Study on the Correlation Between Contamination and Signal Degradation in Multimode Optical Connectors

For iNEMI

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Outline

- Background
- Update / Status
- Analysis Using “Actual Occluded Area” and power distribution factor
- Analysis of Second Data Set
- Combined Data Set
- Proposed Failure Criteria

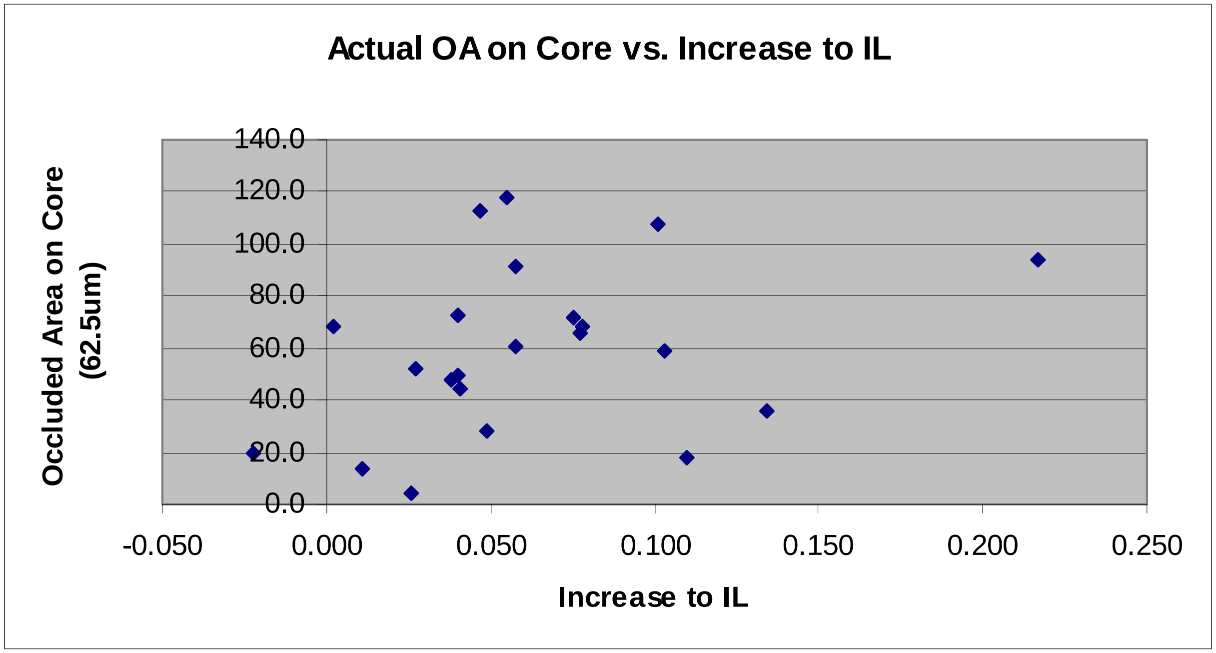
Background

- Using same design of experiment as in singlemode studies, began gathering data over 1 year ago.
- First meaningful round of data collection occurred late in 2006 and preliminary analysis was given to the team in January of 2007
- At that point, we had not found a strong or predictable relationship between levels of contamination and signal degradation
- Proposed new analysis direction that took into account what we termed “Actual Occluded Area” and also the power distribution curve observed in the fiber

Update / Status

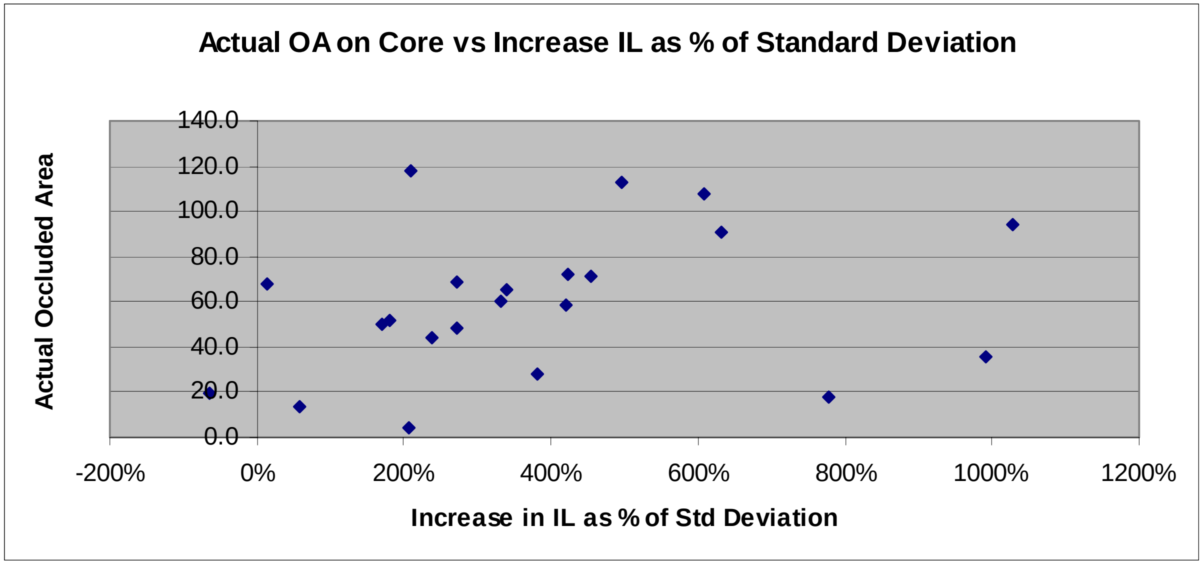
- DOE Overview
- First round ~25 mated pairs
- Analysis inconclusive, new direction proposed
- Second round ~25 mated pairs
- Applied Actual OA method and power distribution with improvement, but still poor correlation
- Modified that analysis method which produced far better correlation
- Applied new method to first data set with favorable results

