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Some Thoughts on Laser Reliability
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Some Thoughts on Laser Reliability

Agenda

- Context
- Reliability of what?
- What are the problems?
- What do you do about it? (Some possible solutions)
- Summary

Context

A number of spacecraft or spacecraft instruments have failed in flight or in late-stage testing due to laser failures.

Lasers fly on nearly every spacecraft.

The reliability / lifetime of these lasers is poorly understood.

Context

- **Lasers are typically tested under a set of conditions recommended by each manufacturer**
- **These include:**
  - **Particular ambient operating temperature**
  - **Particular power level (controlled either by current or voltage)**
  - **Particular pulse duration**
  - **Particular pulse rate**
  - **Particular mounting/packaging scheme**

What are the Problems?

- The trades between the laser operating parameters are linked, but can be separated.
- If any one of the parameters does not match the test conditions of the vendor, then you do not know the lifetime.
- There do not appear to be any standards for lifetime test conditions outside Telcordia which do not always match well for other applications (e.g. aircraft, spacecraft, etc.)

What are the problems?

Numerous failure modes have been observed. Some of them are:

1. **Au-In intermetallic formation**
2. **Solder 'squeeze-out'**
3. **Facet contamination**
4. **Misalignment due to creep**
5. **Sn whiskers**
6. **Void formation under die**

7. **Die damage / Fabrication issues**

Understanding Lifetime

- To understand lifetime –
  - Separate die failure modes from packaging induced failure modes
  - Use statistical design of experiments to create a variable trade space
  - Take lots of data – running lasers until failure
  - Accelerated testing can be performed – but with extreme caution

Standardization

- Need for non-Telcordia testing standards for specific industries (aircraft, spacecraft, etc.)
- Need for standard packaging for testing
- Need ‘bar’ standards

Mitigation of Failure Modes

- Efficient standardized package designs
- Rigorous Statistical Process Control for both die and package
- ‘Class 100’ or better assembly operations
- Segregate package induced and die failure modes
- More intelligent package design
- Co-design of die and package
- Careful consideration of fabrication materials

Summary

- **Lifetime of most lasers under 'use conditions' is not known**
- **Die and package failure modes should be segregated for lifetime testing**
- **Design of experiments can easily be adapted to providing laser parameter trade-space**
- **Many common failure modes for both packages and die have been identified that are relatively easily mitigated through intelligent design and stringent process control**
- **Standardization of testing for different industries is important**
- **Accelerated testing can be used judiciously if failure modes are well known**