_{Con} (dB) = P_{ref} (dBm) – P_{meas} (dBm)

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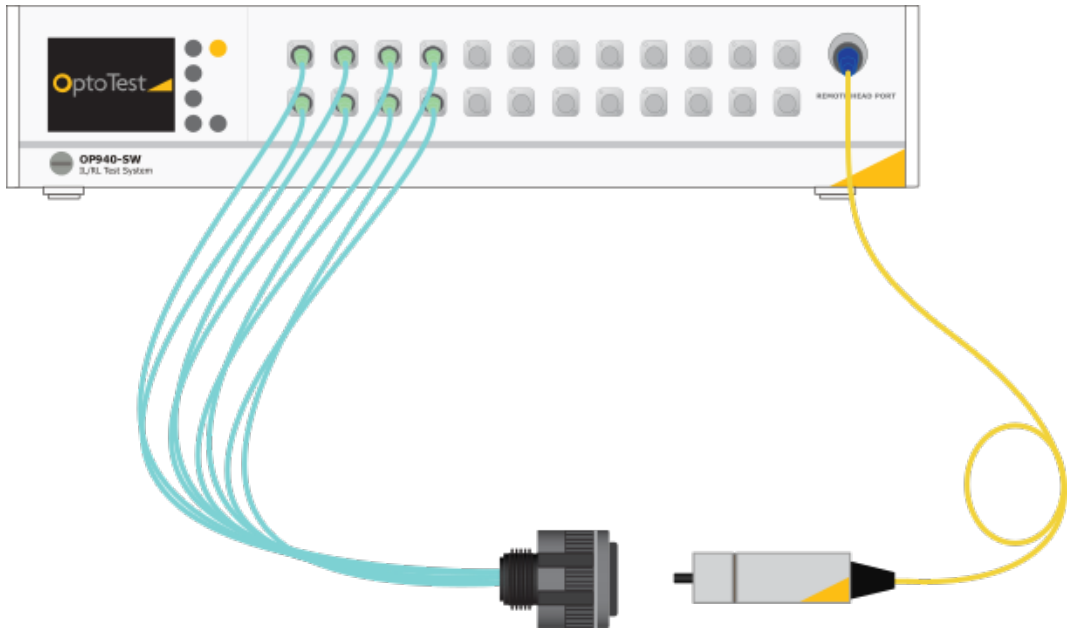
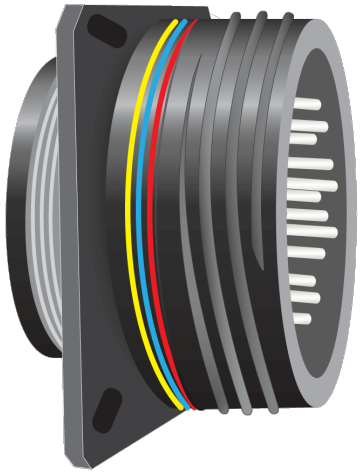
Selecting a Test Method (Connector Loss)

- For ruggedized assemblies this can become very challenging to measure power out of the reference connector or the DUT connector.
  - OPM adapters are not designed for many of these types of connectors.
  - Measuring power out of each ferrule of a ruggedized assembly could be inaccurate and potentially leave the connector open to dirt and damage during the measurement process.





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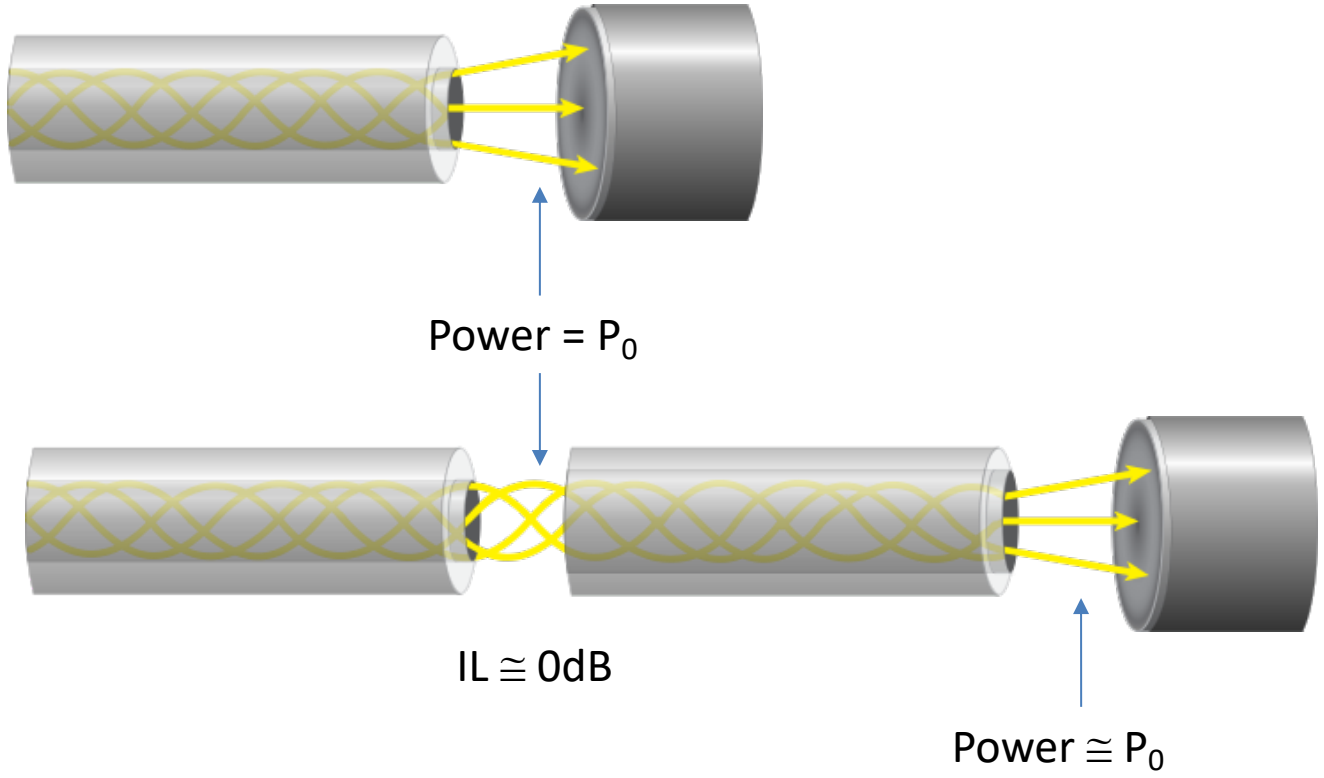
What is a “Bucket” Cable?

- To properly measure the optical power at the launch reference connector we need to get creative.
- Large core “bucket” fiber assemblies.
  - Provides a zero-loss connection to route the light to the OPM.
  - Effectively it is an extension of the optical power meter.
  - Fiber has loss, so receive cable should stay rather short.
    - This loss is referenced out.



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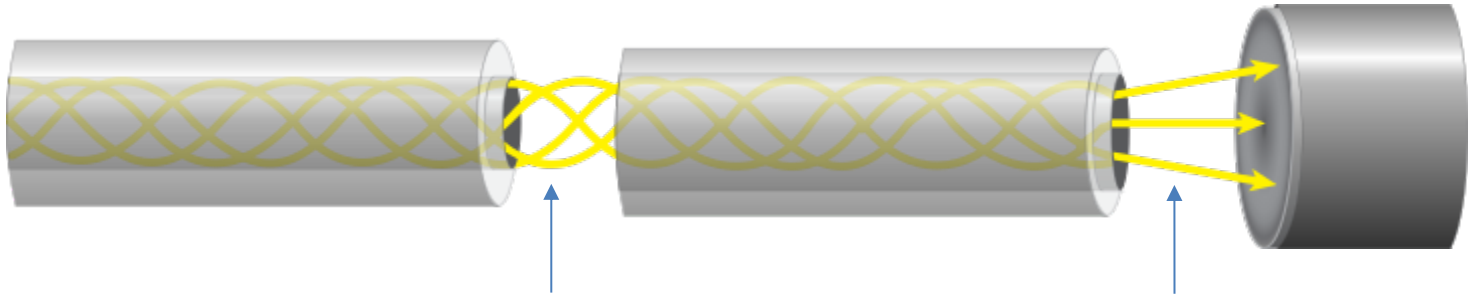
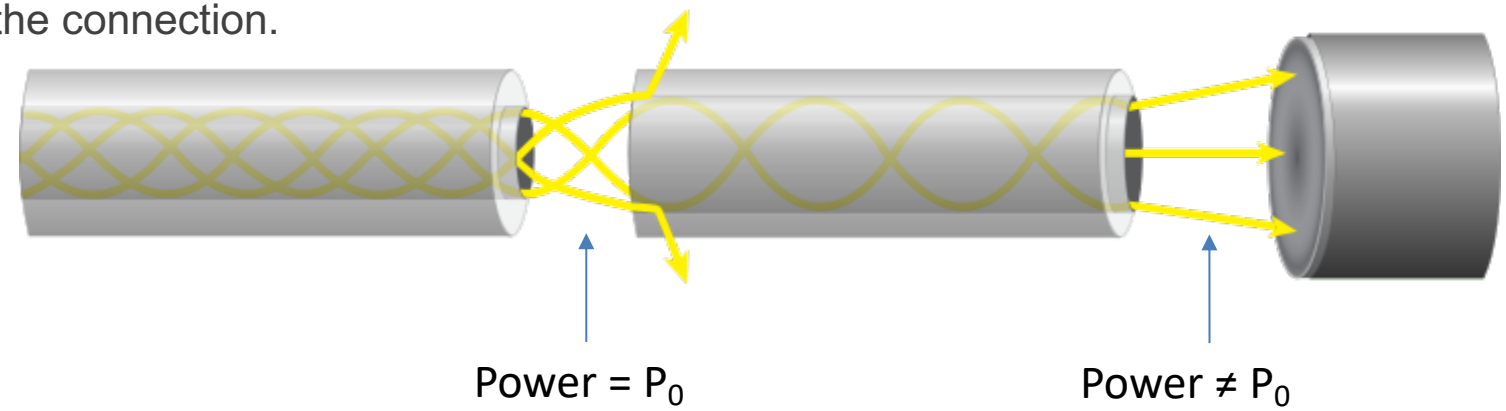
Large Core Bucket Cable Requirements

- Large core fiber, must be significantly larger than test fiber. The larger core allows for all light to be transmitted through the connection even if there are slight offsets.



- Fiber used should also have a larger NA than the DUT.
  - If the fiber has a larger core size, but lower NA, then high NA light will still escape through the cladding, leading to excess loss at the connection.



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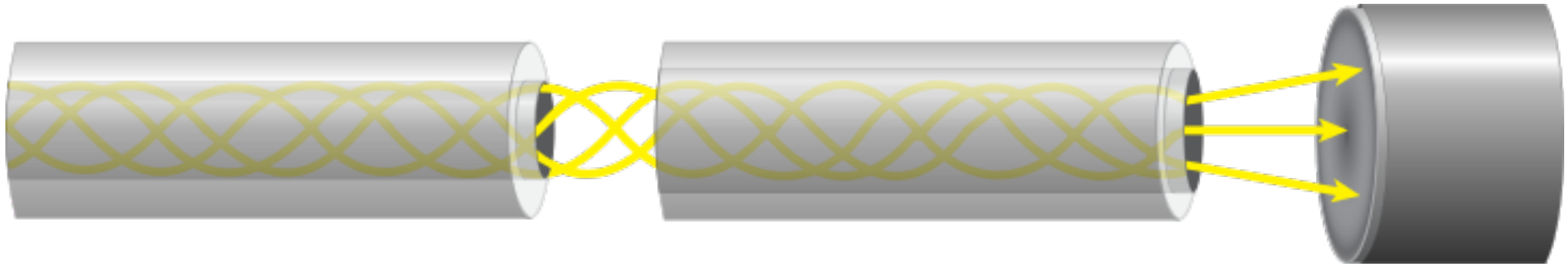
Large Core Bucket Cable Requirements

- If possible, use a bucket cable constructed of graded index fiber.
  - This helps to control the modal distribution in the receive cord.
  - Light remains constrained to the center of the fiber.



