
The effects of dirty connectors on laser based MMF links

IEEE 802.3z Plenary Meeting
March, 1997
Irvine, CA

Mark Nowell & David Cunningham
Hewlett-Packard Laboratories,
Filton Road
Bristol BS12 6QZ
UK.
mn@hplb.hpl.hp.com

Outline

- Purpose of work
- Dirty connectors
 - 'real' dirt
 - 'artificial' dirt
- Splice defects
- Conclusions

Purpose of this work

Concern has been raised about what the effects of dirty connectors and/or splices with defects have on system performance

- it is *perceived* that this *may* be a problem for sources which underfill the fiber

Need to try to understand

- is this a real (likely) problem?
- if it is a real problem - how much of a problem is it?

Specific issues addressed

In the 1/97 interim meeting the following specific issues were raised about dirty connectors:

- systems which use a low mode fill are highly sensitive to dirty connectors while high mode fill is insensitive
- measurements of loss for systems using low mode fill are difficult and require specialized equipment

This contribution will show:

- in a 'real world' test, dirt was seen to have little effect on systems regardless of mode-fill or wavelength
- when dirt did cause a penalty it was quite small (the short wavelength, high mode fill, system generally experienced higher penalties).
- If dirt is present (which it shouldn't be) it is easily detected using an EIA/TIA measurement standard which requires no more than a power meter

Dirty Connector Experiments

Three experiments were done:

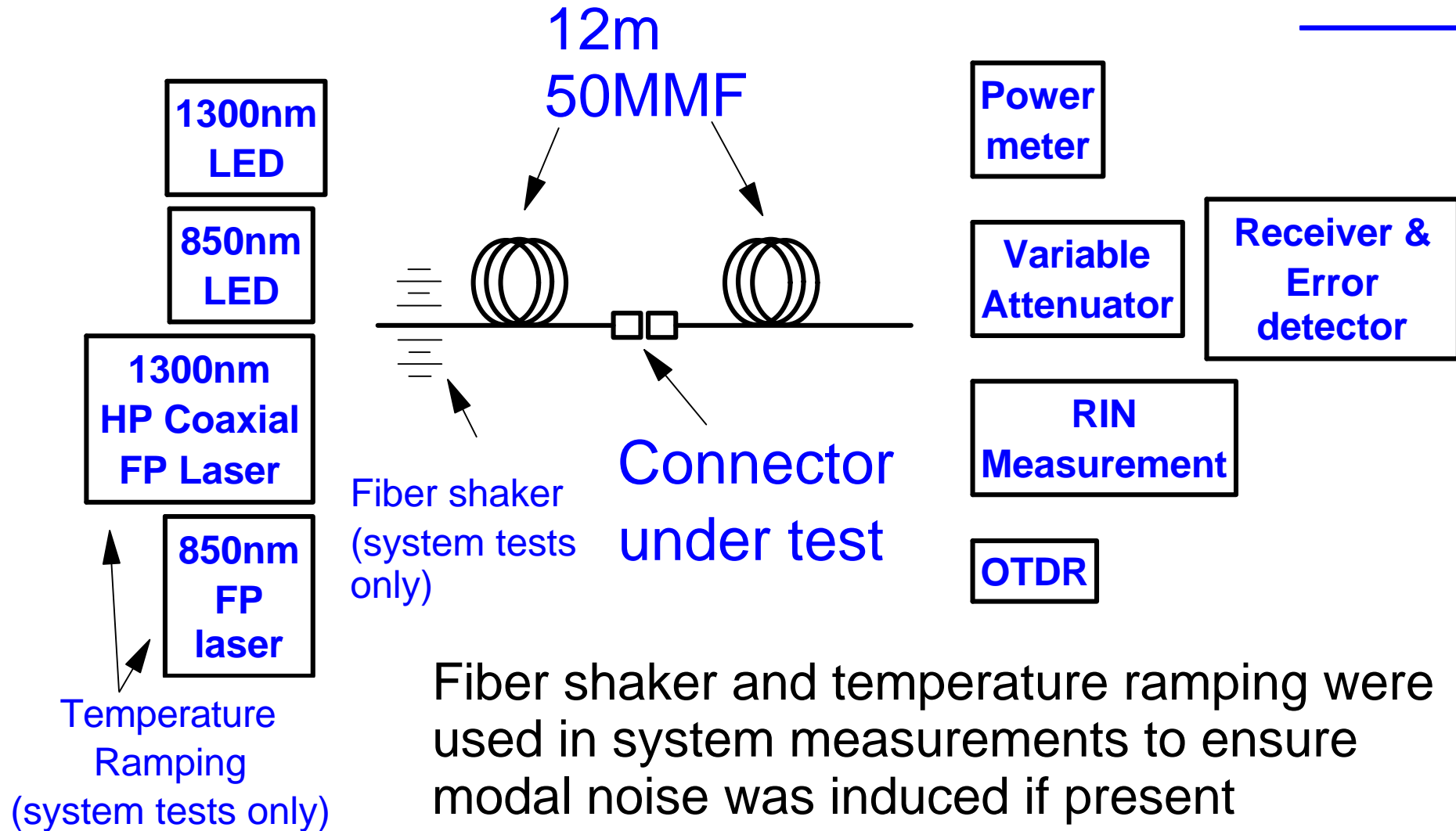
- 1) Collect some real dirt, dip connectors in dirt before mating and then characterise the connectors and their effect on system performance
- 2) Put some artificial particulates of known dimensions into connector and characterise connector and its effect on system performance
- 3) Build a free space 'connector' where controlled 'dirt' can be placed introduced and moved around allowing a more systematic study