Analysis Using Actual OA



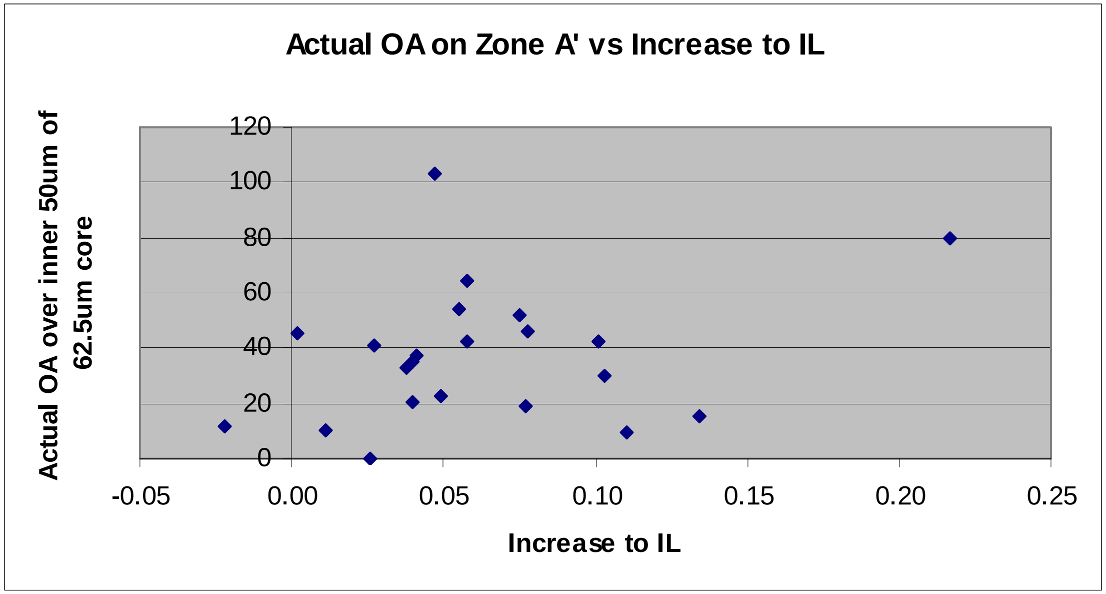
- Data from round 1 using Actual Occluded Area
- Still have poor correlation

Analysis – Actual OA and % of StdDev



- Considered plotting Actual OA against the increase in IL as a percentage of the standard deviation we saw during baseline testing. No better.

Analysis – Actual OA over 50um

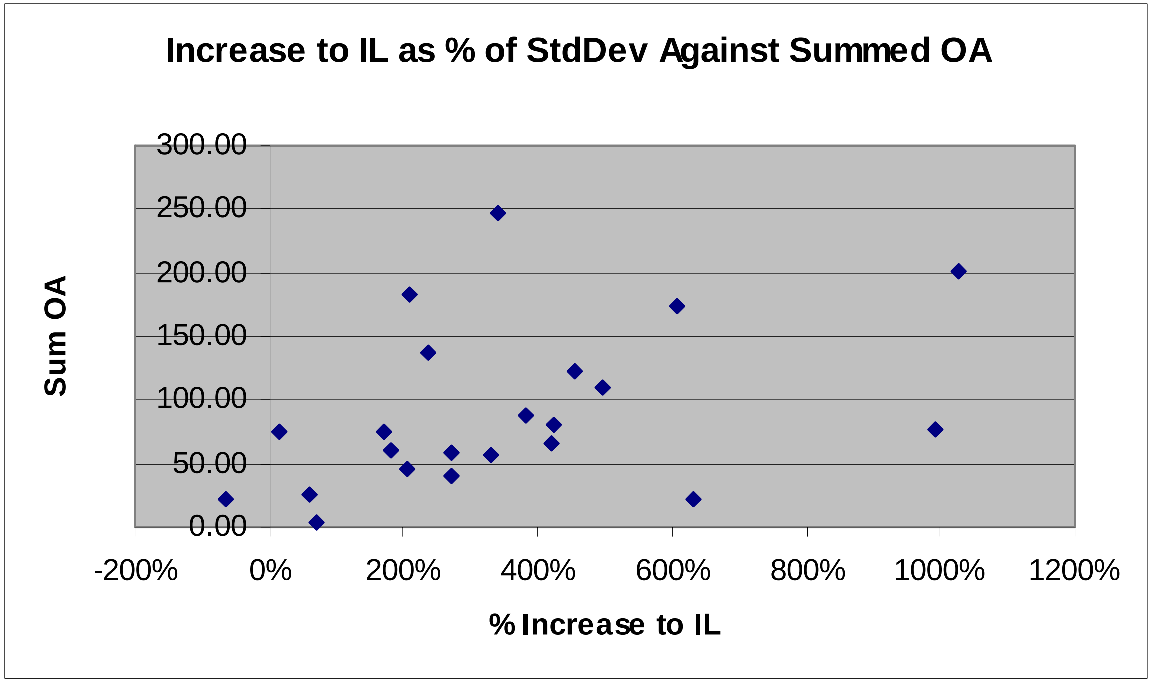


- The observed power distribution (crude method) suggested that the inner ~50.0um of a 62.5um core carries most of the power.
- Plotted Actual OA on this area against increase to IL.

