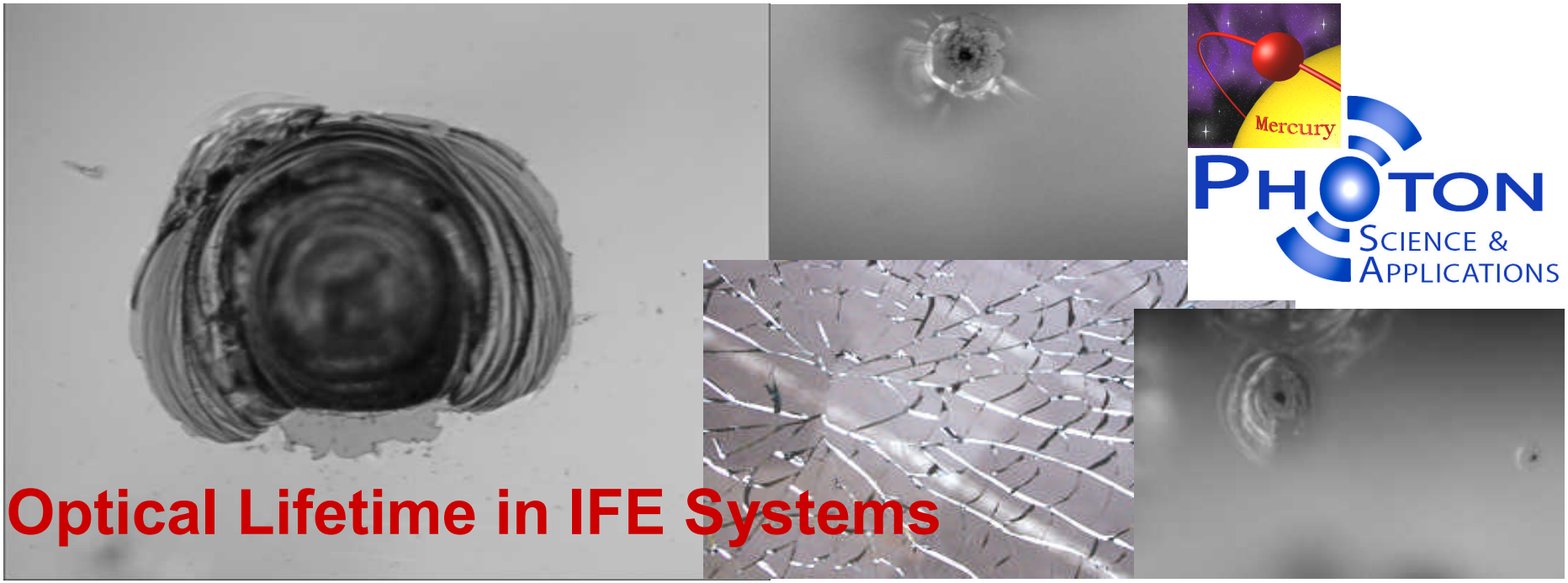

Optical Lifetime in IFE Systems

Zhi M. Liao

Lawrence Livermore National Laboratory

15th LASER IFE PROGRAM WORKSHOP

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Laser-induced damage in optics