Real dirt

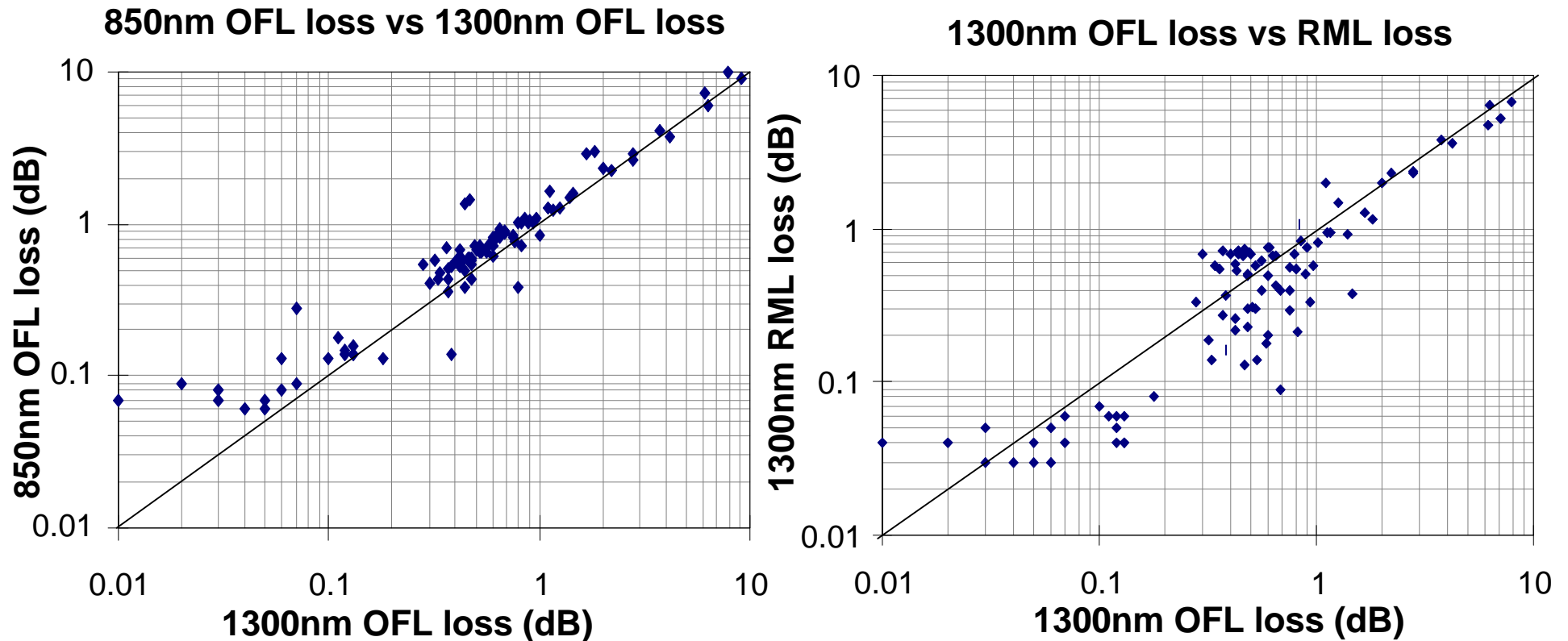
- Dirt was collected from around our lab/office
- >100 dirty connectors were mated and characterised for
 - overfilled loss at 850nm using LED
 - overfilled loss at 1300nm using LED
 - underfilled loss at 1300nm using laser
 - reflections *
 - effect on laser RIN *
 - system penalty *