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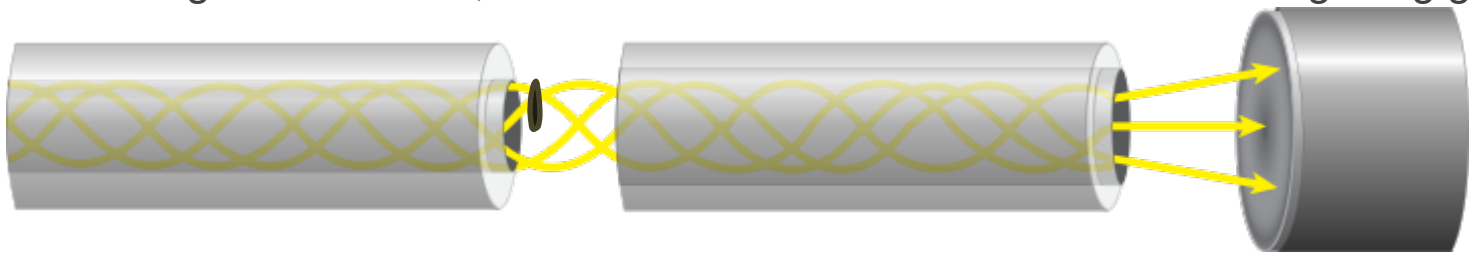
What to Consider When Using a Bucket Cable

- This is typically a physical contact mating.
  - Any time two connectors mate there is a possibility of damage to either or both of the connectors.
    - These are typically large channel count connectors and maintaining, inspecting and cleaning can get time consuming.
    - A standard OPM does not present this problem.
      - This is a non-contact solution.

  - Dirt or a poor connection at the mating will reduce the power level measured.
    - If this occurs during the reference, low losses will be measured -> sometimes getting gainers.



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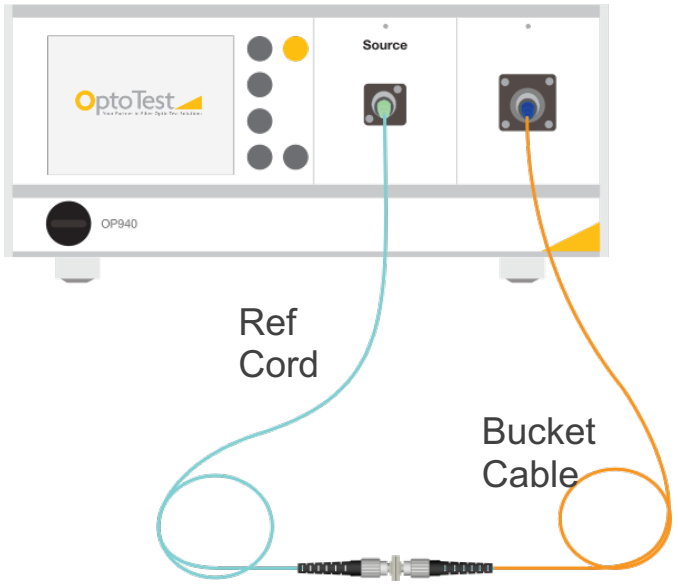
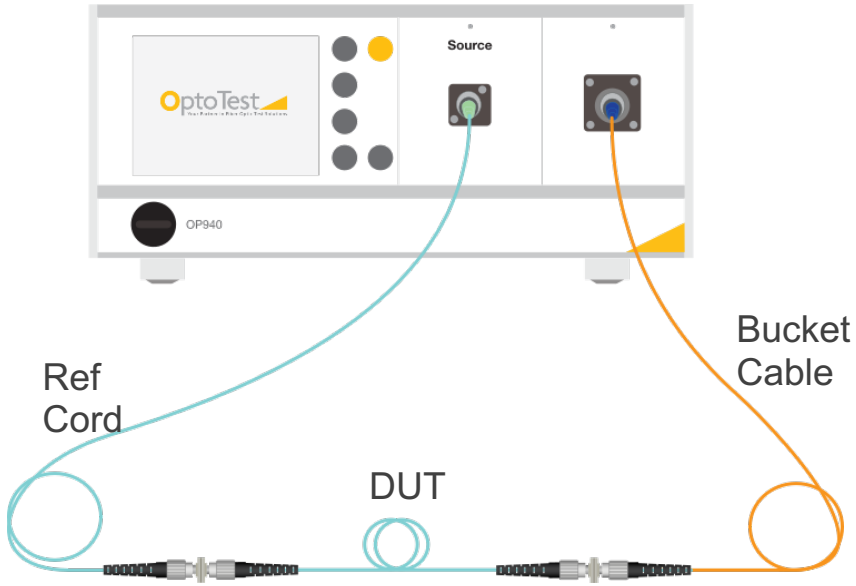
Typical Connector Loss Measurement With Bucket Cable

- Reference and Measure as normal, except treat the bucket cable connector as the OPM connection.



Reference Setup



Measurement Setup

- Because the mating to the bucket cable is essentially zero loss, it is like connecting directly to the optical power meter.

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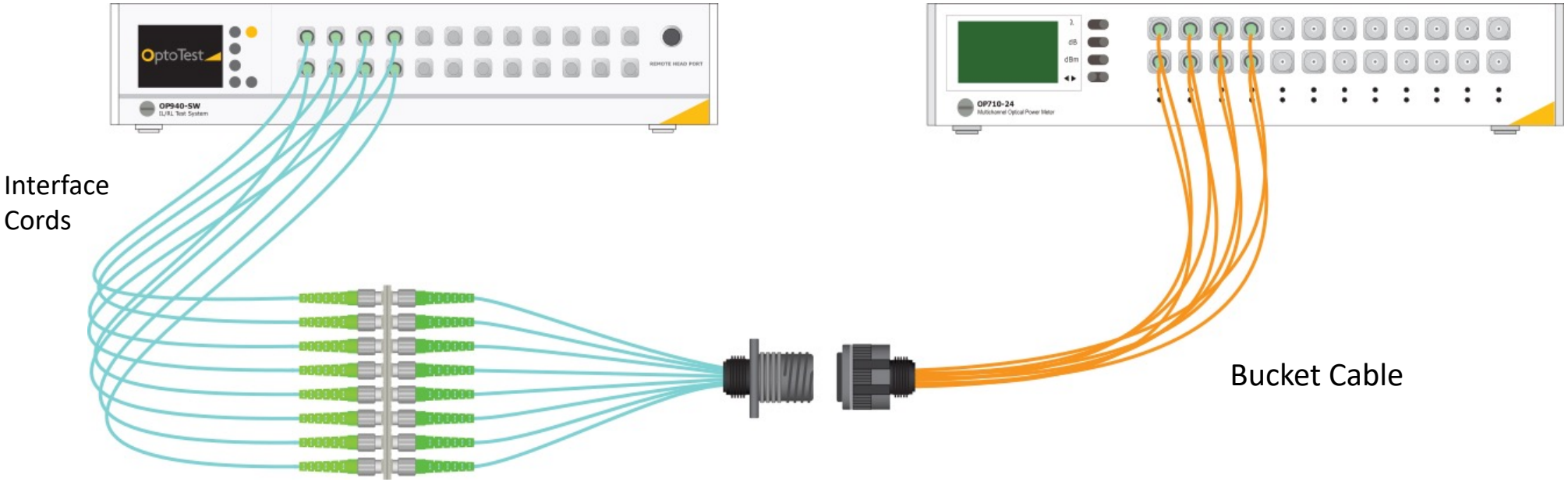
Testing Connector Loss With a Bucket Cable

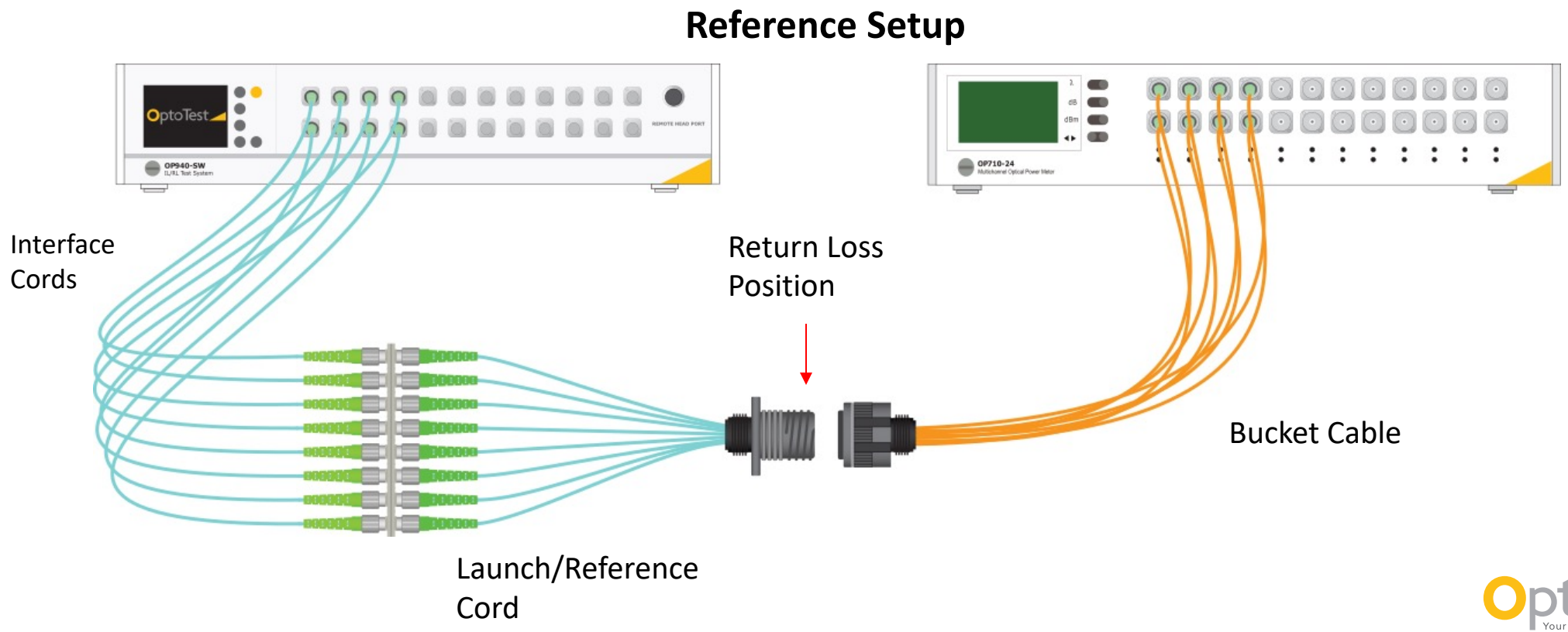
- The structure of the DUT defines the types of source and receive cords necessary for the test.
  - For a DUT where both ends can mate to each other, such as a receptacle to a plug, the same bucket cable can be used for reference and measurement.
  - Using a multichannel power meter assures proper polarity of the DUT.
  - The system will step through each port and reference insertion loss.

Reference Setup



Testing Connector Loss With a Bucket Cable

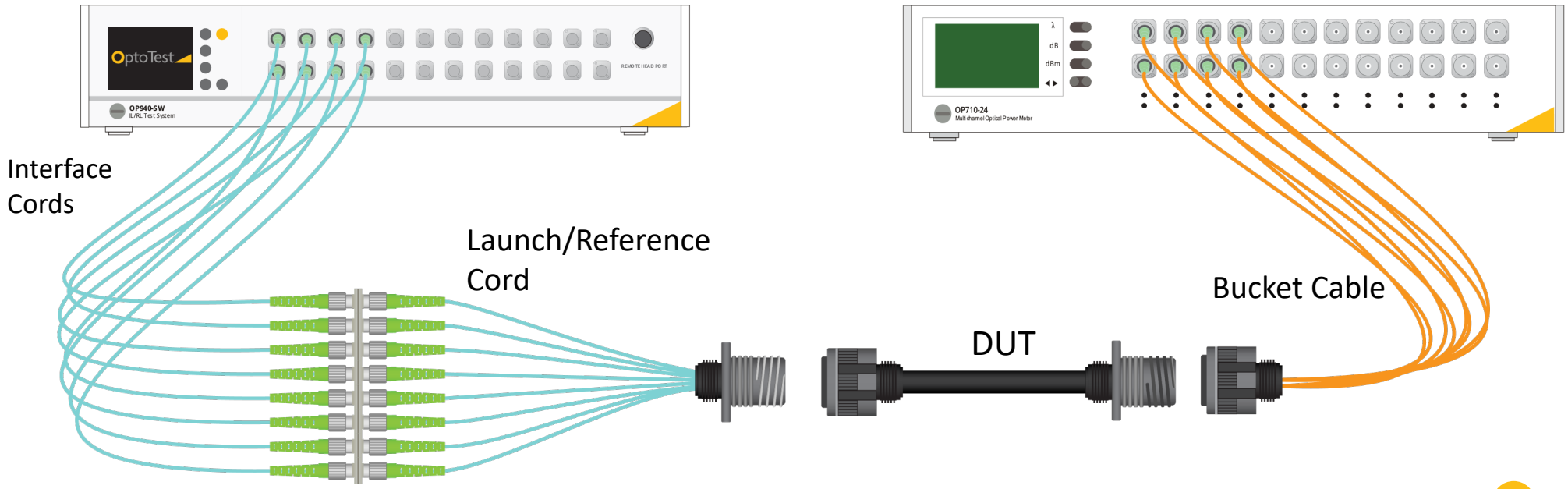
- Referencing return loss, for a pulse-based system, consists of the system finding the position where return loss is to be measured.
  - It is also possible with many systems to specifically tell what position to measure return loss at.
  - For a standard return loss reference leave the bucket cable disconnected from the reference connector.