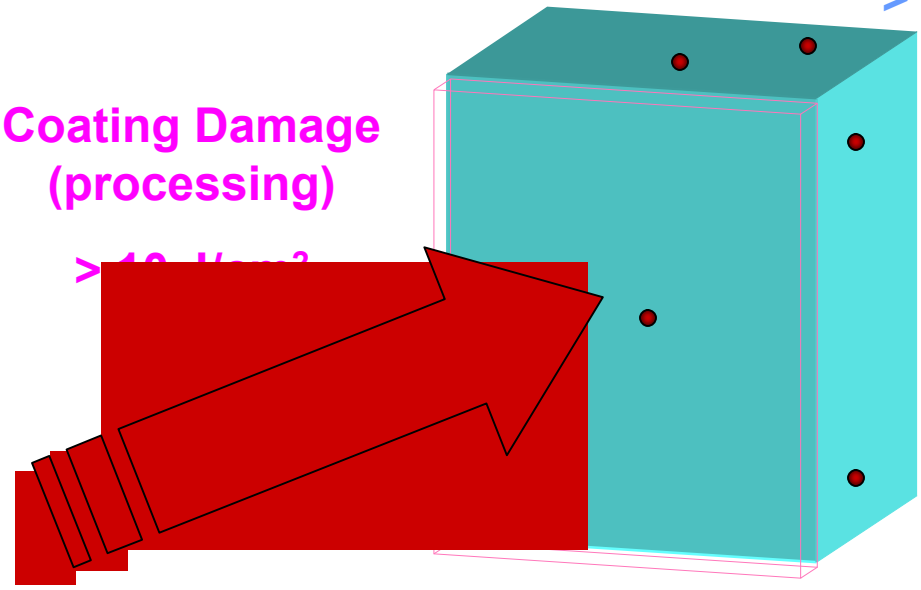
ALL Optics are susceptible to laser damage

- Windows
- Mirrors
- Lens
- Gain medium
- etc.

Surface Damage
(intrinsic material)

> 50 J/cm^2

Coating Damage
(processing)



Bulk damage

(impurities driven)

> 3 J/cm^2

All optics (regardless of laser type) subjected to laser illumination will suffer from wear and tear and are susceptible to damage eventually.

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How do we define Damage?

Damage: *Laser-induced* **flaw** that can be seen or characterized by:

- human eye or microscopy
- scattering or interferometric techniques

Initiation: A **flaw** is created on/in an unblemished region of an optic with laser illumination

- usually due to the presence of a *precursor defect* of native material or an impurity
- cleanliness or material science problem

Growth: A **flaw** changes size upon exposure to laser illumination