* not measured on every connector

Experimental set up

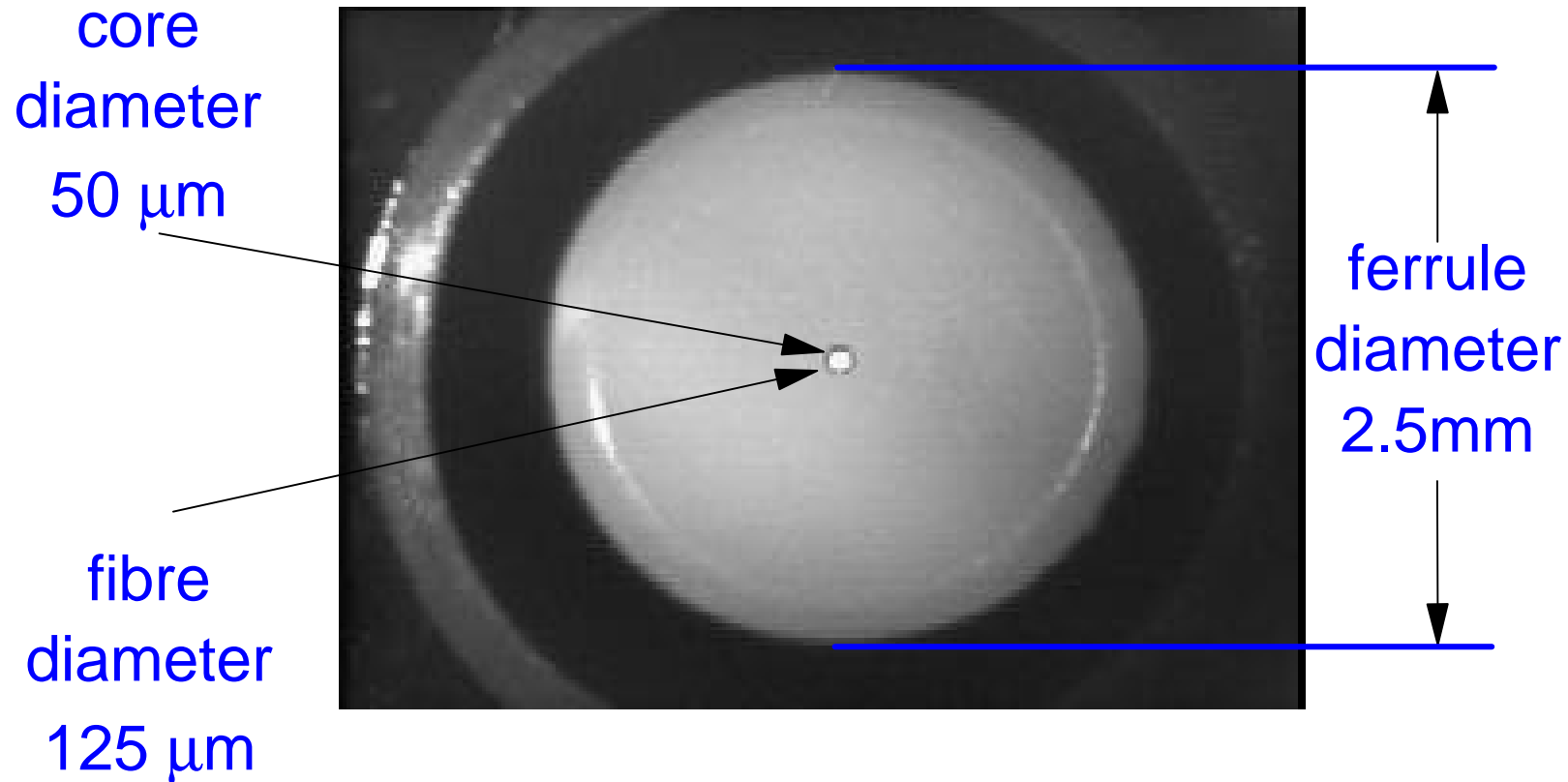


Loss results

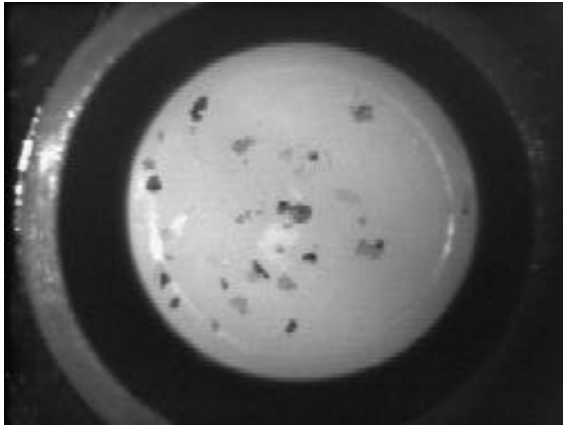


Before mating, each connector was checked to be dirty. Often dipping the connector in the dirt did not result in any dirt staying on the connector. A smear of finger grease was found to solve this problem. Therefore even this experiment is an extreme sample of the values that can be expected.