Testing Connector Loss With a Bucket Cable

- To measure the DUT it is connected between the reference connector and the bucket cable.
  - Because the loss is negligible at the DUT to Bucket cable mating, the loss measured is effectively due only to the reference connector and DUT mating.
  - Any routing issues will be reported as dark measurements.

Measurement Setup



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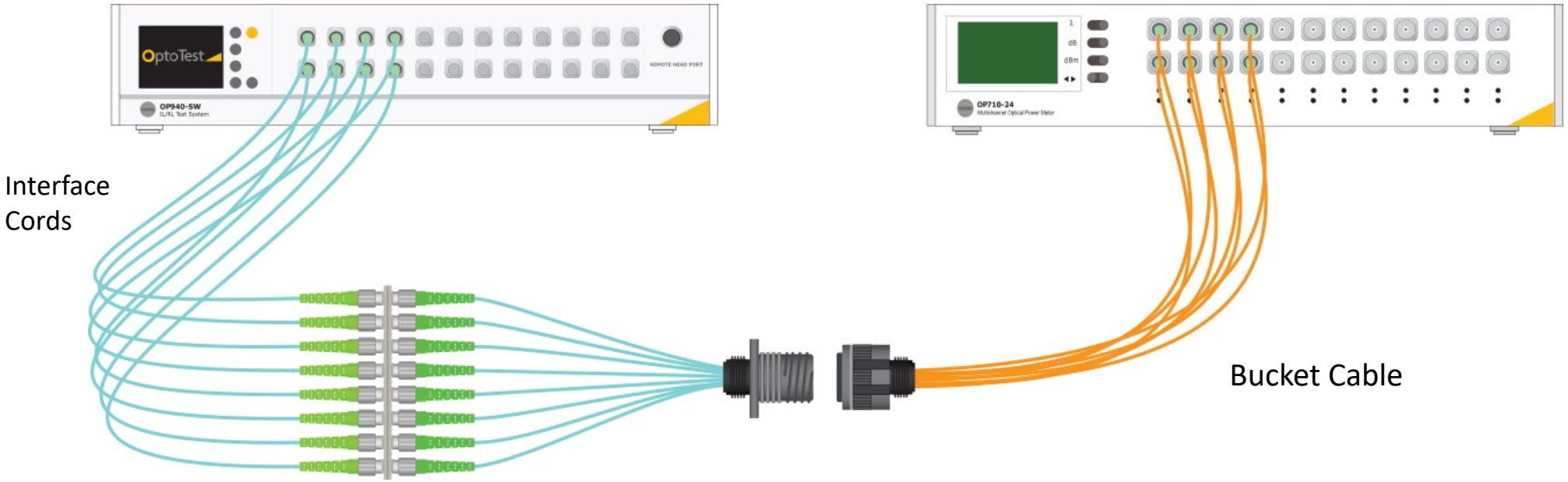
Testing Connector Loss With a Bucket Cable (Cont.)

A DUT where both ends cannot mate to each other and there is no hybrid adapter could require two types of bucket cables for the test.

- The reference setup cable needs to be able to mate to the reference connector.

DUT

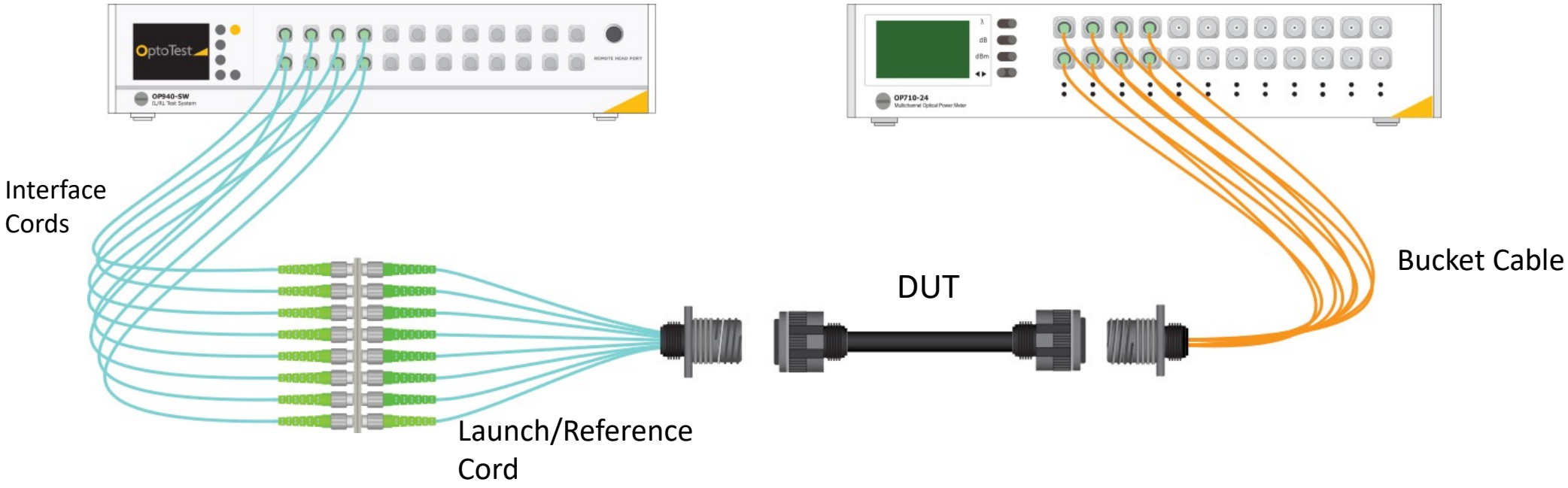
Reference Setup



Testing Connector Loss With a Bucket Cable (Cont.)

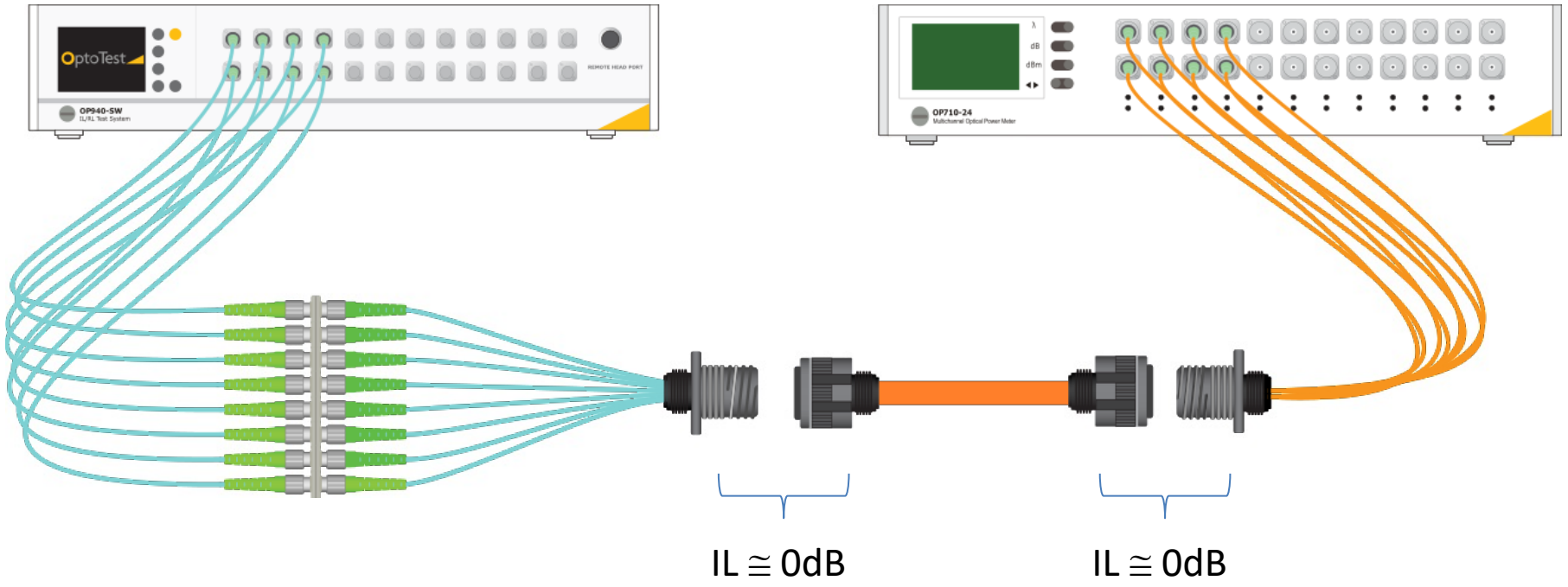
- For the measurement setup, the receive cable needs to be able to mate to the DUT.
- This requires removing the reference receive cable and replacing with another.
  - Potentially introduces error into the test (misrouting receive cable, adding contaminants, etc.)

Measurement Setup



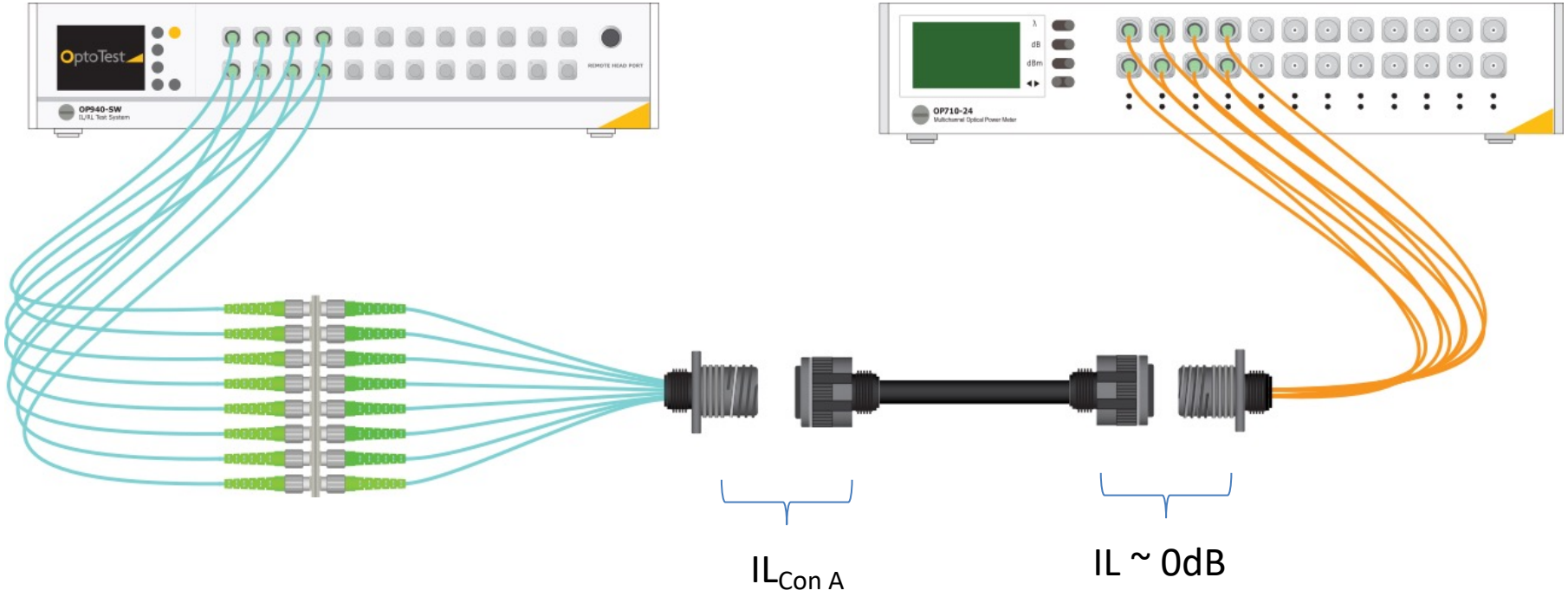
Testing Connector Loss With a Bucket Cable (Cont.)

