Full-field Strain Measurements of Turbomachinery Components Using 3D SLDV Technology

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- Conclusions

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Introduction

- Validated models are required that represent the actual physics of aero engine components.
  - Why?
  - The models inform critical decisions regarding the definition of operational boundaries.

- Structured model validation.
  - Compare predictions with carefully measured data.
  - Is there an adequate degree of correlation?
  - Is model updating or remodelling required?

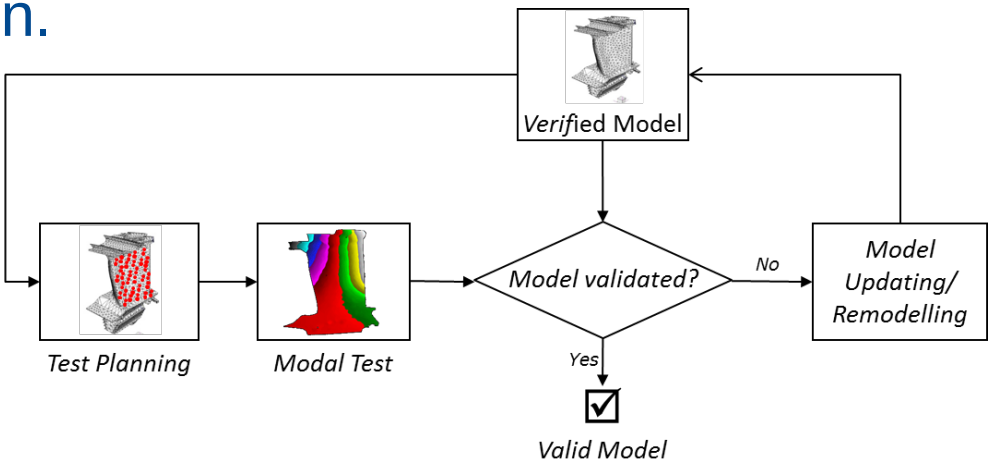

Figure 1: Model validation process

- What should we measure?

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Introduction

- Operational Deflection Shapes.
  - Qualitative comparison.
  - Easy to measure.

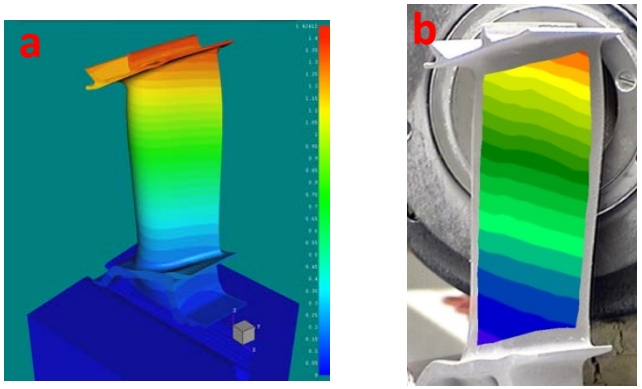

Figure 2: (a) predicted displacement from FE model, (b) measured ODS from SLDV

- Critical decisions are made based on σ and ε.
- Strain gauges can be used to measure ε directly.
- However…SGs are
  - Intrusive
  - Provide averaged values
  - Can only be applied to a small number of locations
- Alternative to strain gauges: 3D Scanning Laser Doppler Vibrometry (SLDV)