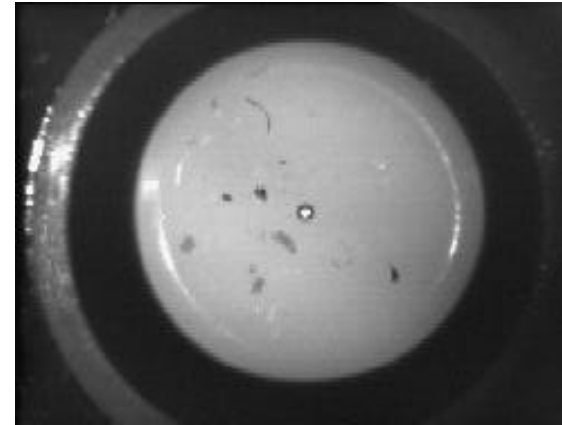
Optical connector



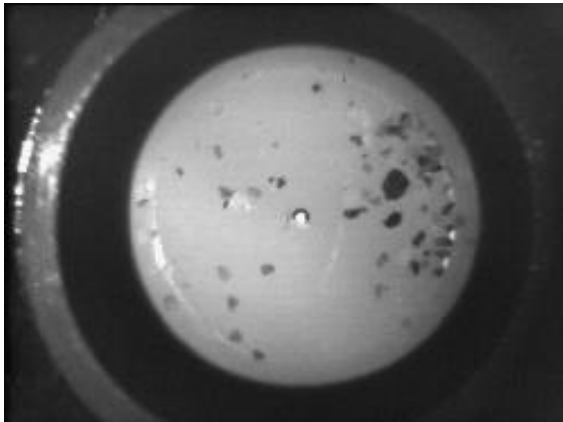
Sample of dirty connectors



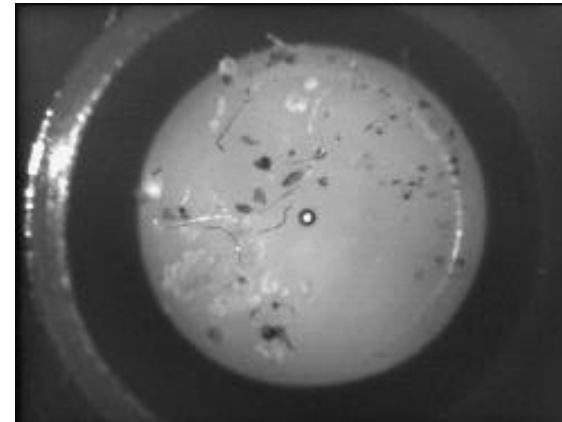
Loss		
1300nm OFL	1300nm RML	850nm OFL
17.30dB	14.34dB	19.45dB