Round 2 - New Data and a New Analysis Direction

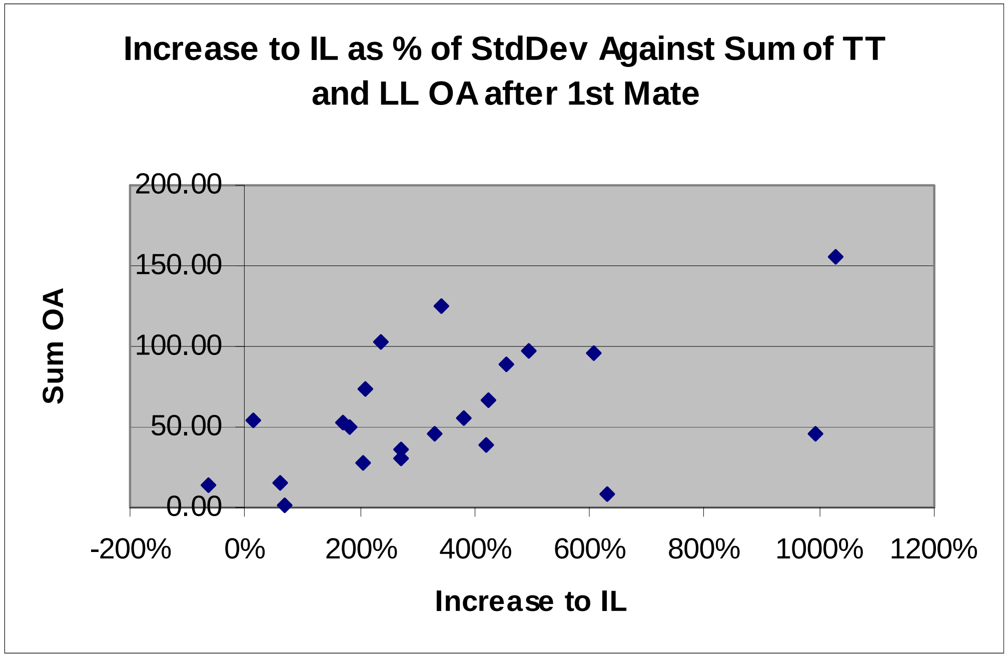
- Frustrated with poor correlation, we collected a new data set and began slicing that data in many different ways.
  - In this data set we used a wide coiled 1m instead of a straight 1m. Standard deviation was tighter in base-lining.
- To save time, I'll show only what ended up working.
- All data to this point was generated by analyzing the image of a contaminated fiber BEFORE it was mated.
- We then started looking at the images after the first mate and generating OA numbers for both the launch and test connectors. We added those together to create a "Summed Occluded Area for the Mated Pair"

Analysis – Summed OA for Pair



Better correlation here

Analysis – Summed OA over 50um

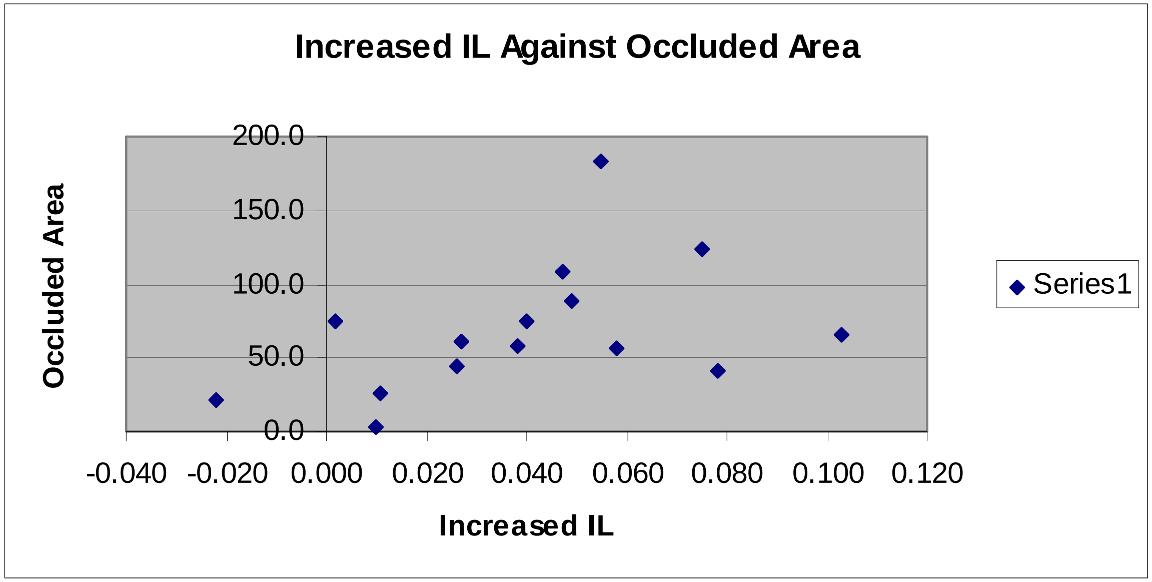


- Plotted the summed occluded area over the inner 50um of a 62.5um core against increased IL as a percentage of the standard deviation