- may be compounded by presence of impurities
- operational strategy problem

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Functional damage specification

Functional Damage: Change in an optic that will inexorably cause that optic or another optic to be removed from use

Functional damage is driven by systems engineering (top level):

1. An initiated flaw site that changes the beam downstream in a manner that can be detrimental to the system.
2. An initiated flaw site that grows rapidly in time in such a manner that might become detrimental to the system.
3. How many initiated flaw sites can be tolerated with respect to beam obscuration or beam quality?

Functional damage is closely tied to the operational cost of the system

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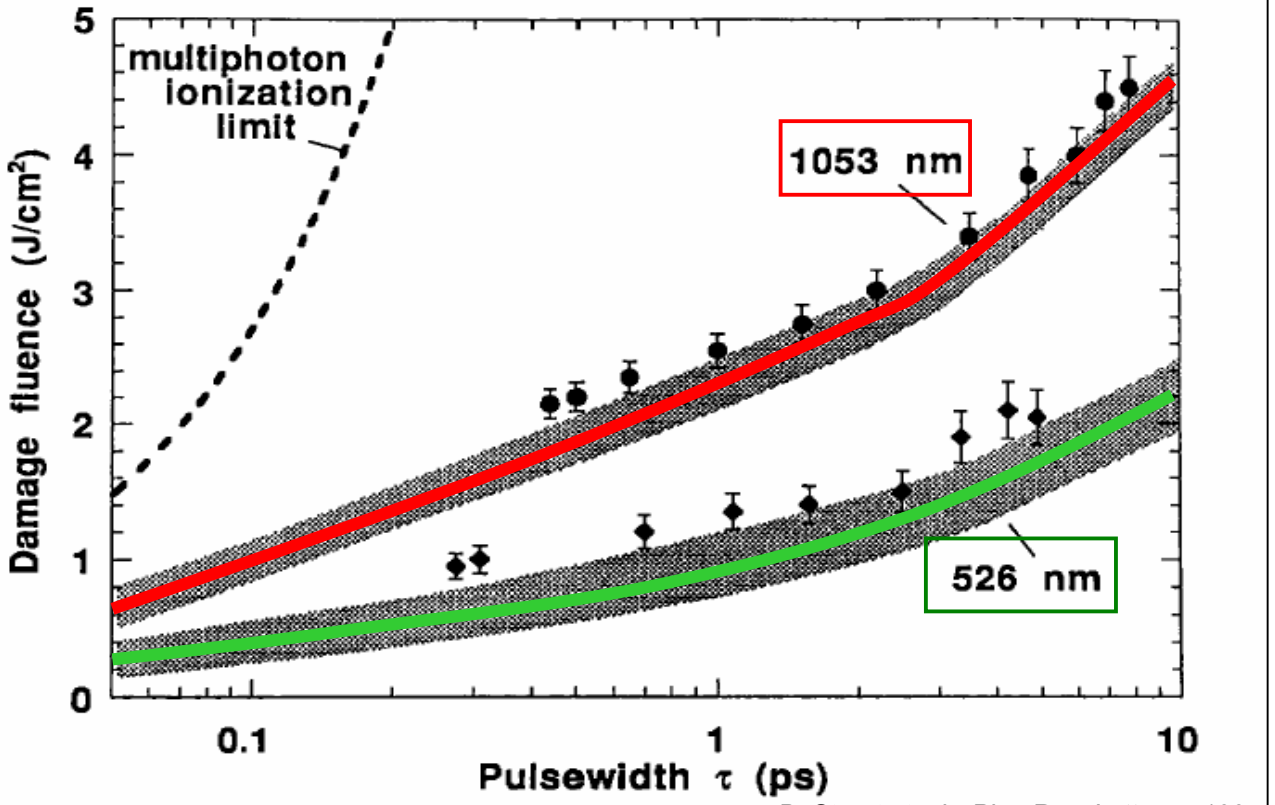
Laser-induced damage depends on many factors