- To limit the amount of connecting and disconnecting between the reference setup and measurement setup a “zero loss” conversion cable can be used.
  - This should be a large core fiber assembly of similar type to the receive fanout cable.
  - This cable should be similar in structure (same connectors on both ends) and polarity as the DUT.



Testing Connector Loss With a Bucket Cable (Cont.)

- To measure the DUT, remove the low loss cable and swap in the DUT.
- There will be a measurable loss on connector A (front) and the rear connector will mate to the large core receive cable yielding negligeable loss at this mating.
- The measured loss of this setup will be due to the mating of connector A.



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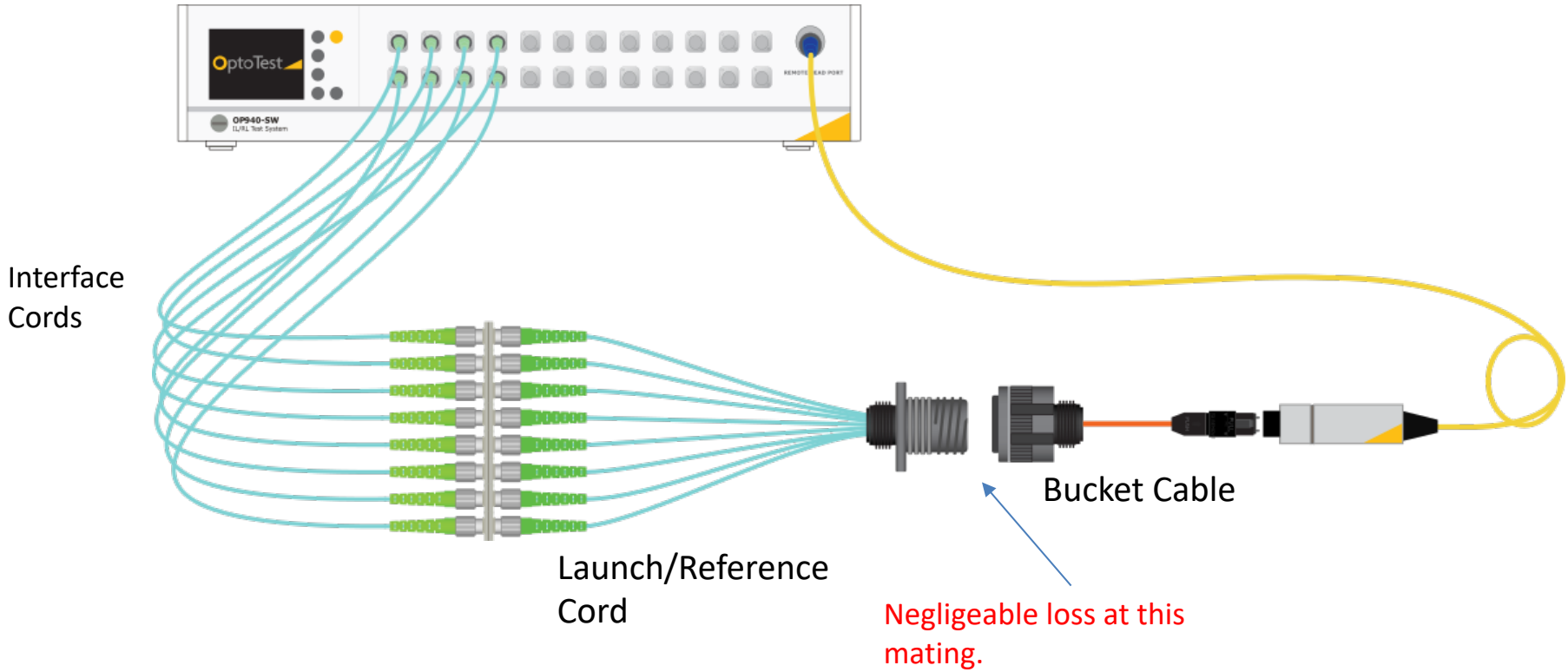
Testing Connector Loss With a Bucket Cable (Cont.)

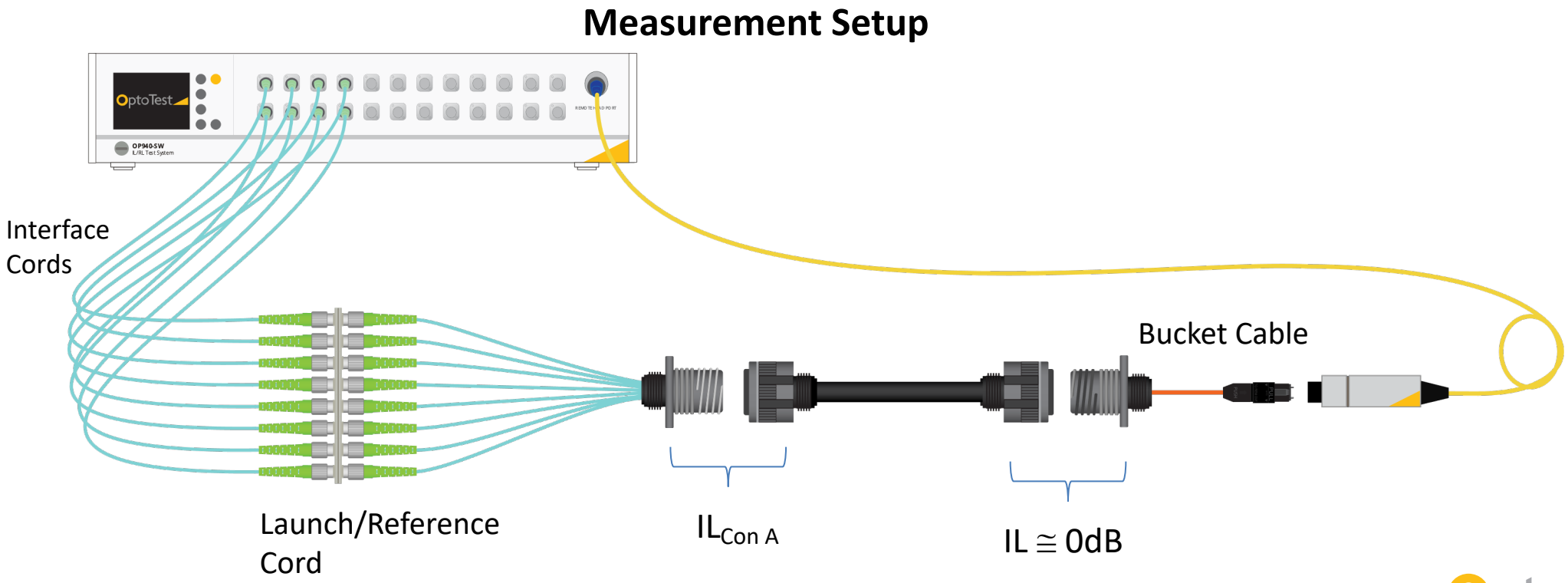
- If polarity isn't a concern, then a different type of receive cable can be used.
  - In this case the receive cable has an MPO connector that can be routed to the OPM.
    - Up to 32 ports in one connector.

Reference Setup



Testing Connector Loss With a Bucket Cable (Cont.)

- In the more difficult case, where the DUT has like connectors that cannot mate to each other, swapping out the receive cable is much easier.
  - Even in this case, where the receive cable is changed out during the measurement process, one is only disconnecting and connecting a single port on the power meter.



Testing Connector Loss With a Bucket Cable (Cont.)

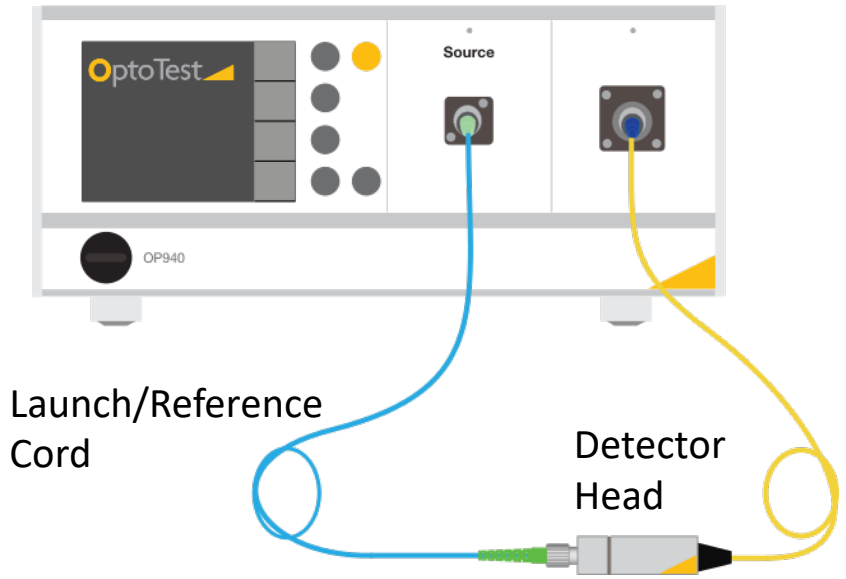
- In some cases, using a simplex system is easier and cleaner to manage.

- Benefits
  - Less expensive than multichannel setup.

- Drawbacks
  - Slower than multichannel test setup.
    - Requires one to manually iterate through each port.
  - Less accurate than a multichannel setup. Typically yields higher loss due to the additional connector during the measurement.

- Referencing is simple because there is no need for a bucket cable.
  - Connect source/launch cable directly to OPM.