Modifications to Analysis

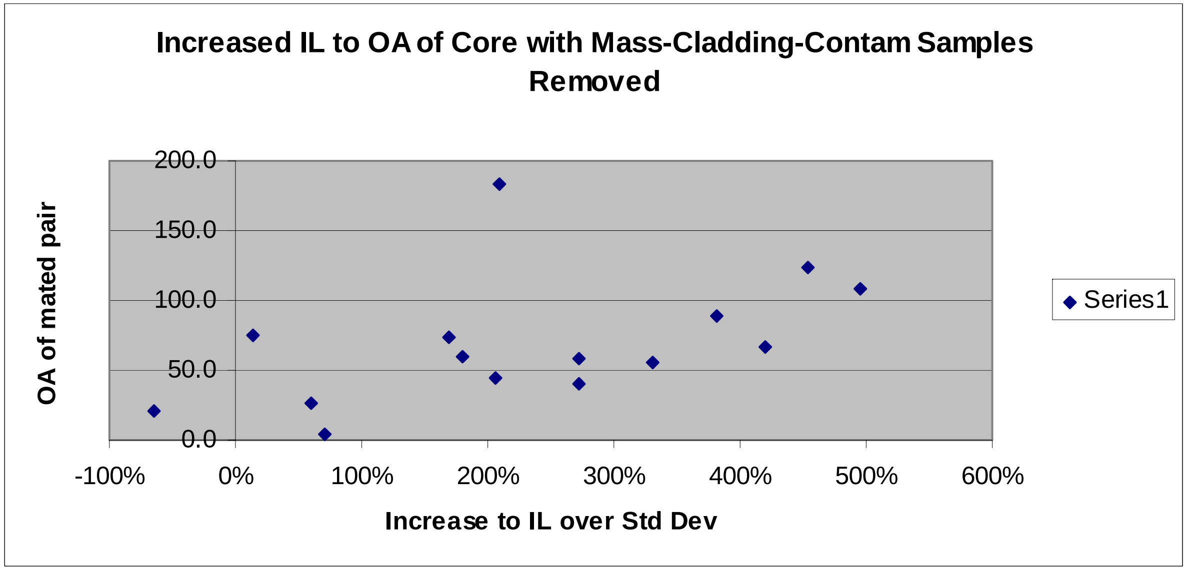
- Correlation was improving, but still had several stray data points. We looked at the stray data points by eye to see if we could deduce where the problem was.
- Led to two changes
  - Several of the images that had minor core contamination, but significant loss. Some had massive contamination on the cladding. We decided to rule these out and focus on the core zone.
  - 2 images of the images were out of focus. We ruled these out.

Analysis – IL vs OA w/o Massive Cladding Contamination Samples



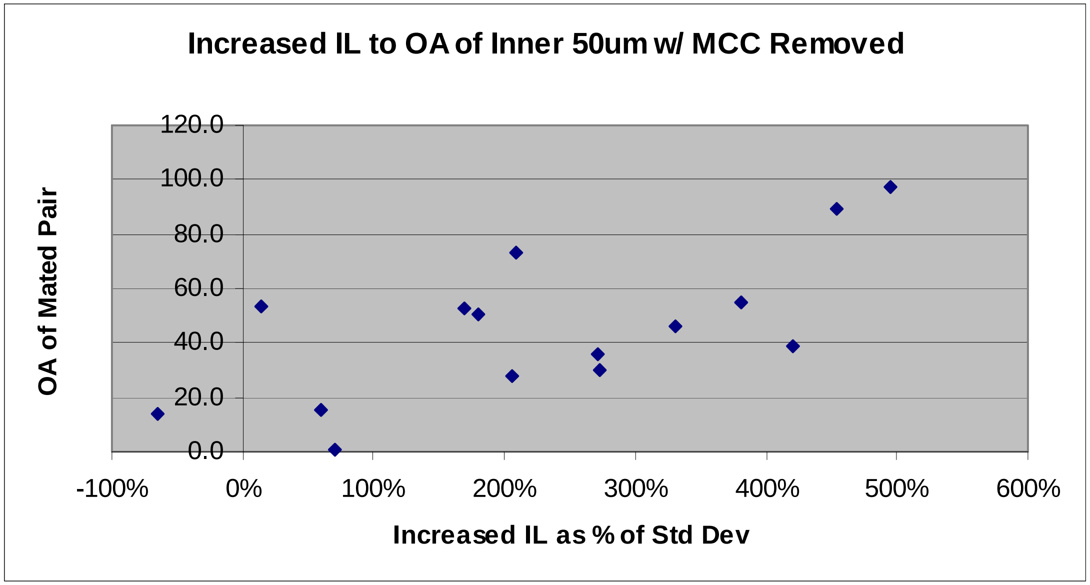
- Increased IL plotted against Occluded Area
- Samples with massive cladding contamination removed from dataset
- Correlation imrpoving