Loss		
1300nm OFL	1300nm RML	850nm OFL
0.70dB	0.25dB	0.46dB

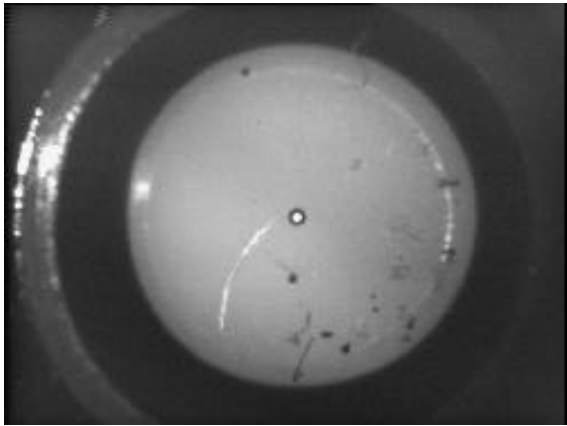


Loss		
1300nm OFL	1300nm RML	850nm OFL
15.86dB	18.46dB	14.75dB

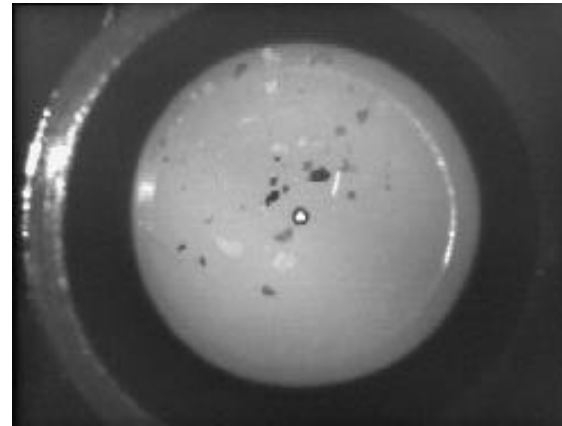


Loss		
1300nm OFL	1300nm RML	850nm OFL
0.48dB	0.47dB	0.53dB

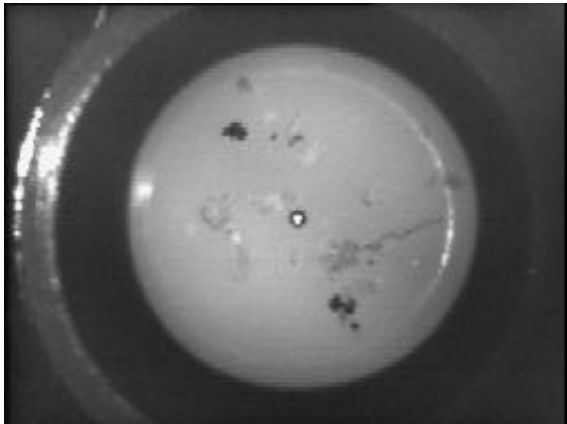
Sample of dirty connectors: II



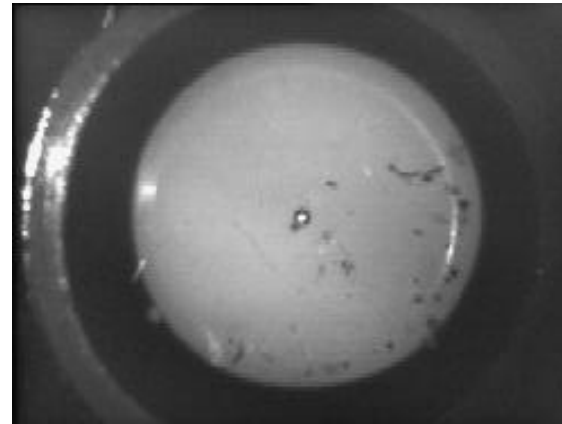
Loss		
1300nm OFL	1300nm RML	850nm OFL
0.63dB	0.48dB	0.75dB