Reference Setup



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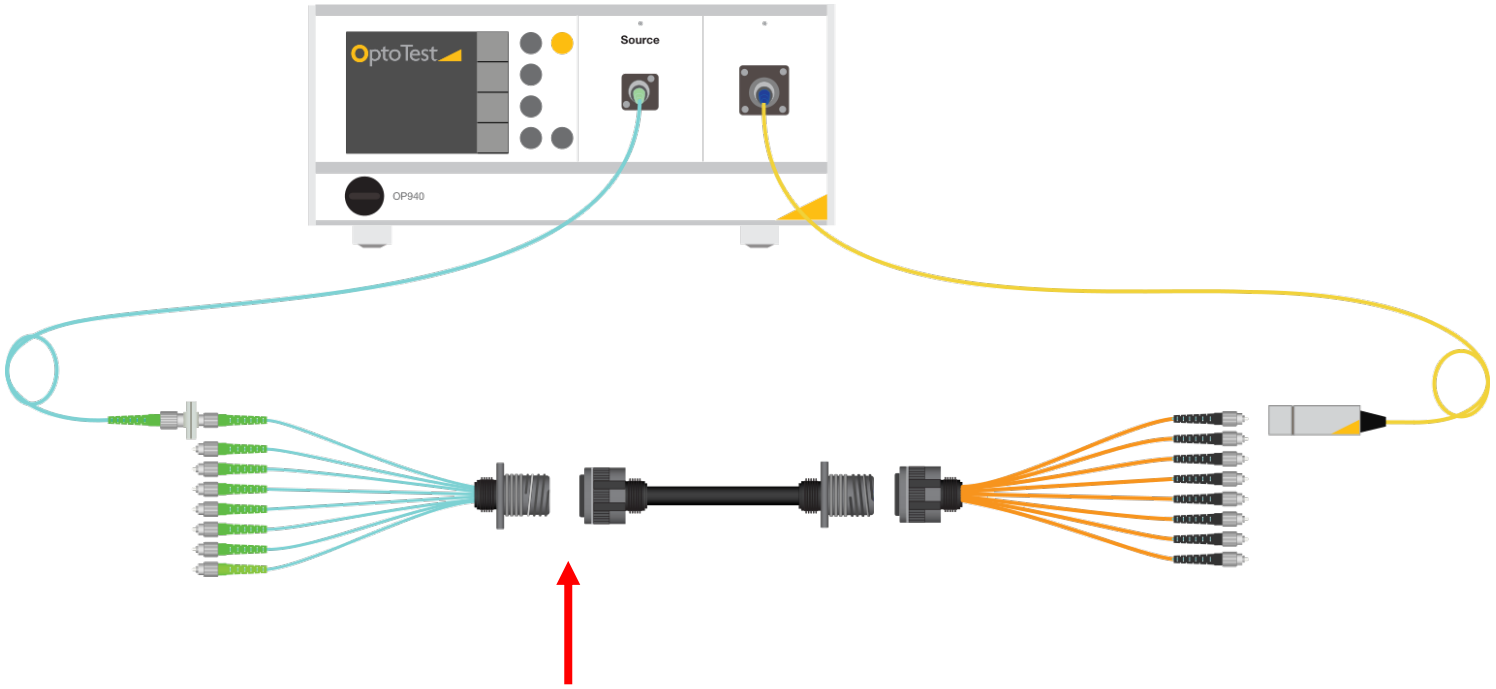
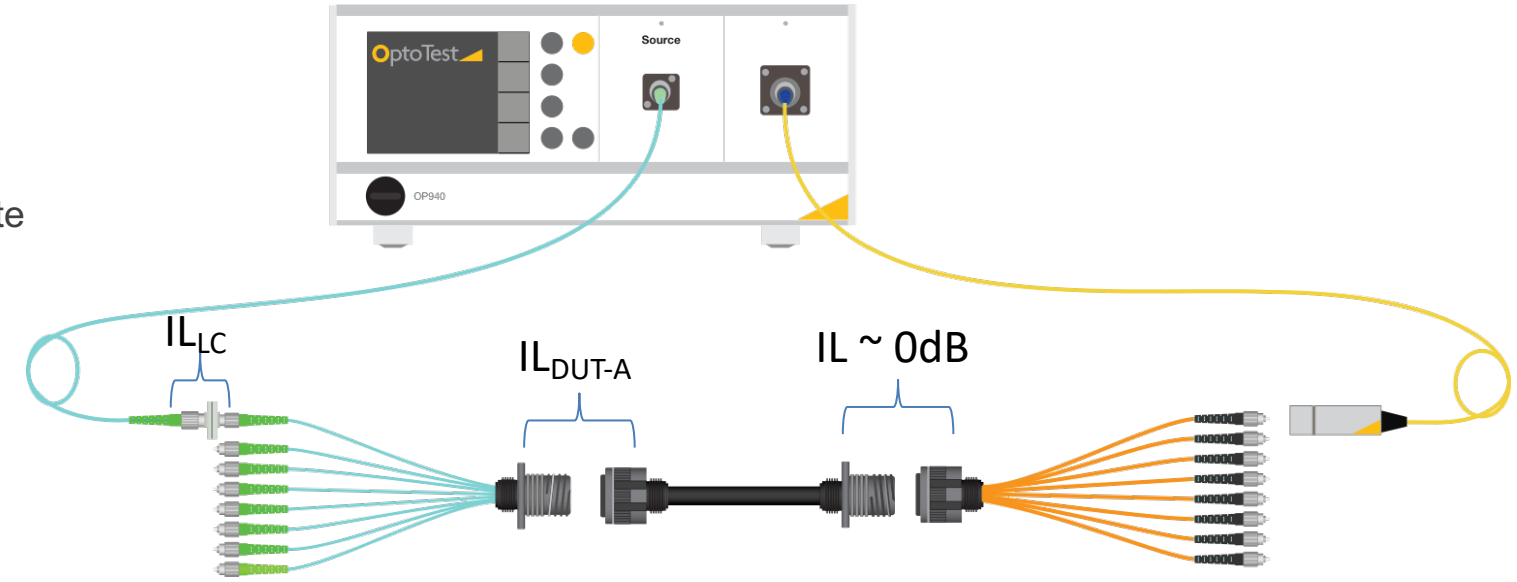
Testing Connector Loss With a Bucket Cable (Return Loss Considerations)

- To reference return loss on this setup, the simplex launch cord needs to be connected to the launch fanout cord.
- Return loss is then referenced to find the position at the end of the launch fanout reference cord.
- Return loss will be measured at this position.



Testing Connector Loss With a Bucket Cable (Cont.)

- Use a bucket receive cable for zero loss connection on back of DUT.
- Introduce a fanout cable to the measurement setup
- For the measurement, the technician needs to iterate through each connector.
  - Inspect and connect to source side
  - Inspect and connect to the OPM.
- What's being measured?
  - Insertion loss is being over-estimated
  - Insertion loss of the launch cable connection to the fanout cord isn't being referenced out and is included in the measurement.
    - May not matter, due to quality of connectors and restricted launch conditions.
    - A restricted launch condition (tight modal distribution) with high quality connectors can yield very close to no loss at a mating.



$$IL_{measured} = IL_{DUT-A} + IL_{LC}$$

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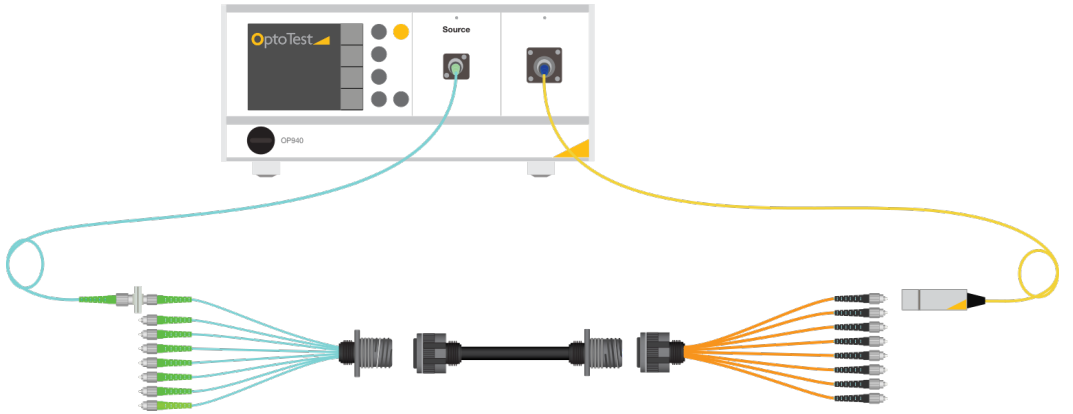
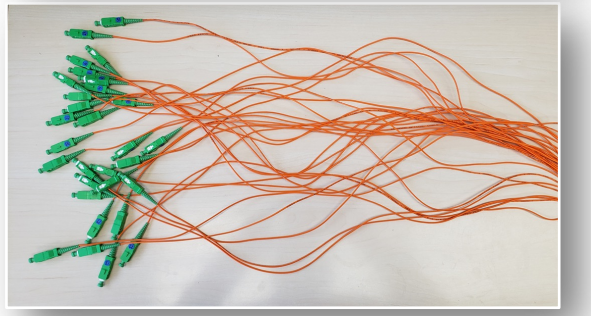
Concerns When Testing With Simplex System

- Identifying port to measure
  - In this graphic the cables look nice and organized.
  - It is almost never like this.
  - It usually looks something like this…
  - Or even worse, after testing/retesting for a few DUTs, it ends up looking like this…
  - The result is that the technician doing the measurement needs to search for the specific port to test or retest.
    - This leads to lost time
    - Potentially incorrect measurements





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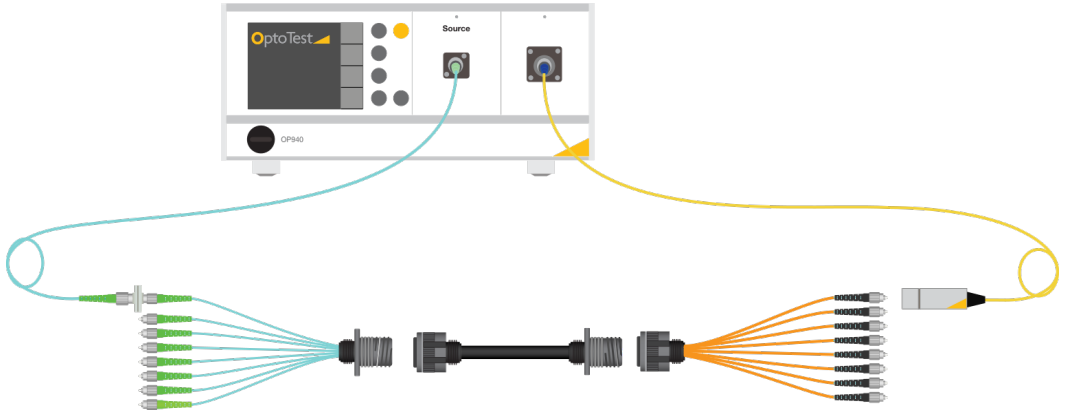
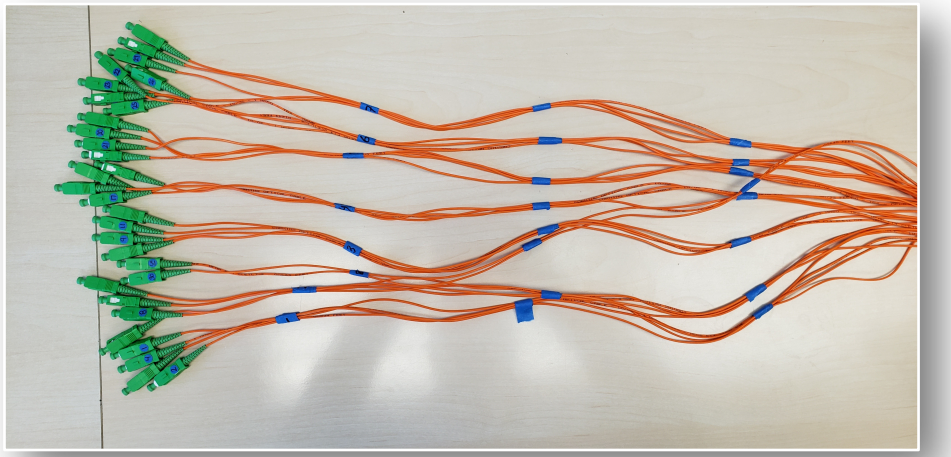
Concerns When Testing With Simplex System

- Identifying port to measure
  - Take a little extra time to organize the launch and receive cables into bundles.
  - These bundles reduce the amount of tangled fibers.
  - Allow for a technician to quickly identify the bundle of the port to be tested.
    - Easily identify the port within the bundle.
  - Bundles can be numbered or color coded.





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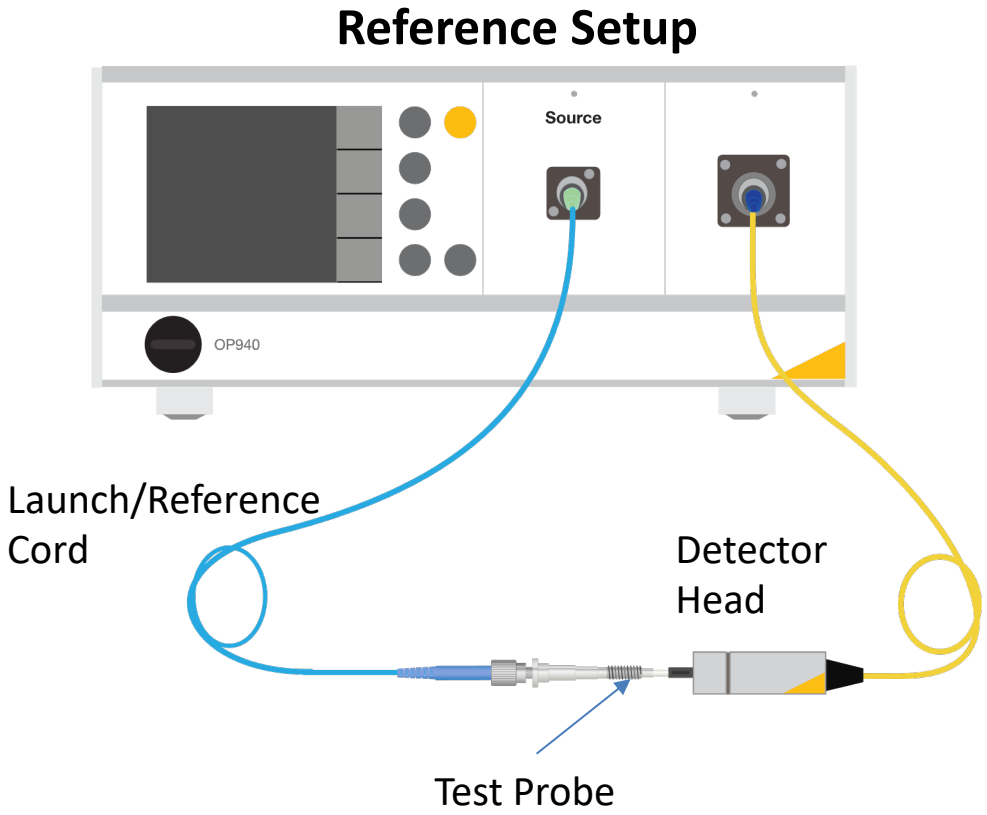
Testing Connector Loss With a Test Probe

- A test probe can be used to mate a simplex port to a multiport DUT without the need for a fanout launch cable.
- A test probe mimics a real interconnection.
- These probes many times have a quick release system to easily insert and remove from the mating adapter.
- If using a test probe, simply connect the test probe to the OPM using a suitable adapter to reference the test.
  - These are usually: 1.25mm, 1.6mm or 2.5mm universal adapters.