Wavelength and Pulse Width Dependent Damage



B. Stuart et. al., *Phy. Rev. Lett.*, **74**, 1995

Other factors include:

- **Effect of multiple-shots of the laser beam**
- **Changes in optic's quality, processing, handling, and environment**

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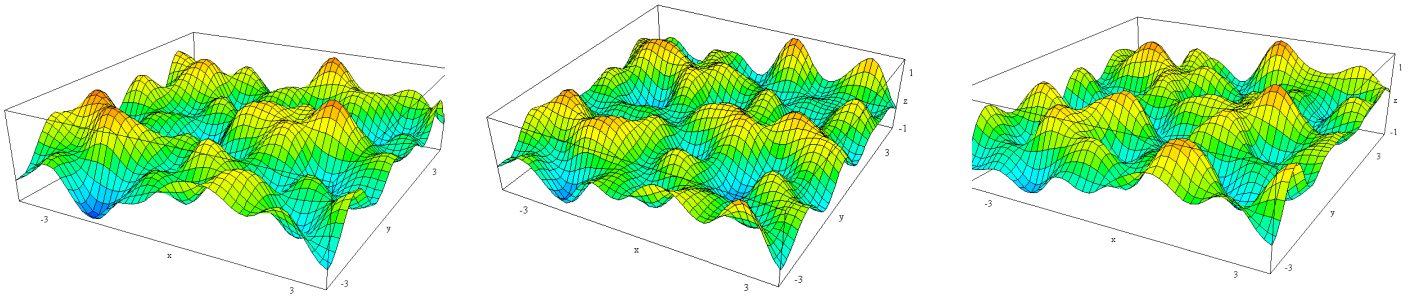
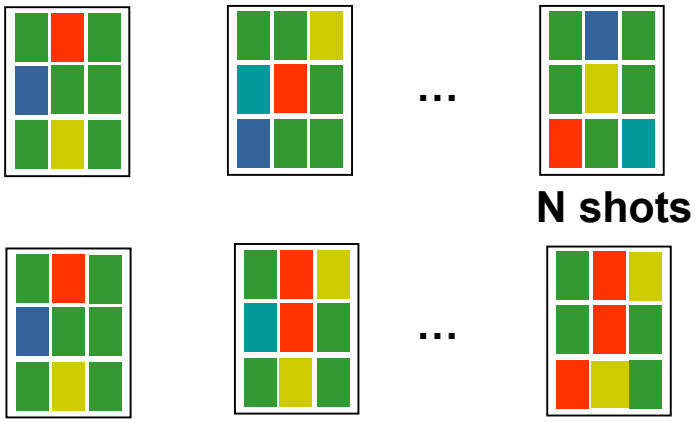
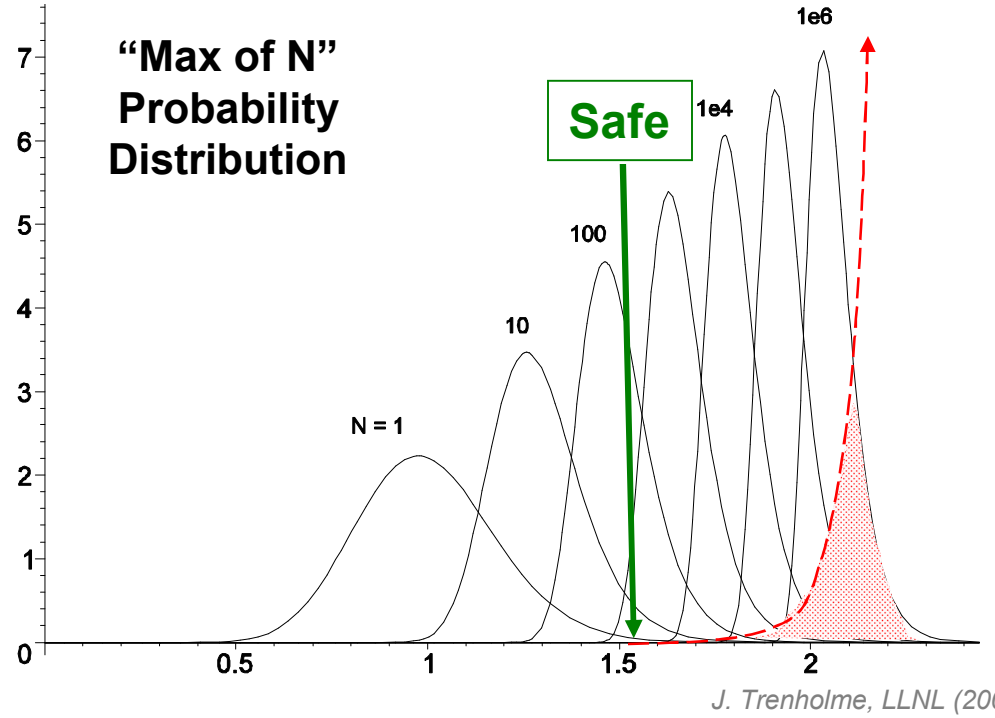
Effect of multiple shots

Since the spatial profile of the beam changes from shot to shot …







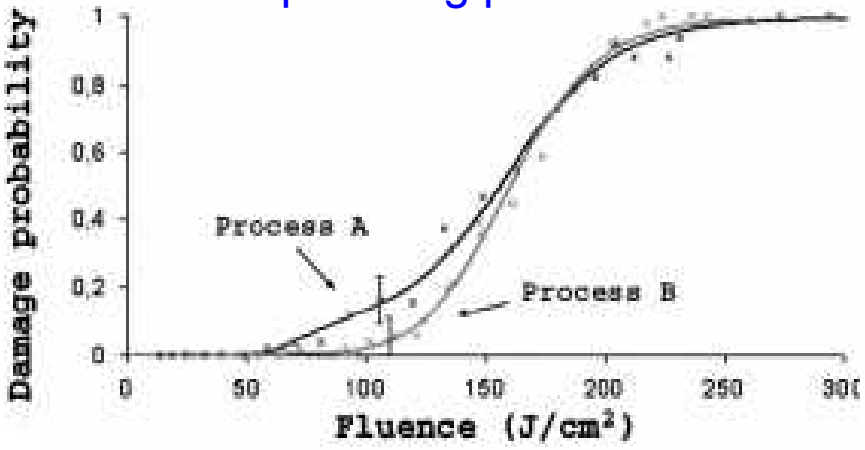
J. Trenholme, LLNL (2005)

What's a good formulism to describe damage?