Analysis – IL as % of Std Dev. vs OA w/o Massive Cladding Contamination Samples



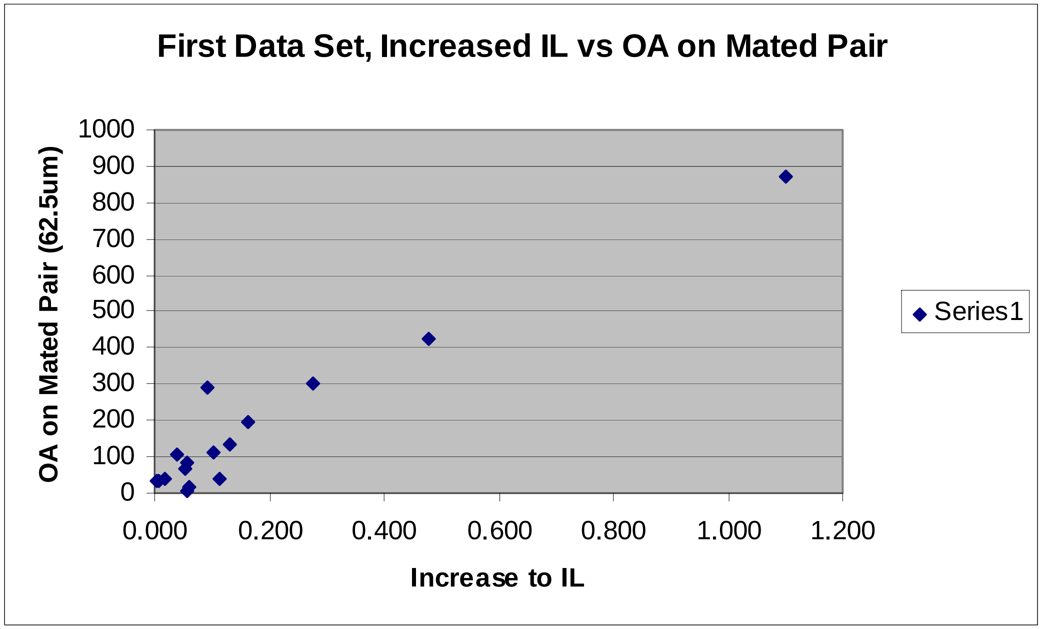
- Same as previous slide but increased IL expressed as % of Standard Deviation

Analysis – Same as above, but only over 50um region



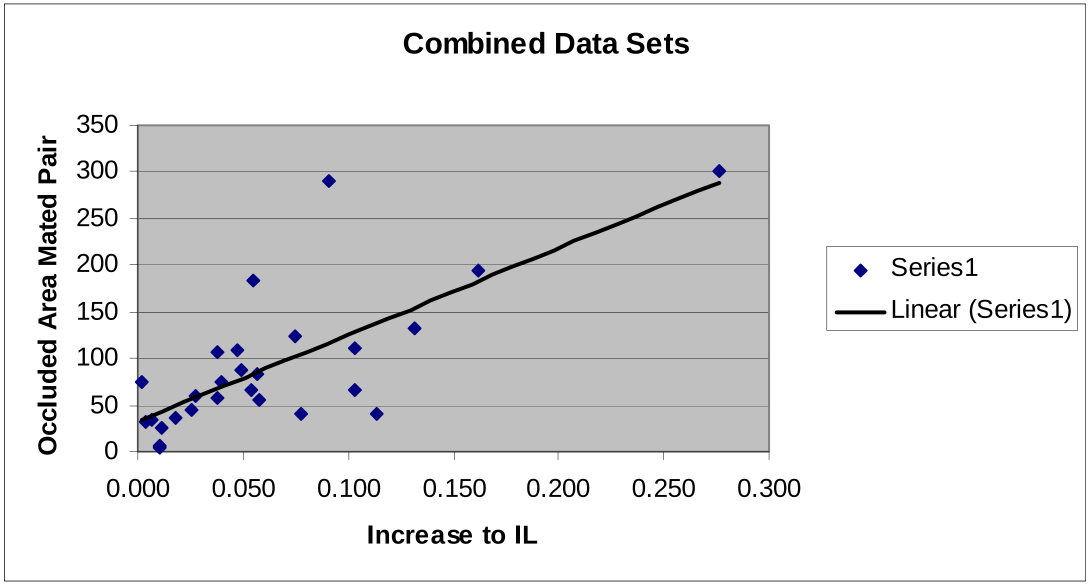
- Reduce the zone analyzed to the inner 50.0um of a 62.5um fiber. This to reflect the power distribution observed.

Analysis – Apply method to Previous Data set



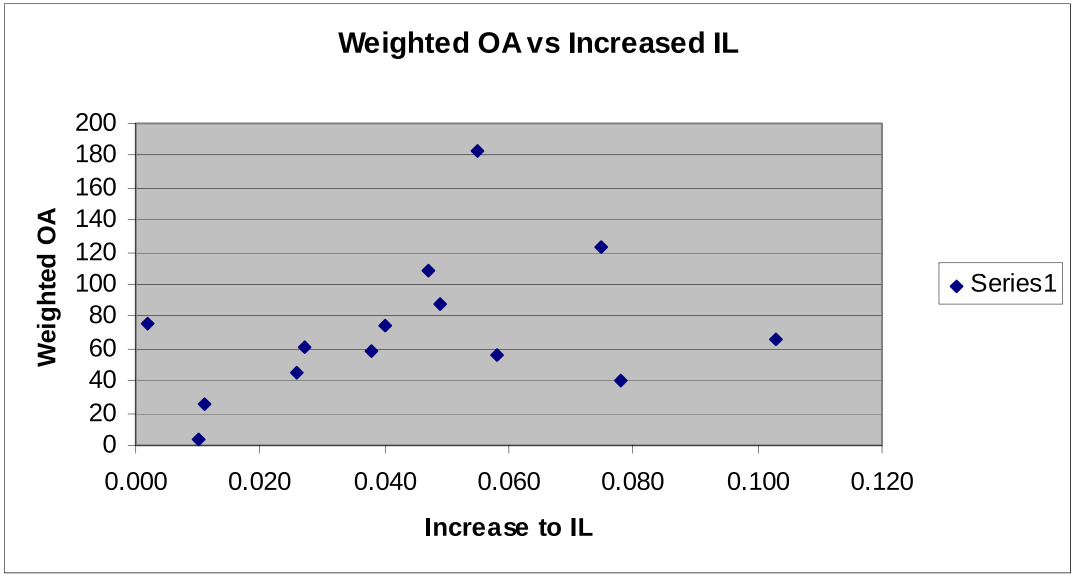
- First data set used far less dust as an average.