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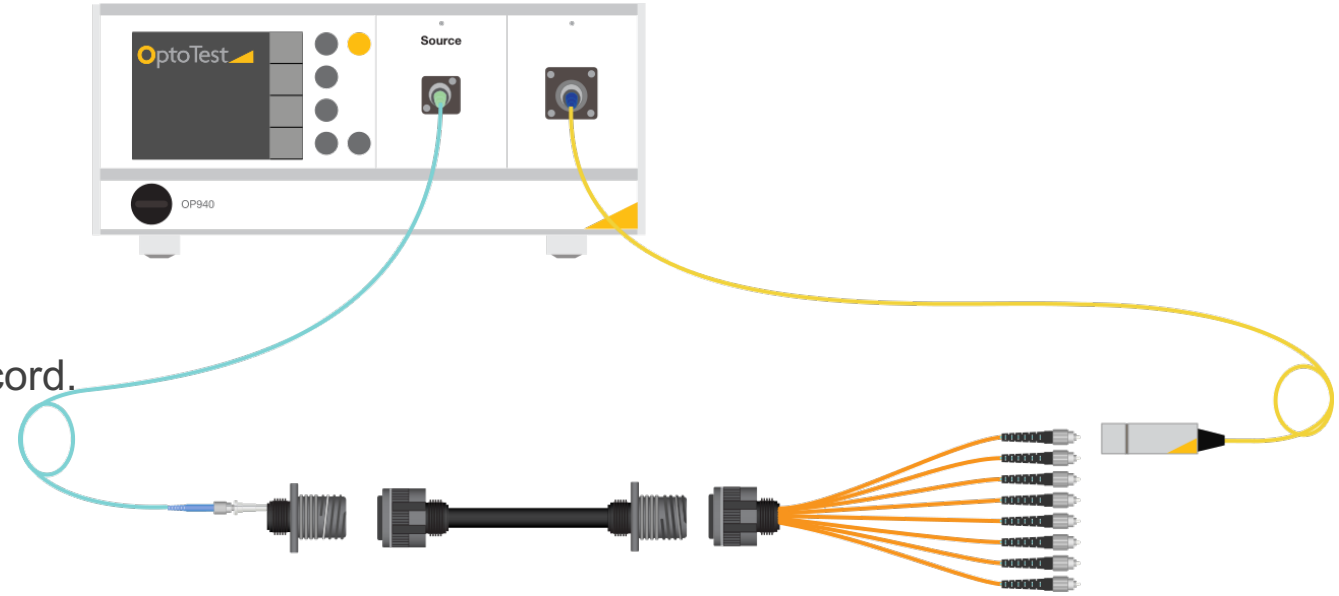
Testing Connector Loss With a Test Probe (Alternative)

- To test each port:
  - Insert the probe into each port on the adapter.
  - Connect the corresponding receive bucket cable leg to the OPM port to measure IL.
  - The use of an adapter ensures that the mating properly mimics an actual full mating.
  - The loss measured here does not include an additional connection as it did when using the launch fanout cable with a simplex equipment cord.
    - Losses will be more accurate.
- Other types of probes are available with standard ferrule sizes that don't properly mimic a true connection.
  - Don't latch in properly
  - Probe RL is susceptible to pressure applied.



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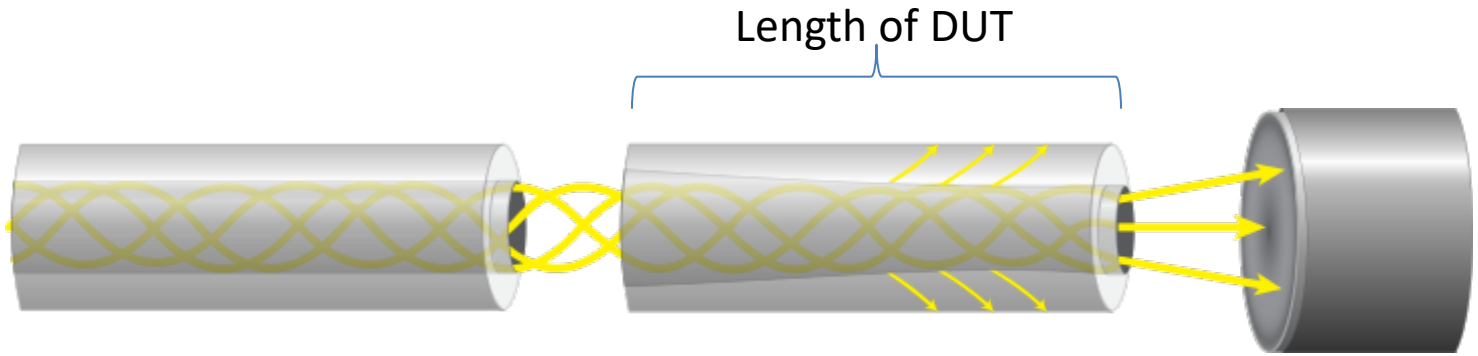
Considerations When Testing Bend Insensitive Multimode Fiber

- It is recommended to use non-bend insensitive fiber for launch cords.
  - Non-BIMMF maintains launch conditions better.
  - BIMMF can be used but launch conditions shall be conserved.

- Short BIMMF DUTs, will hold on to cladding modes for longer lengths of fiber.
  - Under-represent insertion loss because a short BIMMF DUT looks like a large core fiber with low loss.



  - As light travels down the length of a bend insensitive multimode fiber, initially lossy modes are retained. Then at some length these lossy modes will escape out of the cladding inducing loss.
    - Short BIMMF assemblies may not experience this loss, which may underrepresent the true loss of the mating.

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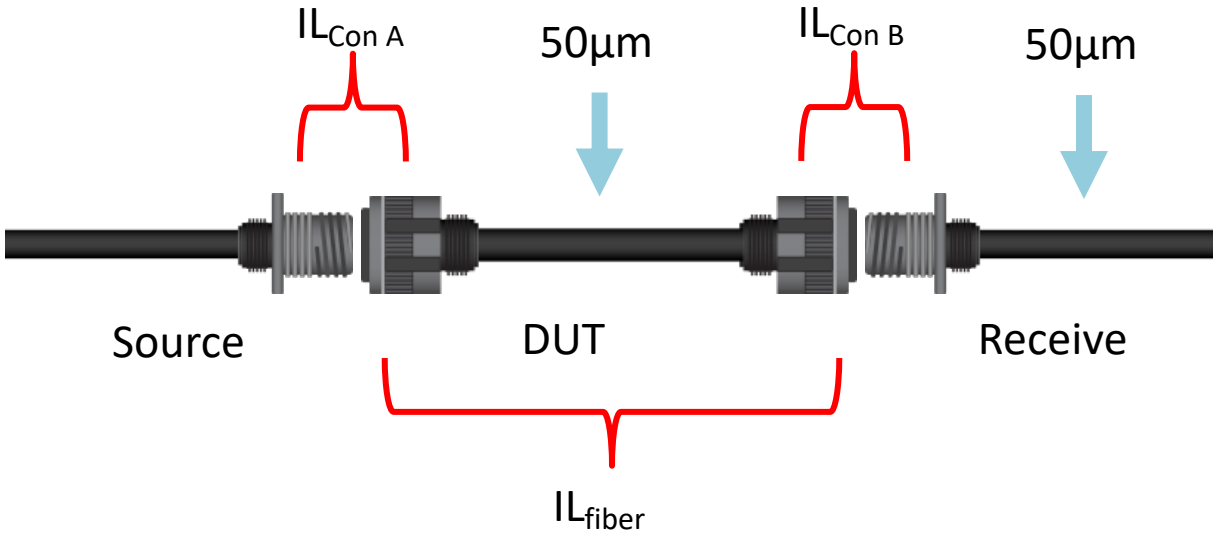
Testing Link Loss of an Assembly

- When testing link loss the entire loss of the assembly is to be measured.
  - This includes:
    - The front connection
    - The fiber contribution
    - The rear connection



  - Unlike with the connector loss setup, a receive cable of the same fiber type should be used to capture the rear connectors insertion loss.
    - If the DUT is 50µm then the receive cable should be constructed with the same type of 50µm fiber.

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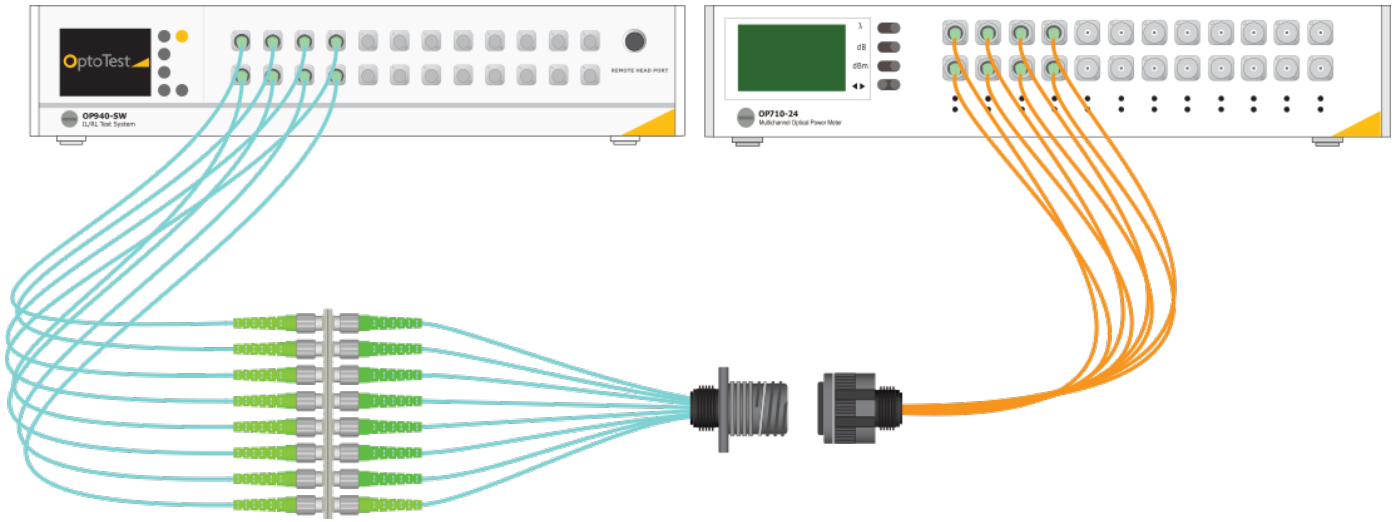
Example Link Loss Test

- For a total assembly loss test the source side setup stays the same.
- The reference can be performed with a bucket cable to capture the power at the reference connector.
  - For a link loss test try to not use a receive reference cable of the same fiber type as the DUT.
  - Creates additional losses during the reference setup and leads to loss measurements that are too low.
- Return loss is still reference to the end of the reference connector which will be connected to the front end of the DUT.