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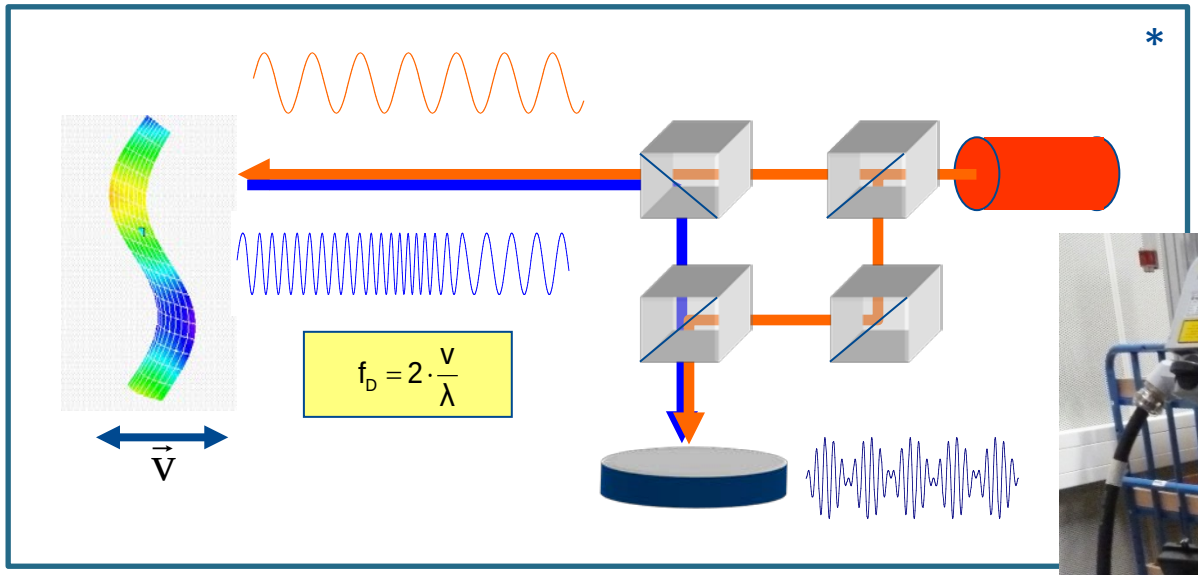
3D SLDV – The Basics



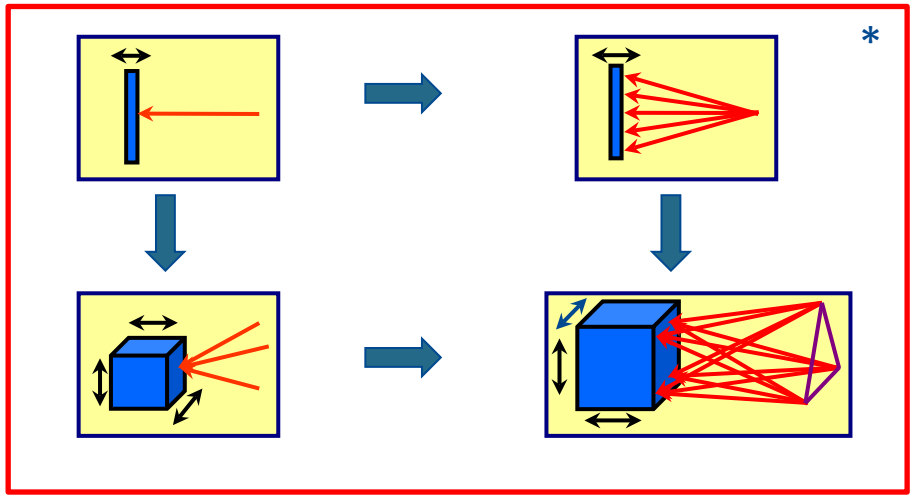


Figure 3: 3D SLDV test set-up

*Diagrams reproduced from Polytec training material with permission.