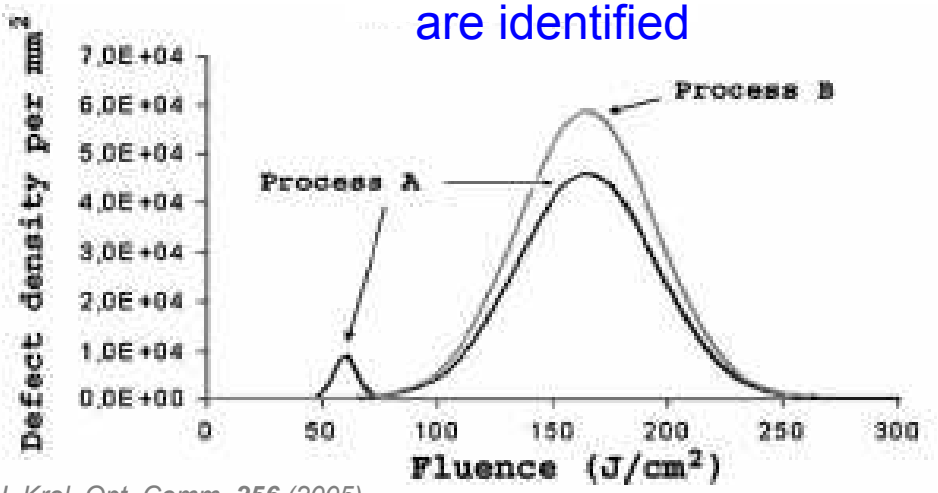
- Damage tests are conducted to obtain a damage ***probability density function***, $\rho(\phi)$
- Phenomenological models - fit to the data with parameters such as …

- **Damage threshold** (fluence at which flaws are formed)
- **Defect density** (precursors that initiate the flaw)
- **Damage threshold distribution** (different species or classes of precursors)
- **Shot number** (for damage fatigue studies).

Effect of using two different polishing processes



2 possible species of precursor are identified



H. Krol, Opt. Comm. ***256*** *(2005).*

Phenomenological models can be used to help interpret the damage test data and help identify possible causes of damage initiation

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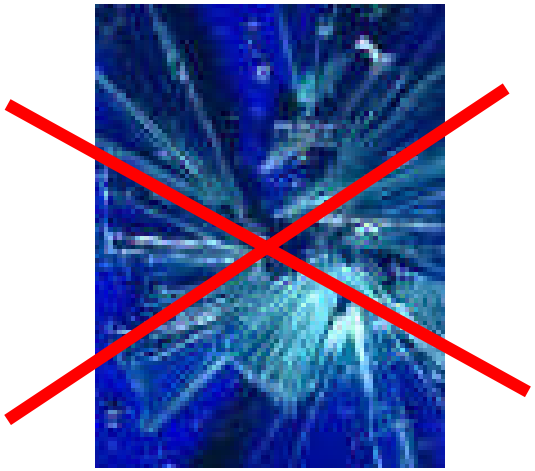
What's needed for a high-rep-rate laser system?

IFE drivers must find a regime where optics degradation is affordable

- 10 Hz @ 24 hrs/day x 7 days/wk x 52 wk/yr = **3 x 10^8** shots/year
- Over a 30 year lifetime = **10^{10}** shots