Analysis – Combined Data Sets



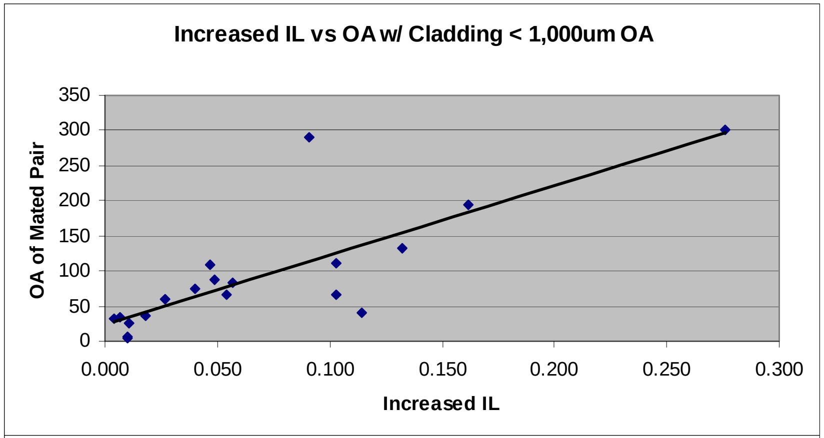
- Both data sets combined.
- Plotted increase to IL against OA on mated pair

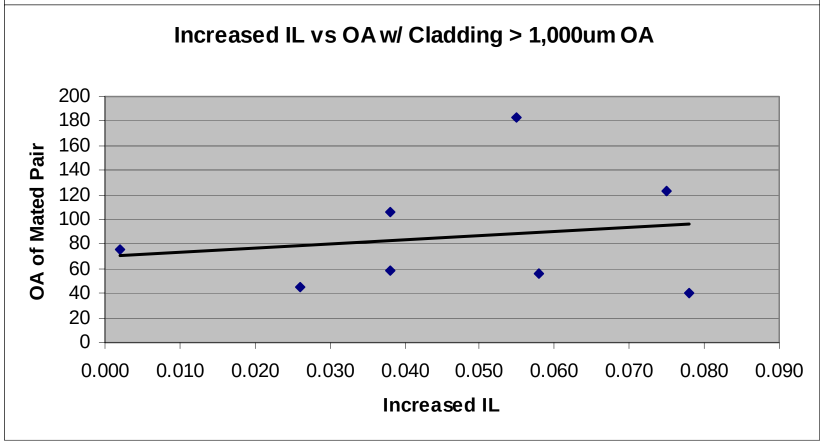
Analysis – Stray Data Points



- Looked at several stray data points, and found several where the core was occluded, but mostly at the periphery.
- Applied a 2-zone weighted approach. As we didn't have a precise curve, applied various weighting to the 30-62.5 zone (50% shown).

