# ASPE Tutorial – Opto-Mechanical Design

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## Opto-Mechanical Design - Part 1 (4h)

### Introduction

- Introduction to Opto-Mechanics; backgrounds of the participants and trainer
- Overview of tutorial topics and their interdependence

The first day starts with a brief overview of the field and an exchange on the backgrounds of the participants and trainer. This is followed by an outline of the tutorial topics for day 1 and 2 and their interconnections.

### Sensitivity of Optical Components

- Role of optical sensitivity in driving design choices
- Movements in which DoFs matter for optical performance
- Optical component types (e.g., lens vs. mirror) and their typical sensitivities
- Optional: Use of Opto-Mechanics table to record requirements
- Optional: Mini-exercise on determine sensitivities for 1–2 simple optics in a system

The sensitivity of optical components to mechanical disturbances forms the basis for defining mechanical requirements from optical performance targets. Different classes of components respond differently, for example, plane mirrors are insensitive to in-plane motion but sensitive to out-of-plane shift and tilts, while spherical lenses are sensitive to all translations but first-order insensitive to rotations.

### Mounting of optical components

- How material properties influence mounting; brittle vs ductile, TCE mismatch
- How optics manufacturing influences mounting: decenter, functional vs. non-functional surfaces
- Clamping: form closed, force closed, elastic averaging, friction constraints
- Adhesive bonding: soft mounts vs hard mounts, thermal vs mechanical load-case-paradox
- Exact constraint and semi-kinematic principles, lens tubes, adjustment lathing
- Case examples of mounts

While typical mechanical components made of ductile materials can tolerate micrometer-level deformation, optical components often require sub-micrometer stability, are frequently brittle, and typically involve CTE mismatches. This necessitates tailored mounting solutions. Various mounting considerations and practical design guidelines are introduced, focusing on two main approaches: mechanical clamping and adhesive bonding. Both are illustrated with examples and simple calculations to assess performance under thermal and mechanical stress. Examples of failed mounts are also discussed to highlight common pitfalls.

### Key Takeaways, Q&A and Discussion

- Main takeaways of Part 1 and links with Part 2
- Q&A on sensitivity, and mounts
- Invite input by participants on application challenges they face

# Opto-Mechanical Design - Part 2 (4h)

### Introduction

- Introduction to Opto-Mechanics; backgrounds of the participants and trainer
- Quick summary of Day 1 for continuity
- Overview of tutorial topics and their interdependence

The second day begins with a brief overview of the field and an exchange on the backgrounds of the participants and trainer. This is followed by a recap of Part 1 and an outline of Part 2 topics, highlighting the links both within Part 2 and with Part 1.

### Measurement for alignment optics to mechanical references

- Measurement of optical performance
- Use of detectors, pinholes, apertures, and rotation for alignment
- Interactive session on measurement for alignment of:
    - a fiber collimator
    - a laser beam to a mechanical structure
    - a laser to a stage
    - optics to a laser beam

Due to the high sensitivity of optical systems, required tolerances often exceed standard manufacturing capabilities, making alignment mechanisms essential. But how do you measure what you're aligning, and how do you bring optical and mechanical axes into alignment? This segment covers some practical measurement methods and tips for aligning optical components to mechanical references.

### Alignment Mechanisms

- Requirements and performance criteria for alignment mechanisms
- Key functions: Guidance, Adjustment, Locking
- Overview of off-the-shelf opto-mechanical alignment mechanisms
- Examples of dedicated, custom-designed solutions

When assembly based on manufacturing tolerances falls short due to tight tolerances, alignment mechanisms become essential. This session discusses the requirements, performance, and key functions of alignment mechanisms, such as guidance, adjustment, and locking, followed by off-the-shelf opto-mechanical alignment mechanisms and a range of dedicated solutions.

### (Thermal) stability and athermalization

- Exact constraint and predictability
- Material properties
- Passive thermal expansion compensation
- Thermal center
- What limits passive solutions?

How can exact constraint design support thermal and dimensional stability in opto-mechanical systems and enable predictable behavior? This session covers key material properties, passive thermal compensation strategies, including thermal centers, and concludes with limitations of passive approaches.

### Key Takeaways, Q&A and Discussion

- Main takeaways of Part 1 and Part 2 focusing on the latter
- Q&A on alignment, and stability
- Invite input by participants on application challenges they face