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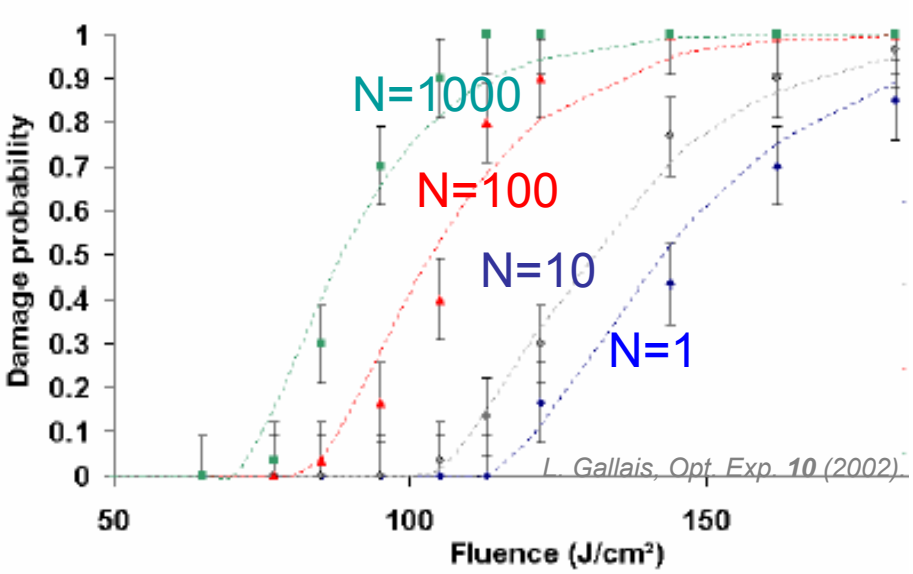
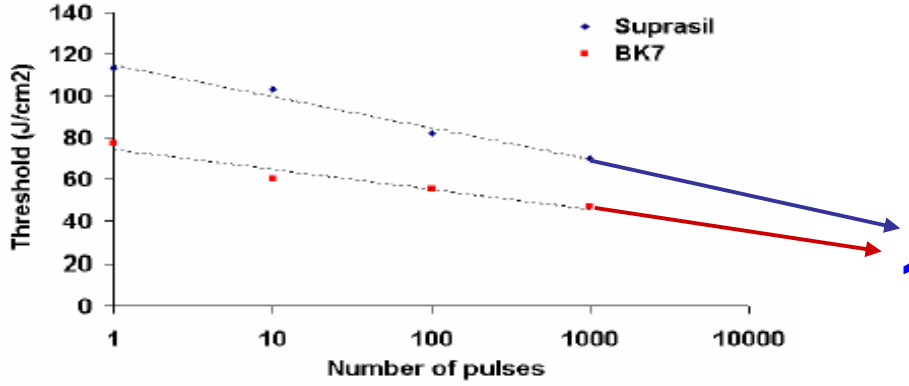
Additional damage mechanisms may exist for 10^{10} shots



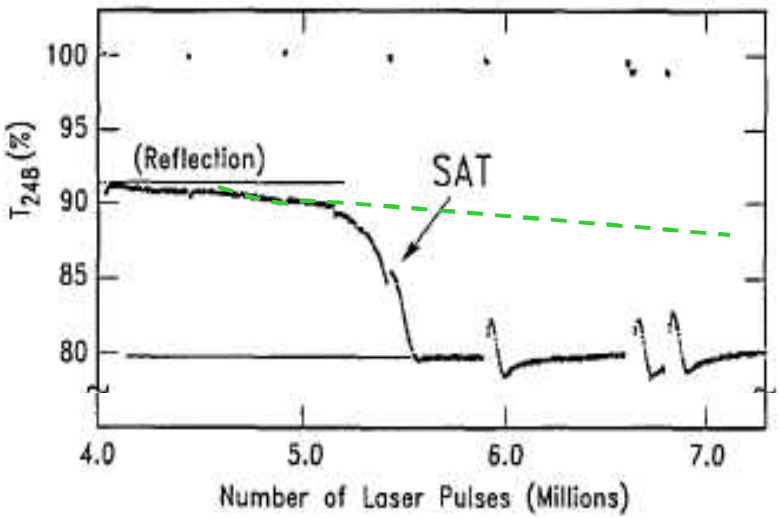
Optic fatigue Damage



10^{10} ?