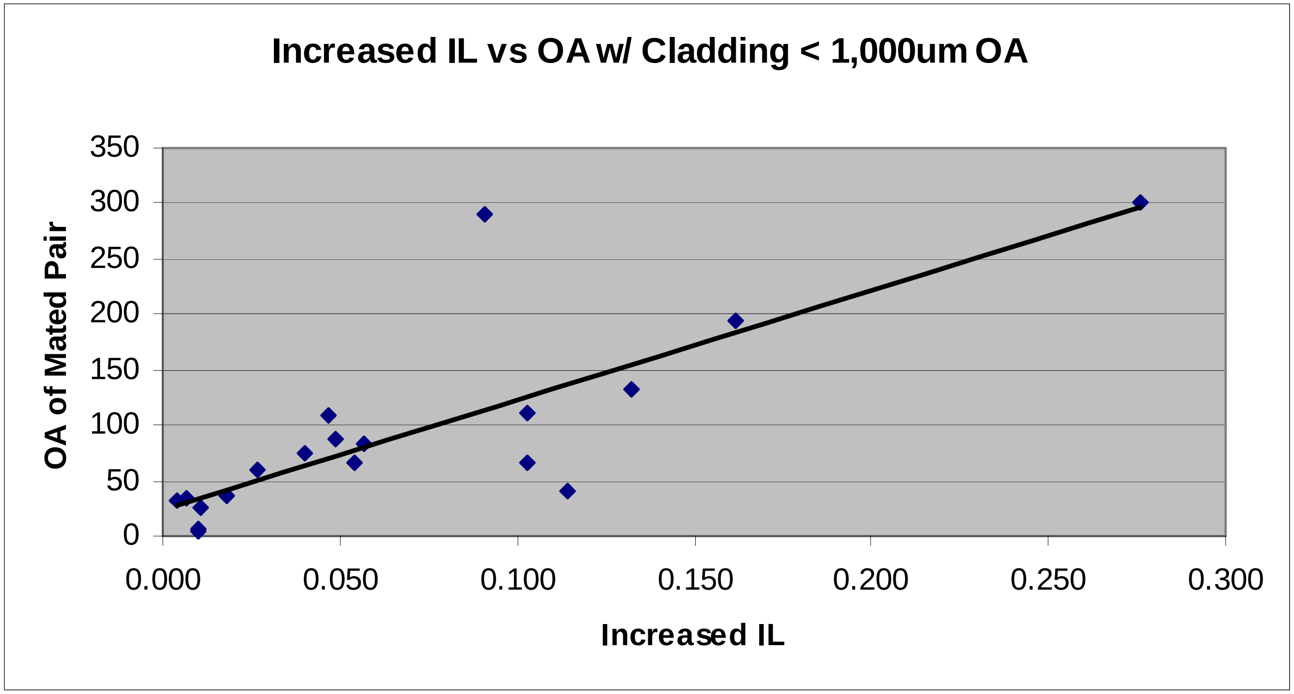
Analysis – Stray Data Points





- Revisited topic of cladding contamination and sorted data by OA in cladding.
- Found that by lowering the limit on cladding contamination to 1,000um (previously 2,000) the correlation improved significantly.

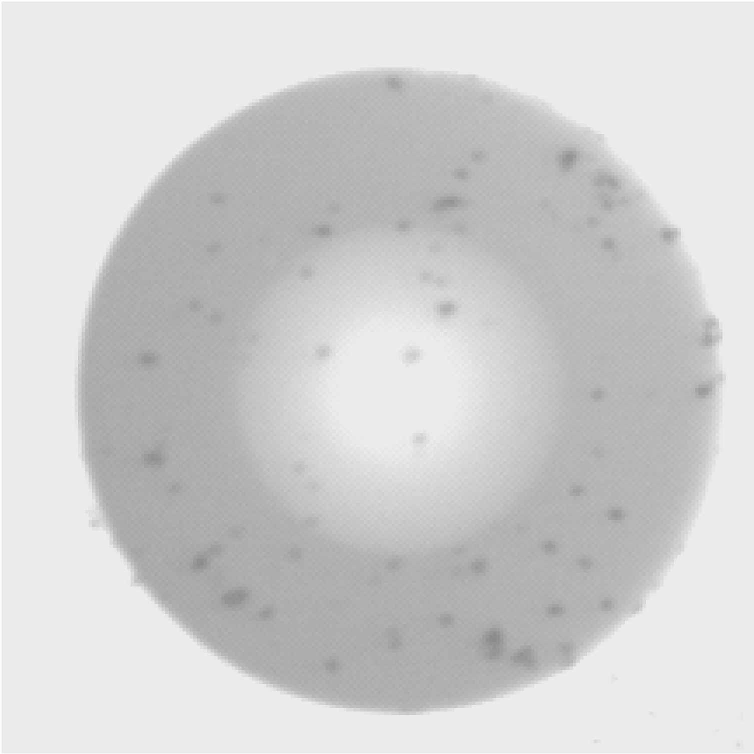
Analysis – Combined Data w/ cladding contamination > 1,000um removed



- Here is our strongest correlation, and in our opinion sufficient to begin deriving failure criteria.

Failure Criteria

- The data suggests that we definitely want a limit of 1,000um OA in the cladding.
- That is for the mated pair suggesting that a limit of ~500um for each is required.
- The image at right has 470um of occluded area in the cladding. It seems entirely reasonable to make the restriction somewhat tighter than this to provide some headroom.
- We suggest 350um. This will need to be translated into particle size/count limitations