Reference Setup



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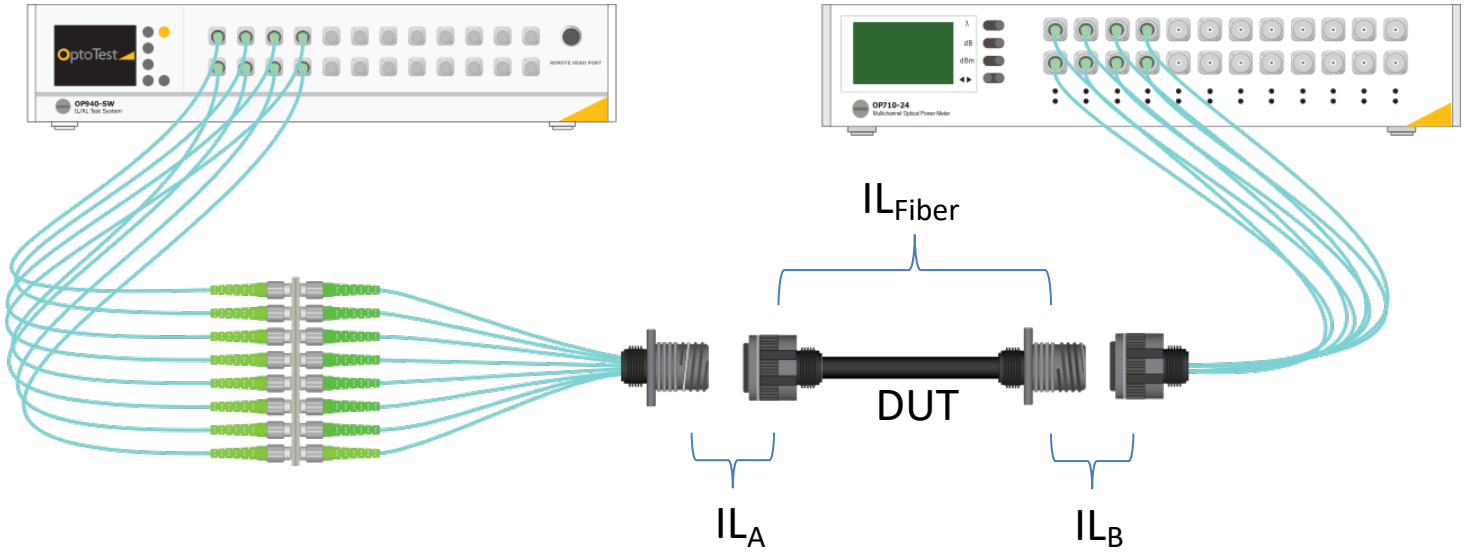
Example Link Loss Test

- For a total assembly loss test the source side setup stays the same.
- To measure a DUT, it is possible to replace the receive bucket cable with a receive cable of like fiber type as the DUT.
  - Yields loss across connection A, fiber, and connection B.
  - This replacement is cumbersome though.

Measurement Setup



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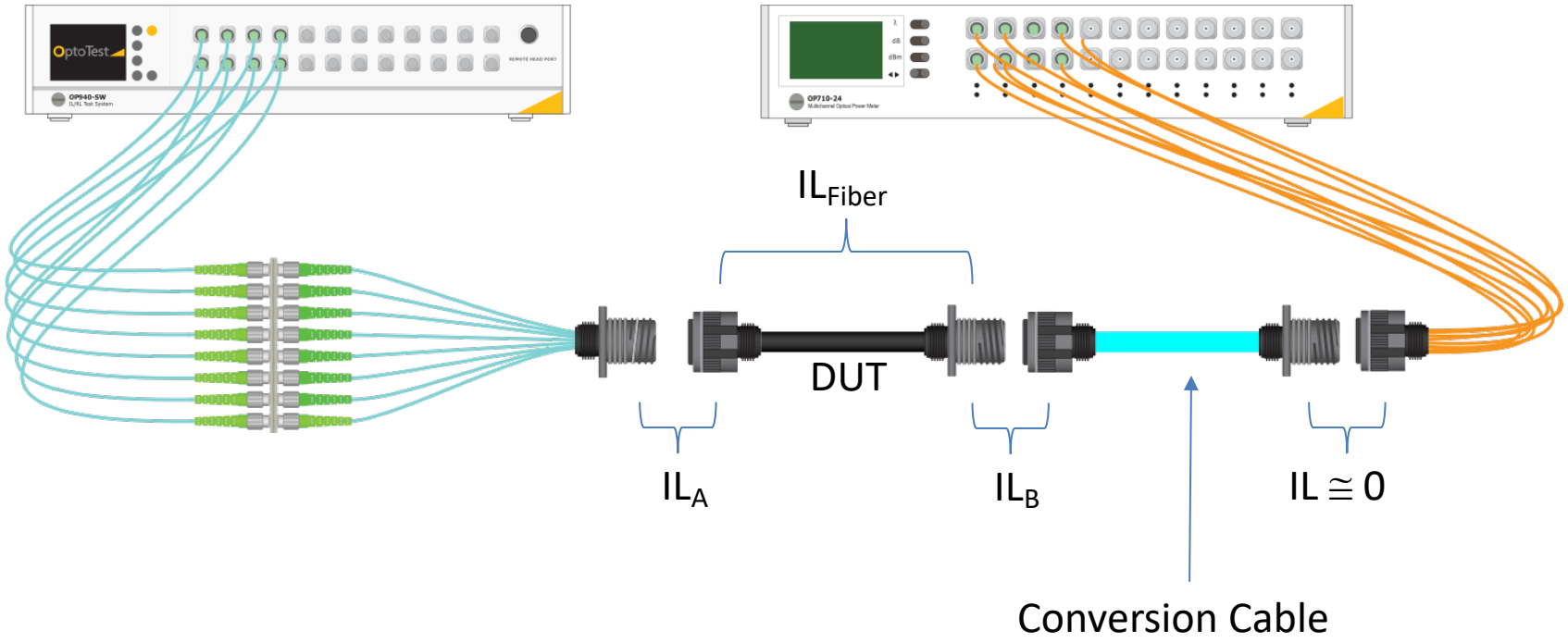
Example Link Loss Test

- Use “conversion” cables to help mate between the DUT and the large core receive cable.
- This cable should be constructed of the same fiber as the DUT.
  - This will measure the insertion loss at the corresponding mating at the back end of the DUT.

Measurement Setup



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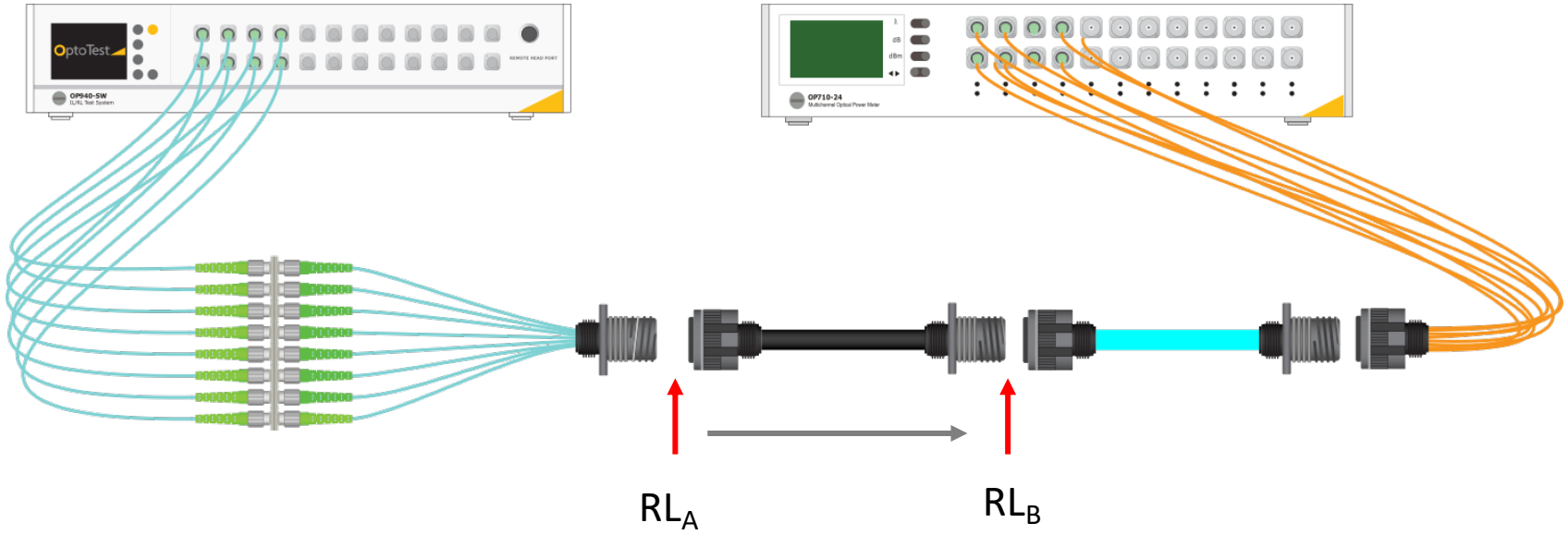
Example Link Loss Test

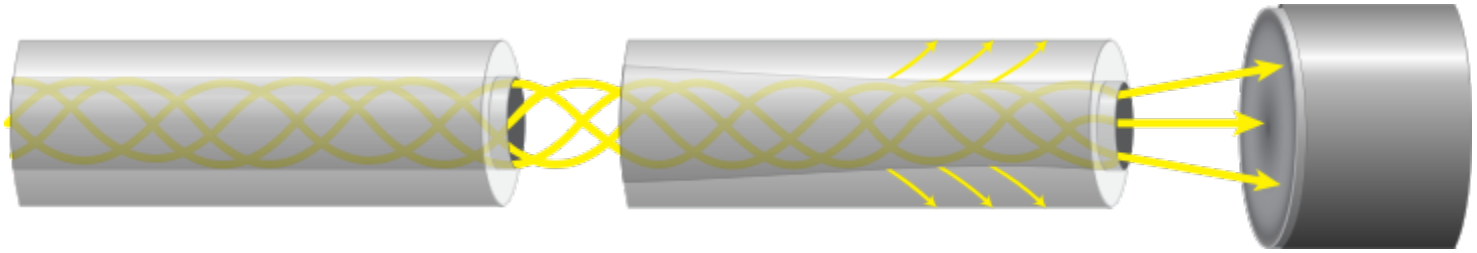
- Measuring return loss on the front end is straightforward.
  - The position was found during the referencing process.
- To get the second reflection, at the back side of the DUT, the system must scan out and find the second reflection position while the DUT is connected.

Measurement Setup



Considerations When Testing Bend Insensitive Multimode Fiber

- For receive cords, care should be taken when choosing a length of receive cable
  - Too short and losses will be measured too low.
  - BIMMF holds on to lossy modes that standard MMF would have lost dissipated
  - For short lengths this is effectively a bucket cable.
  - Might need to discuss with fiber manufacturer, but usually 10m of fiber is sufficient to remove the lossy modes.