Transmission Degradation

D. Krajnovich et. al., *Opt. Lett.*, **18**, 1993

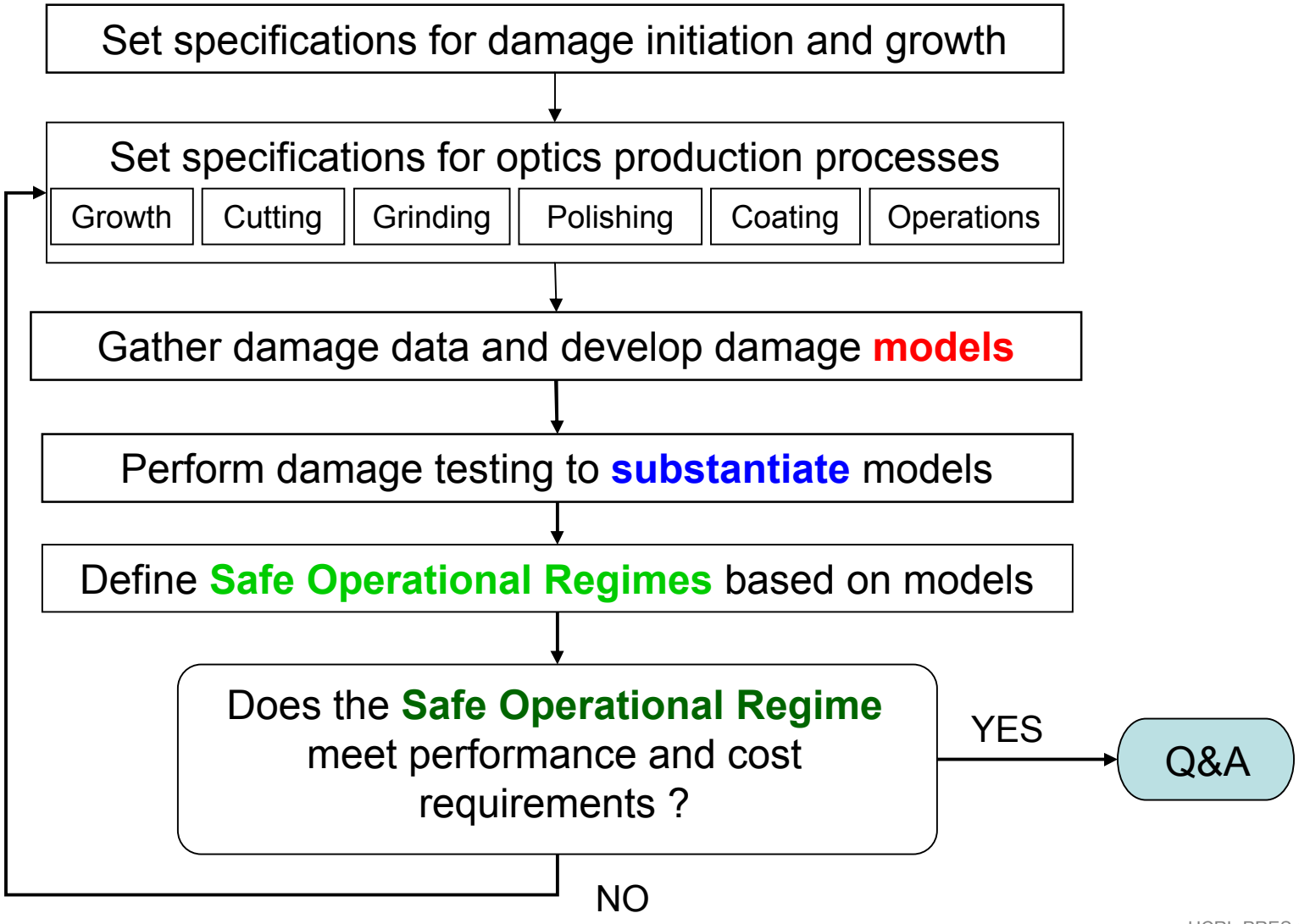


1 cm window at 0.5 J/cm2 at 16ns

How do we study damage mechanisms for 10^{10} shots?

What is a 10^{10} shot strategy?