Loss		
1300nm OFL	1300nm RML	850nm OFL
0.95dB	0.81dB	0.95dB

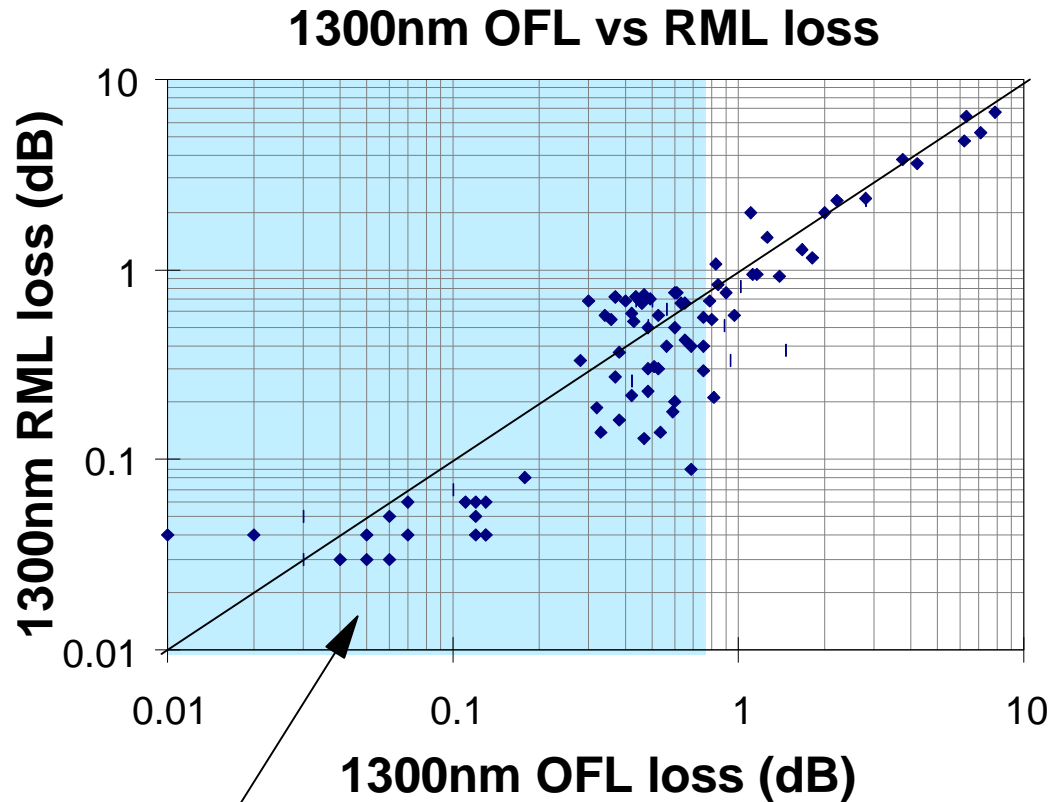


Loss		
1300nm OFL	1300nm RML	850nm OFL
0.59dB	0.23dB	0.71dB



Loss		
1300nm OFL	1300nm RML	850nm OFL
4.01dB	3.43dB	3.80dB

RML vs. OFL loss



Loss measured with an RML source or OFL source were similar.

$$m\left(\frac{RML\ loss}{OFL\ loss}\right) = 0.93$$

shaded area would be considered in specification if measured with an LED

Effect of dirt in the connector on system performance

Dirt in a connector can affect the system performance in many ways:

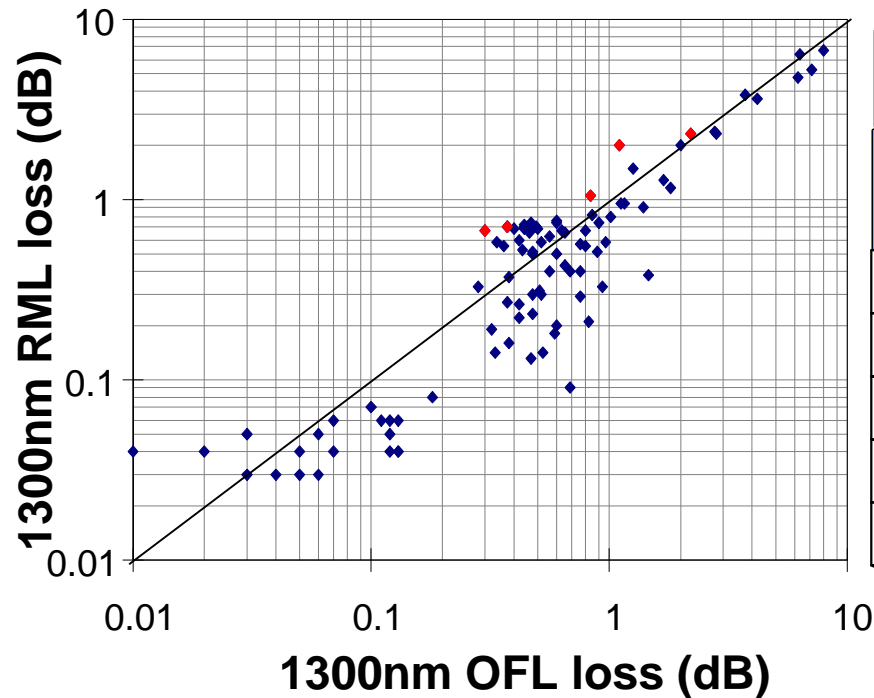
- attenuation
- reflections
- modal noise
- RIN
- scattering

$$\propto \frac{1}{l^4}$$

All of these can seriously affect system performance.

Dirt can also damage connectors permanently.

Power penalties



Loss (dB)			Penalty (dB)	
1300nm OFL	1300nm RML	850nm OFL	850nm	1300nm
0.37	0.71	0.43	0.6	0.1
0.3	0.68	0.41	0.1	0.1
2.20	2.30	2.27	0.4	0.1
0.83	1.06	0.73	-	0.1
1.11	2.0	1.26	0.5	0.25

measured points shown in red

- 850nm source for system measurements was FP laser which overfilled the fiber. 1300nm source was HP coaxial laser which underfilled the fiber
- Power penalties were measured using the modal noise procedure which includes temperature ramping and fiber shaking to ensure modal noise was induced if present.
- Reference curves were measured with clean connectors.

Air gaps due to dirt

Dirt in the connectors can result in the fiber endfaces not reaching physical contact

- return losses of $> 14\text{dB}$ were measured at 850nm and 1300nm (higher reflection than air/glass interface)
- RIN was seen to rise in lasers by $>8\text{dB}$

Therefore dirt in connectors could force the physical plant out of specification

- may result in the laser RIN being out of specification due to the reflections.

What to do if you have dirty connectors

To clean connectors ideally you would use a lint-free cloth and some cleaning solution (isopropyl alcohol)

BUT

you could just wipe it with your finger (not a recommendation!)