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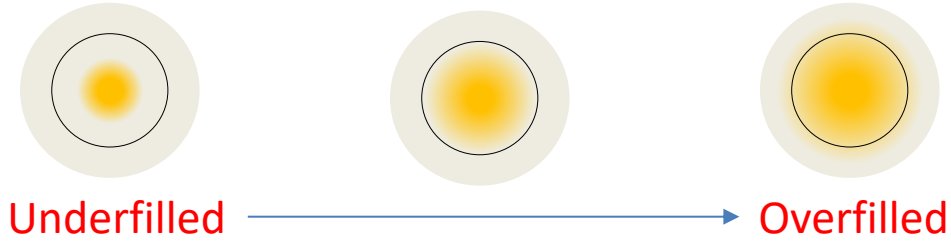
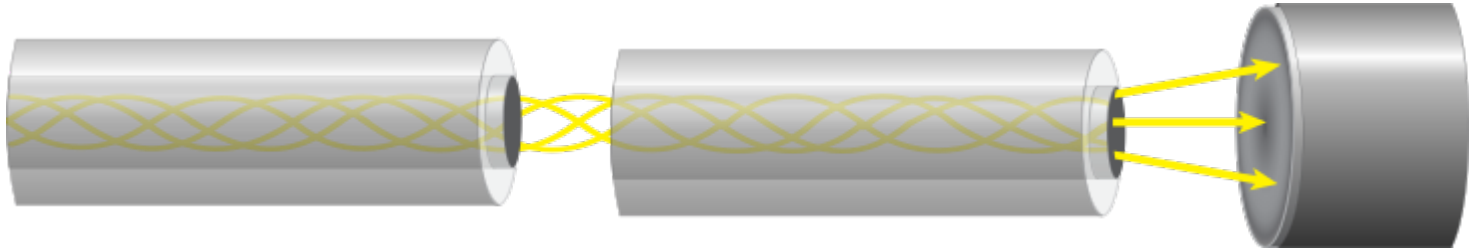
Launch Conditions for Multimode Assemblies

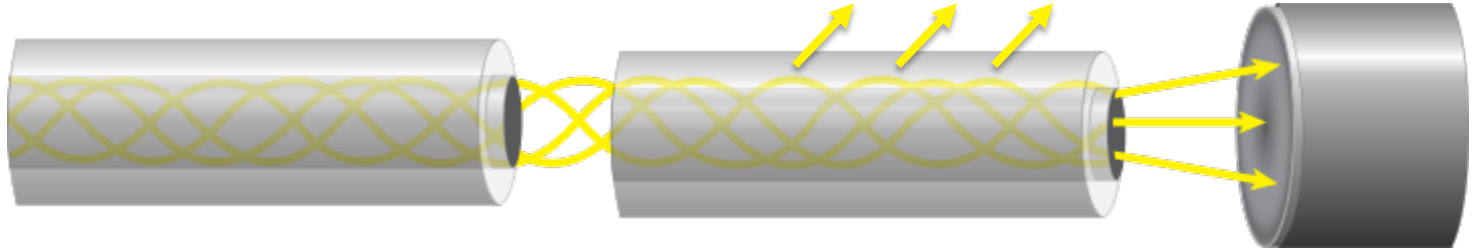
- Multimode insertion loss is highly dependent on the launch condition of the reference cord.
- Military standards call out many different launches.
  - 70/70 (70% spot size, 70% NA).
  - AS50, AS62, AS100.
  - Overfilled (loosely defined)



- Underfilled -> lower measured insertion loss -> less affected by core offsets.



- Encircled Flux -> Slightly underfilled launch -> more affected by core offsets.



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Summary for Insertion Loss and Return Loss measurements

- Always keep the work station organized
  - Rack mount test equipment to free up space and go vertical.
- For connector loss tests
  - Use bucket cables to measure power out of launch cord
  - User large core golden (zero-loss) cables when launch and receive cords can’t mate to each other.
  - When testing with a simplex setup and a simplex (non-test probe) cable organize the fan in and fanout cords to reduce testing time
  - When using a test probe, use a test probe that properly mimics a real connection.

- For link loss tests
  - Use a bucket cable to still capture all the power from the launch cable.
  - Use a receive cable of the same fiber type as the DUT to connect between the DUT and the large core bucket cable.

- For multimode cabling tests
  - Always remain conscious of the launch conditions.

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Shock and Transient Monitoring of Ruggedized Connections

- Ruggedized connectors and assemblies are intended to be used in harsh environments.
  - Exposed to constant vibrations and quick shocks.
- Assemblies should be qualified to ensure that connectivity is sustained through the vibrations and shocks.
- For these tests, a high-speed detector system is necessary.
- The OP740 has:
  - Wide dynamic range (+10dBm to -70dBm).
  - IEC 61300-3-28 Transient Loss monitoring.
    - 250µs Sampling.
  - MIL STD-1678-2A.
    - 25us Sampling.
  - Virtually unlimited buffering.

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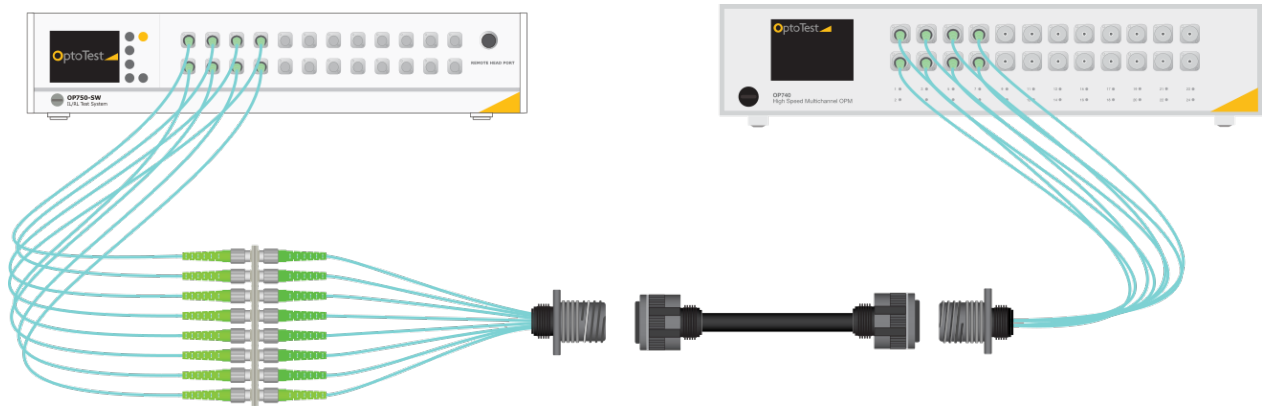
Shock and Transient Monitoring of Ruggedized Connections

- To monitor transients a continuous optical source is needed.
  - For SM a laser source is suggested.
  - For MM an LED source is suggested.
    - With appropriate launch conditions
  - An optical switch cannot be used.

- In this case the DUT is inserted during the reference process and a zero level is taken with the DUT connected.
  - All transient measurements will be taken relative to this zero level.



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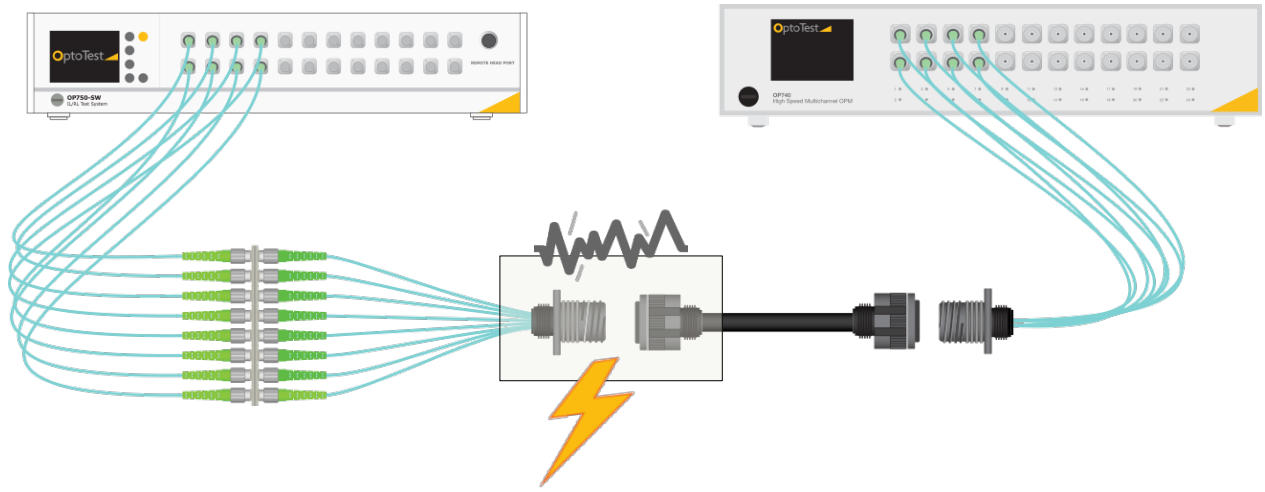
Shock and Transient Monitoring of Ruggedized Connections

- Many times, it is only a connection that is being monitored and affected.
- Once the system is referenced the high-speed power logging can start.
  - For vibration testing the vibration apparatus can start.
    - Typically, vibration testing is done for multiple axes.
    - Requires long logging (deep buffer)
    - Tests typically last for 15 minutes to 1 hour.
  - For shock testing the shock can be induced on the connection.
    - A shock can be induced on multiple axes as well.
- After the mechanical stress has stopped, the system should still be allowed to relax.
  - This allows for one to monitor residual loss, which is that signal fluctuation as the system returns to steady state.
  - The optical monitoring should continue while the system reaches steady state.



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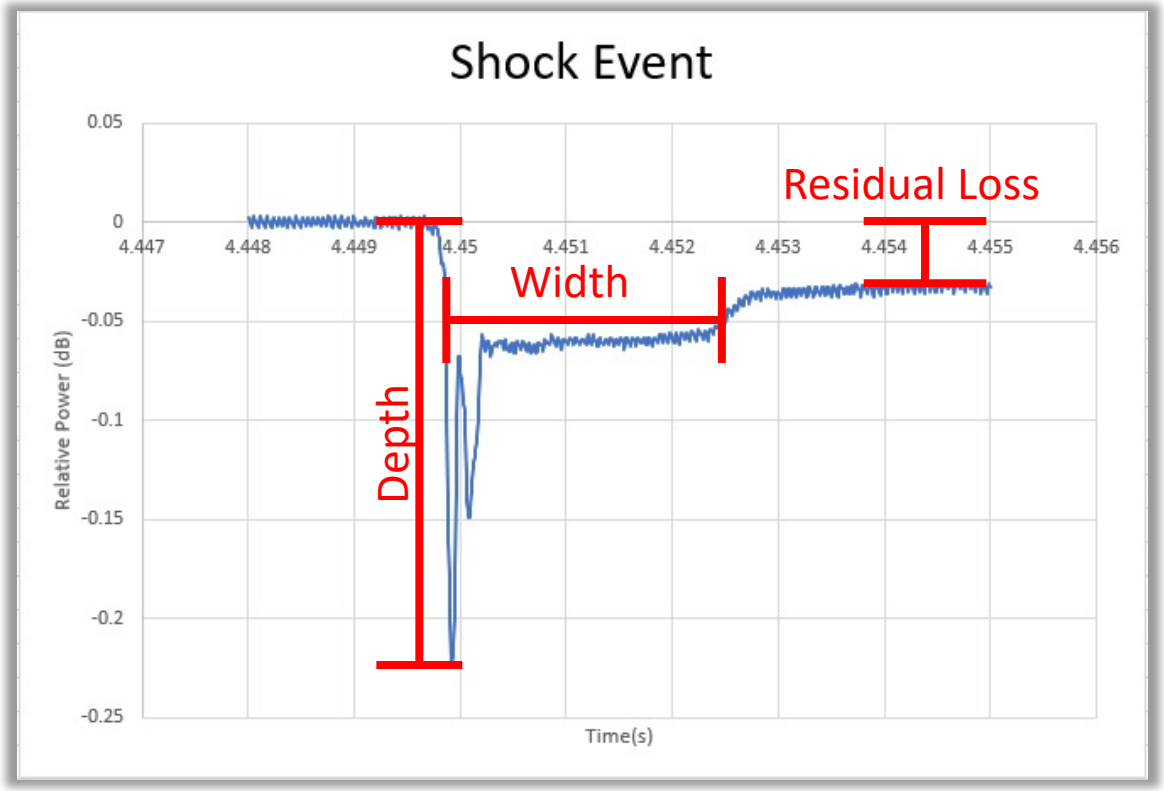
Shock and Transient Monitoring of Ruggedized Connections

- Analyzing Data
  - Typically, one looks for events of data where optical power either increase or decreases by a certain level.
  - There are 3 characteristics
    - The depth is the largest level the signal changes.
    - Width is the length of time the signal drops below the defined threshold.
      - (0.5dB to 3.0dB)
    - Residual loss is the steady state loss of the connection.
      - Once the transient has occurred, where does the signal level out at?
      - This can sometimes be a positive value.



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Transient Loss Summary

- Use continuous sources and not a switched source.
- System needs to be able to log long buffers
  - Vibration typically requires 15 minutes to 1 hour for testing
  - Allows for monitoring residual loss long after the event has occurred.
- Events have a depth, width and a residual loss.

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Q&A | Resources

Visit the link below for more resources on the topic covered in this webinar:

www.optotest.com/webinar-ruggedized-fiber-assemblies/

Chris Heisler
Chief Technical Officer

OptoTest

Thank you for attending!
Questions?

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