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3D SLDV – Full-Field Strain

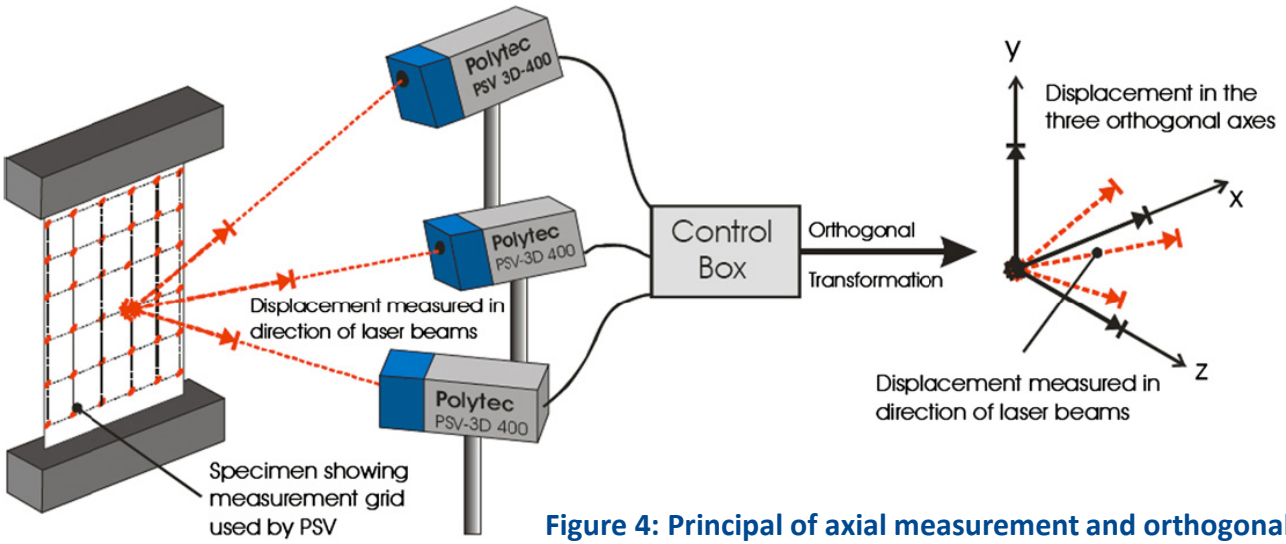

Figure 4: Principal of axial measurement and orthogonal transformation [1]

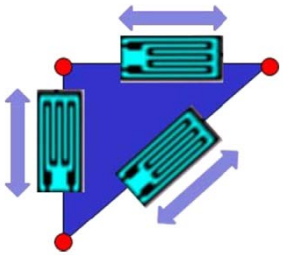

Figure 5: Triangle element with virtual strain gauges [2]

$$\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

[1] Cazzolato. B. *et al*. Scanning laser vibrometer for non-contact three-dimensional displacement and strain measurement. In: Proceedings of acoustics 2008; 2008.
[2] Polytec. Polytec data sheet – Optical Measurement of Dynamic Stress and Strain. Waldbronn: Polytec. 2011.

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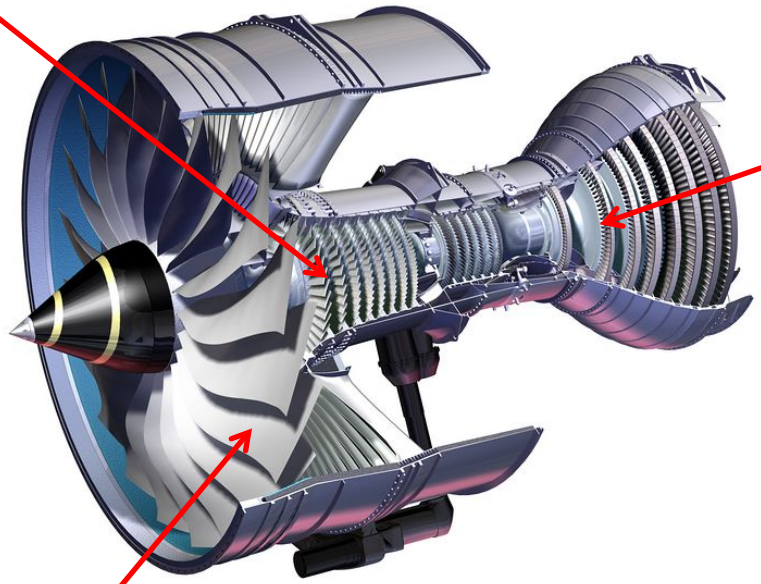
Test components