GOAL: **10^{10} shots with acceptable cost of maintaining of various optics**



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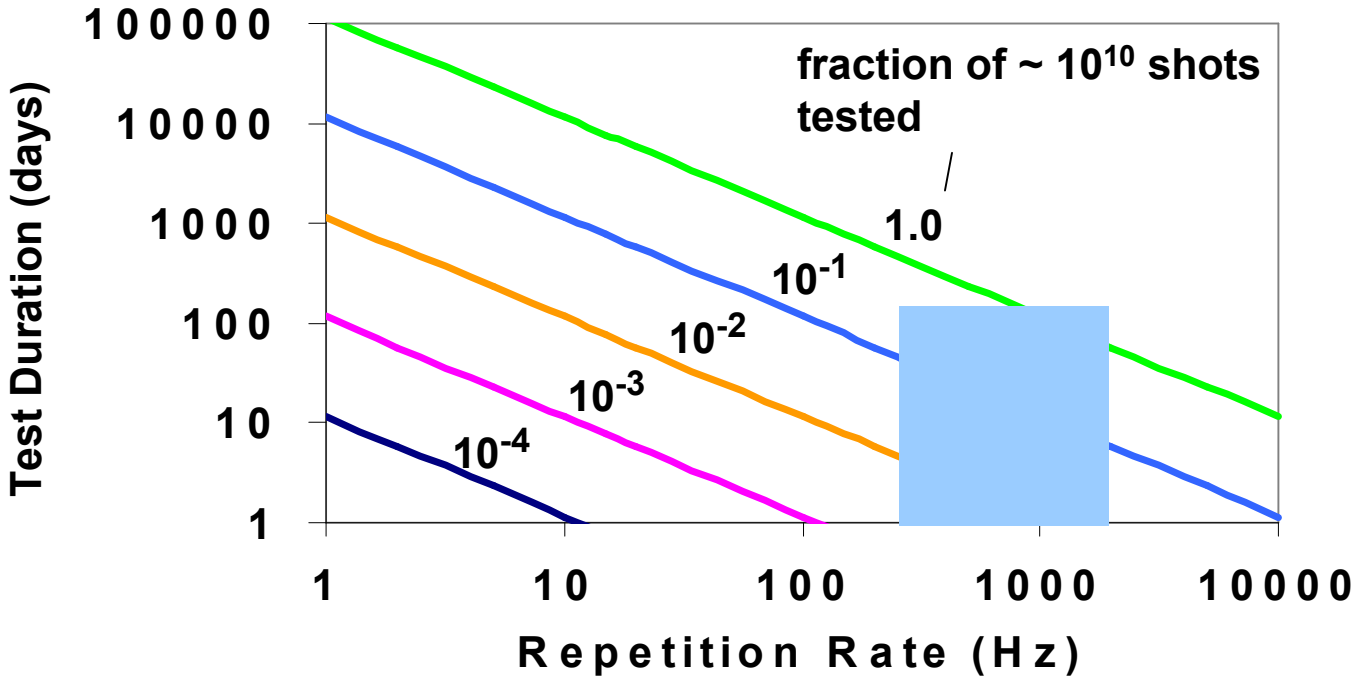
Development of optics for IFE laser drivers will require accelerated damage tests



- Testing for a significant fraction of ~10^{10}-shots will take excessive time unless ~kHz repetition rates are used
- Tests of relatively small ~ 1 cm^2 areas at fluences of a few J/cm^2 at 1 kHz will require laser powers of several kW!
- Methods for accelerating tests, e.g., by running tests at elevated fluences to cause damage to occur in fewer shots appears necessary
- Statistical methods for extrapolating damage results from small samples to large optics must also be applied

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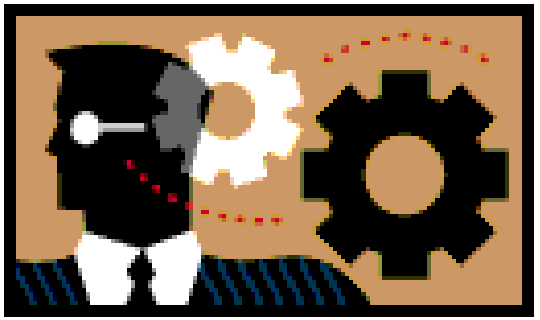
Summary

All optics will suffer wear and tear. Laser-induced damage is directly linked to operational cost of the system.

How do we translate knowledge base from a low-rep-rate laser system to a high-rep-rate laser system?



What efforts & developments should we be working on NOW ?

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