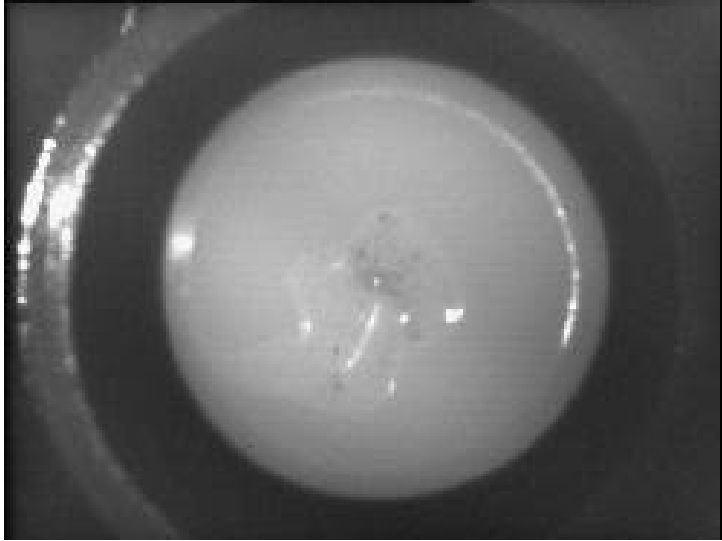
Loss with dirt present (dB)			Loss after wipe with finger (dB)		
1300nm OFL	1300nm RML	850nm OFL	1300nm OFL	1300nm RML	850nm OFL
6.3	6.4	6.1	0.05	0.04	0.07
15.47	10.9	16.0	0.03	0.05	0.07
17.87	17.77	19.48	0.06	0.05	0.08
2.0	2.0	2.3	0.07	0.06	0.09
0.89	0.51	1.02	0.42	0.59	0.67
12.2	11.97	15.76	0.48	0.50	0.54
15.84	18.46	14.75	0.14	0.06	0.06

Connector damage

- Connectors can become permanently damaged by dirt. Once damaged they have to be replaced.
- During this experiment, the patchcords had to be replaced 4 times due to damage

This would be a major problem in an installation which is why keeping connectors clean is standard practice.