Intermediate Pressure Compressor (IPC) Blade

Intermediate Pressure Turbine (IPT) Blade



Low Pressure Compressor Fan Blade

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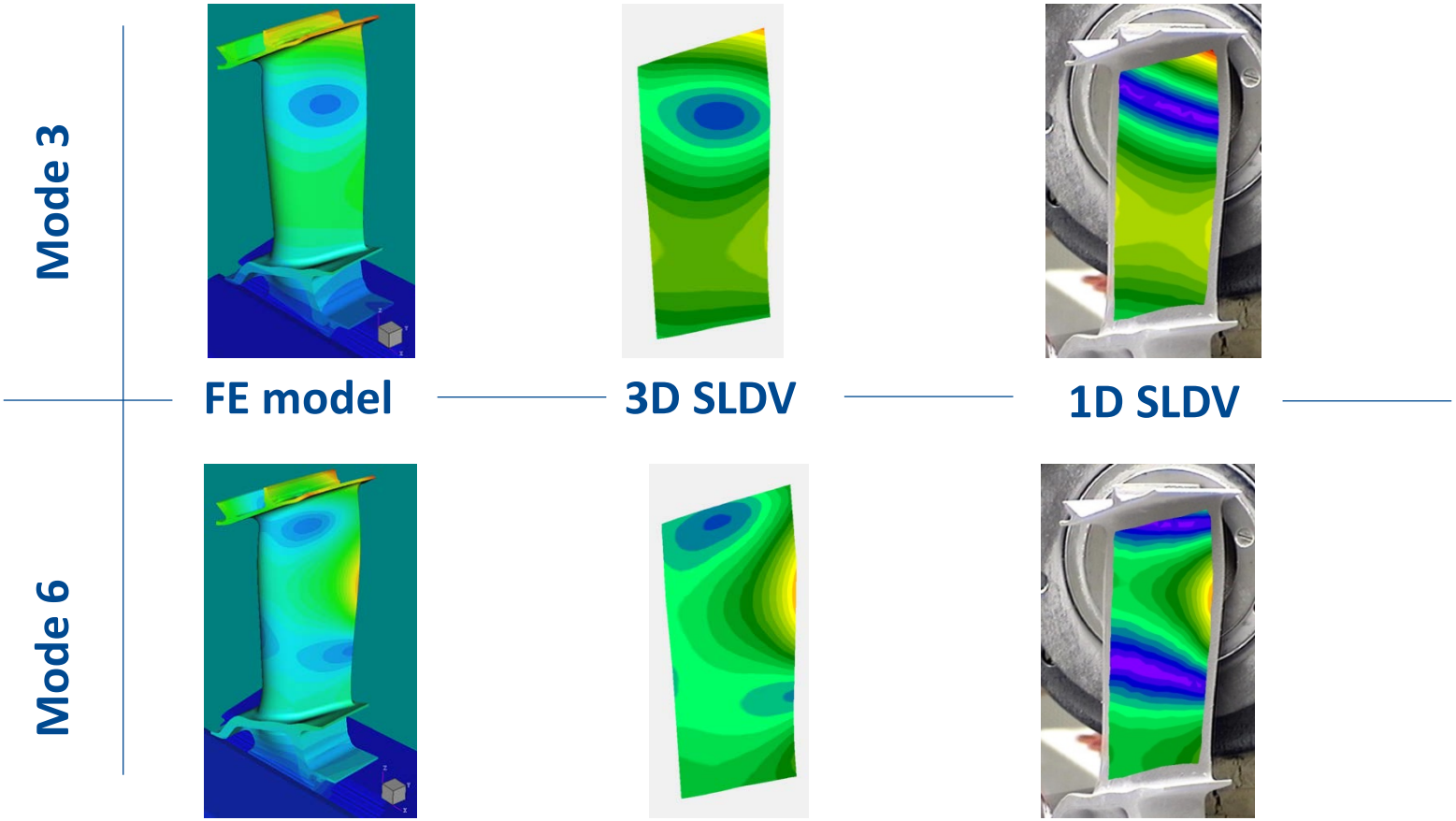
Results – 3D ODS measurements