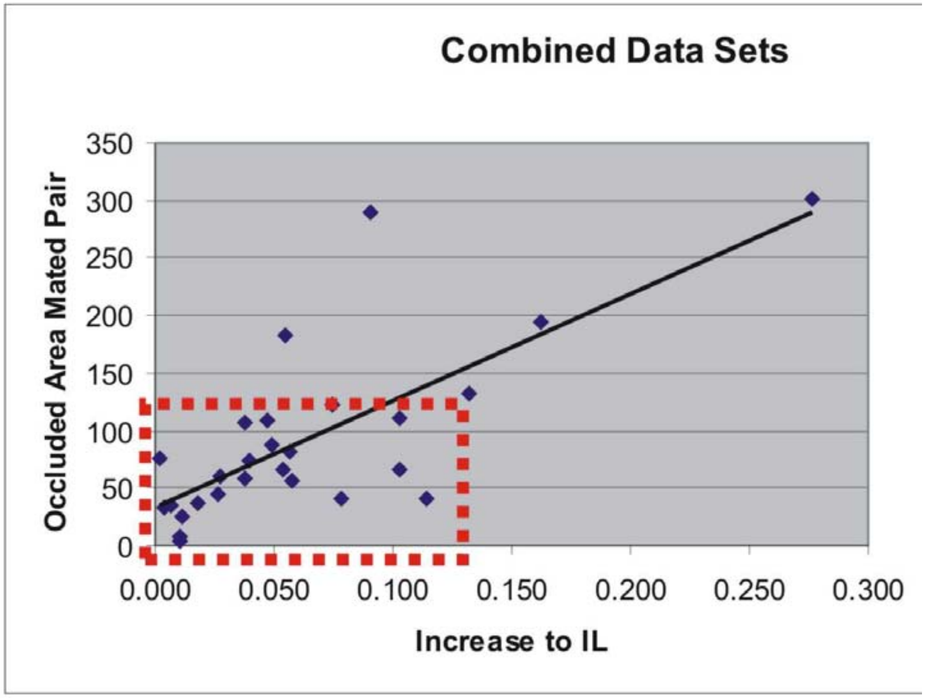


Failure Criteria

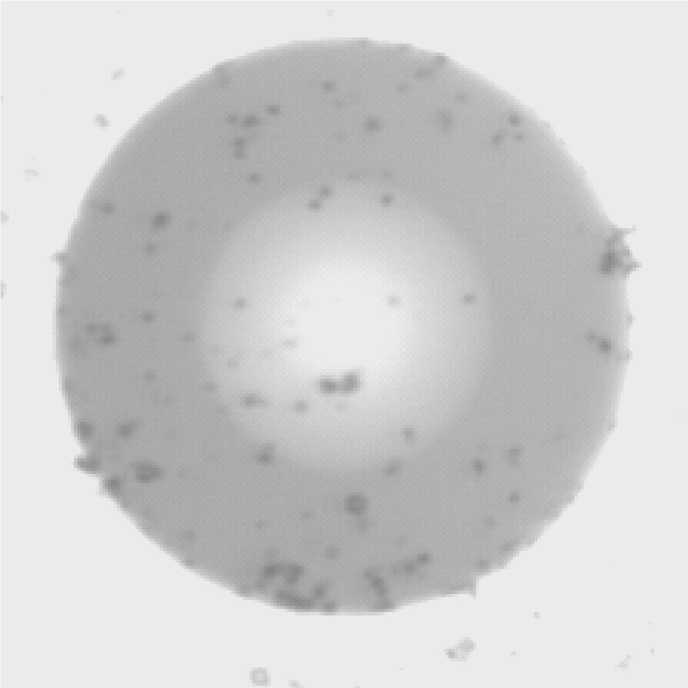
- If we limit the cladding zone to < 350um, we can look at the data for the core zone as being well correlated.
- The question becomes, how much loss is acceptable? Using the 3 sigma approach:
  - For my data set the standard deviation for the entire set was 0.043dB
  - That would suggest that if dirt increased IL by 0.129dB, it would result in a failure
  - These are huge assumptions as they really don't take loss budget or head-room into account

Failure Criteria

- For discussion, if we used 0.129 as our target, the data would suggest we restrict core contamination to < 125um.
- This is for the mated pair suggesting, we would want <63um for a single end face.
- This doesn't leave much head room, so perhaps <50um is better.



Failure Criteria – Example Images

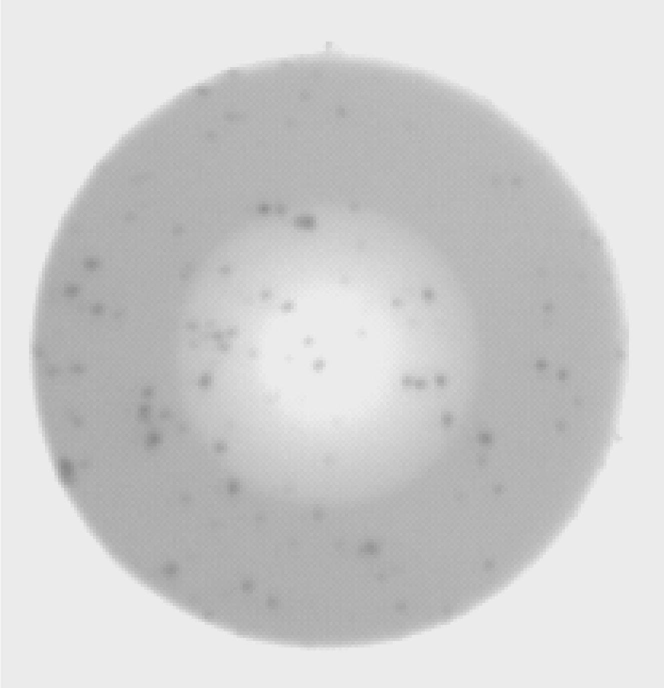


*****MARGINAL PASS*****

Core OA: 49.9 um

Cladding OA: 407.6 um

Increase to IL = 0.040 dB (167% of Std Dev)



*****MARGINAL FAIL*****

Core OA: 58.6 um

Cladding OA: 194.0 um

Increase to IL = 0.103dB (412% of Std Dev)

Failure Criteria – Convert to Count

- Whatever we propose must be useable by humans or machines.
- We will pursue doing both in the standard, but we need to convert OA to a usable value for humans.
- IPC Chart?
  - Core Zone allows 5 < 5um and 0 > 5 um
    - Ironically, the worst case is 98um of OA which is close to were the data suggests we go for a mated pair
    - Probably not strict enough given the possibility that if each connector had that much it would probably produce unacceptable loss. (debatable since we didn't mirror images)
  - Cladding zone allows any < 2 um, 5 from 2-5 um, and 0 > 5um
    - 0 > 5um is too strict

Failure Criteria – Discussion

- Consider the following:
  - Core Zone:
    - 5 < 4 um ~62 um worst case
    - 1 particle at 9 microns is ~63um
    - “any < 2 microns”?
  - Cladding
    - None > 5 um is too strict
  - Ferrule
    - Need to evaluate data further
  - How do we dumb this down to make it usable in the field?