Artificial dirt

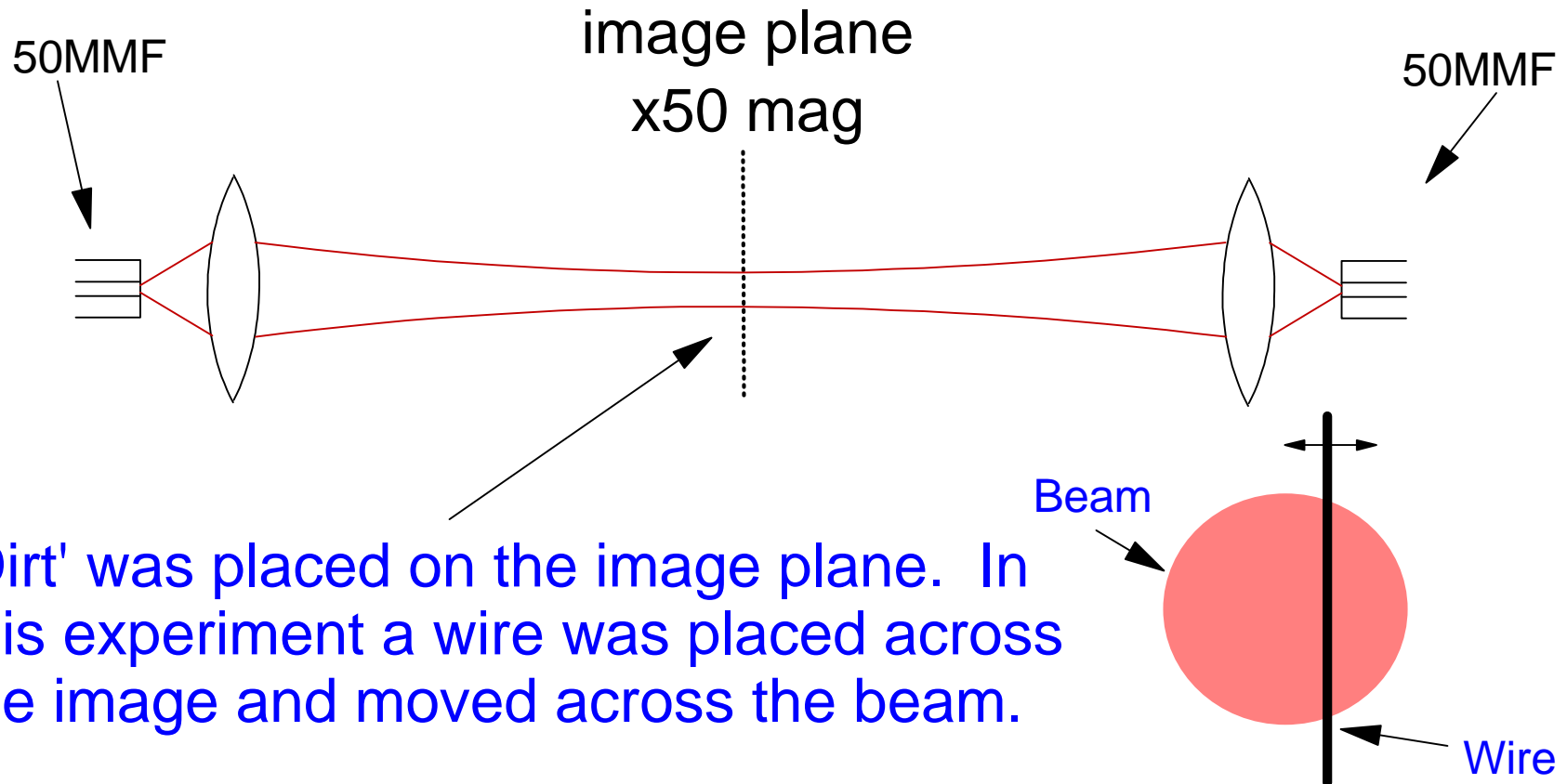


To increase the chance of seeing a small speck of dirt in the beam, fused alumina particulates (particle mean size $5\mu\text{m}$) were mixed with index matching gel and smeared on the connector endface before mating.

Loss (dB)			Penalty (dB)	
1300nm OFL	1300nm RML	850nm OFL	850nm	1300nm
0.81	1.31	0.67	1.5	1.0

Lab bench connector setup

A free space 'connector' was built to allow precise measurements of penalties with controllable dirt



'Dirt' was placed on the image plane. In this experiment a wire was placed across the image and moved across the beam.

Lab bench connector results

- Connector had 2.8dB insertion loss which was determined to be due to reflections at interfaces and non mode selective
- 'dirt' was a 250 μ m diameter wire which was moved through the beam at image plane (equivalent to 5 μ m line in real connector)
- penalty was measured at different positions of wire using HP coaxial 1300nm FP laser

Max Loss (dB)		Max Penalty (dB)
1300nm OFL	1300nm RML	1300nm
1.2	3.0	2.0

As with all other system measurements, fiber shaking and temperature ramping were used to induced modal noise if present.

Only a penalty.
Not a floor.

Measurement of cable plant (dirty connectors)

EIA/TIA OFSTP-14A has just closed ballot

- addresses measuring the cable plant loss specifically for laser based systems
- recommends using source with class of launch similar to that of the system transmitter
- implies that the network can be diagnosed for lossy connectors using only the network transmitter and a power meter

Fusion Splicing

To obtain a good fusion splice you must have:

- perpendicular cleave of the fiber ends
- clean ends before fusing

Modern cleavers

- provide very consistent perpendicular cleaves
- are automated (manual devices are less consistent)
- come integrated onto many modern fusion splicers

Fusion Splicing

Modern fusion splicers

- use short burst of arc to plasma clean the fiber endfaces - very efficient form of cleaning.
- automated and programmable - can be optimised for SMF or MMF.
- allow re-fusing of splice to improve and splices before splice protection is added.
- primarily designed for SMF users
 - in SMF the kind of defects we are worried about would severely affect the system therefore the possibility of their occurrence is designed out.

Splices defects

Over 50 fusion splices were made to try to observe the types of defects we are worried about.

I was only able to make bad splices if I:

- turned off pre-fusion cleaning and either
 - deliberately introduced dirt
 - made a bad manual cleave (i.e. with penknife)

Results

- was unable to make a splice which was in spec for loss and which caused a penalty of > 0.25 dB
- if bubbles were present re-fusing always reduced their loss
 - a bubble which induced 14dB loss was reduced to 0.8 dB loss through re-fusing (system penalty was then measured to be 0.2dB)

Conclusion

It is VERY difficult to make a bad splice which is within spec and will cause system degradation using common installation practices

Summary

- >100 dirty connectors made and characterised
- no significant penalties measured
- dirt can result in penalties due to:
 - attenuation
 - reflections
 - modal noise
 - RIN
 - scattering
- if dirt is present and causing problems it can easily be solved (as long as it hasn't caused physical damage).

Summary

It is conceivable that there may exist a pathological piece of dirt which can cause various system penalties

BUT

- ▶ it is not specific to any wavelength or launch
- ▶ it has a very low probability of occurring

Conclusion

Dirty connectors have a very low probability of being both undetected and capable of causing significant system penalties.

This is not a real world issue.