- IPT Blade



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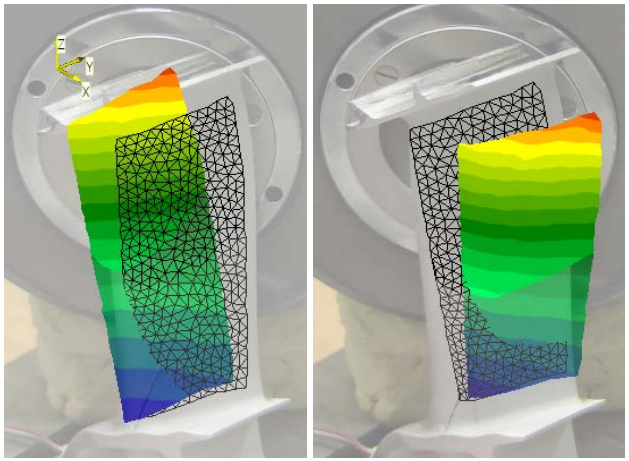
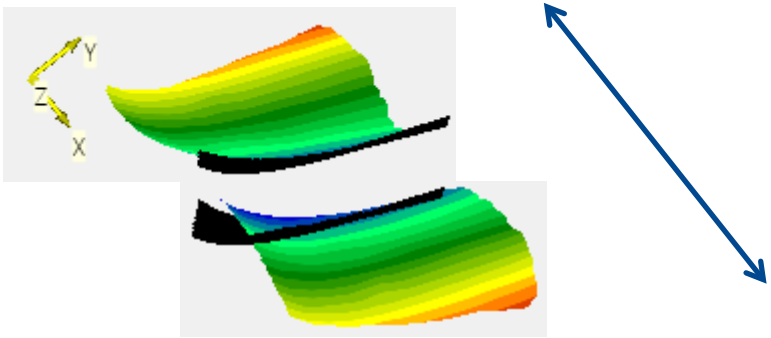
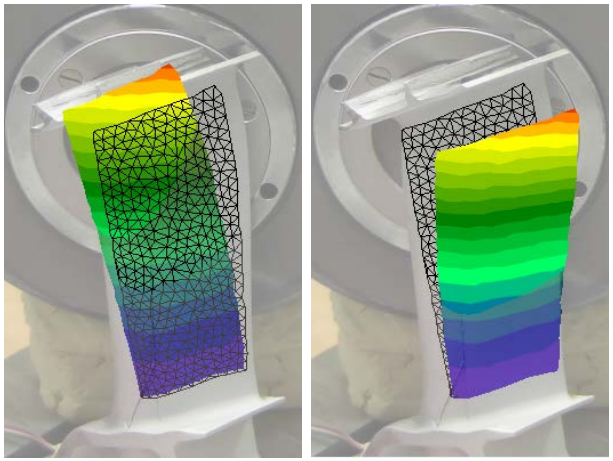
Results – 3D ODS measurements

- IPT Blade – mode 1E ‘edgewise’

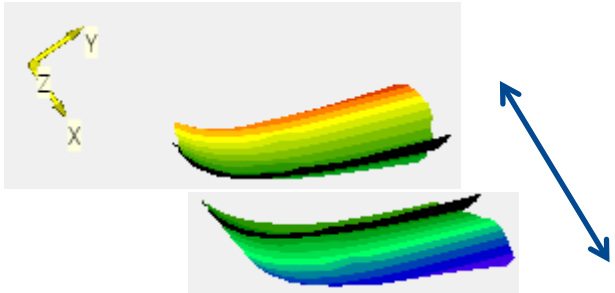


3D SLDV





1D SLDV



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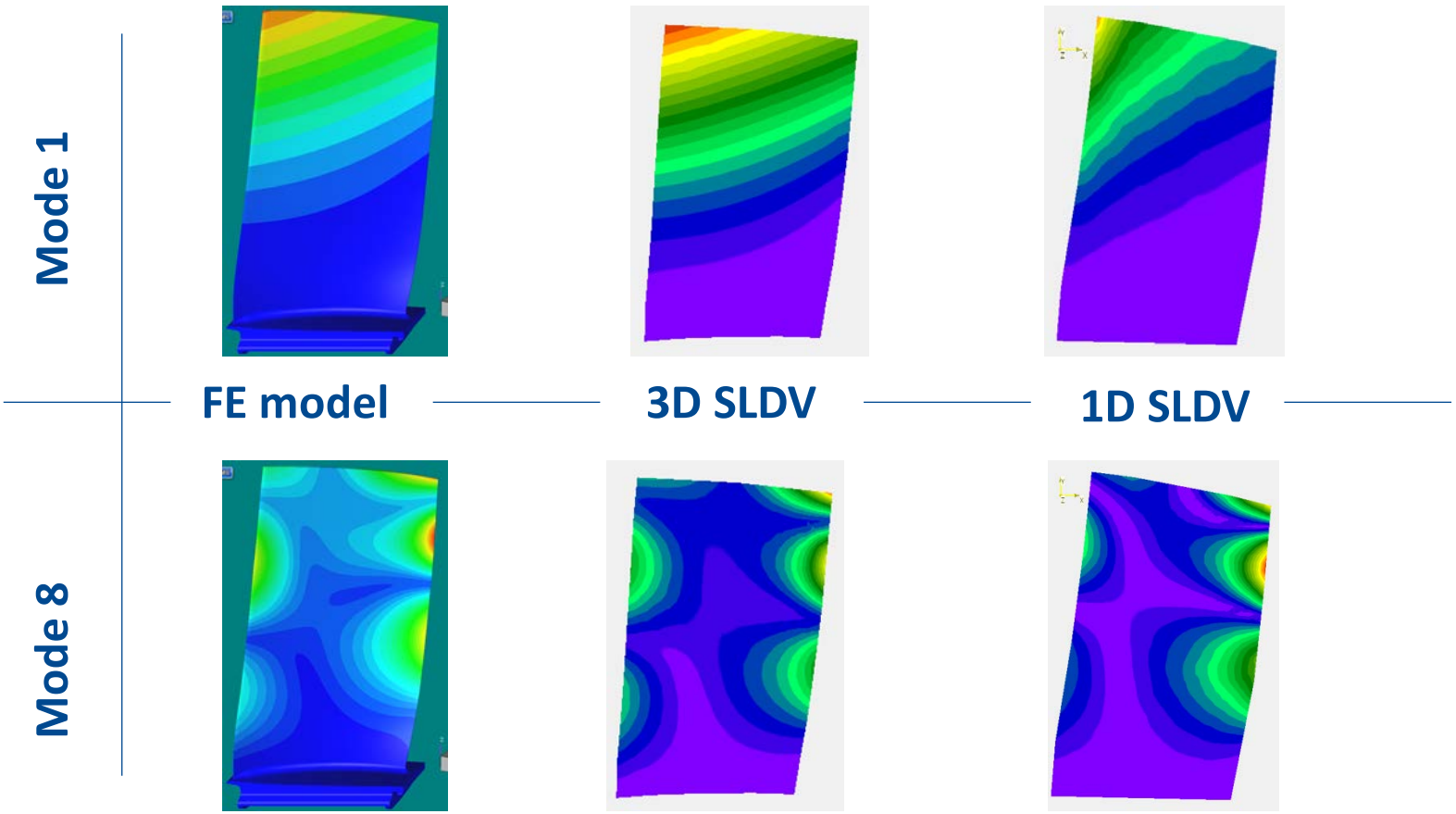
Results – 3D ODS Measurements

- IPC Blade



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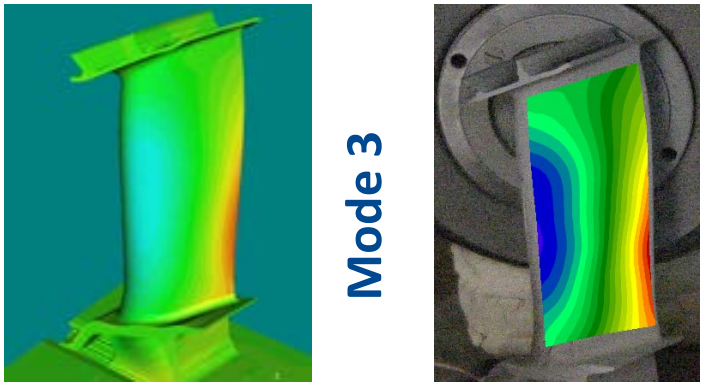
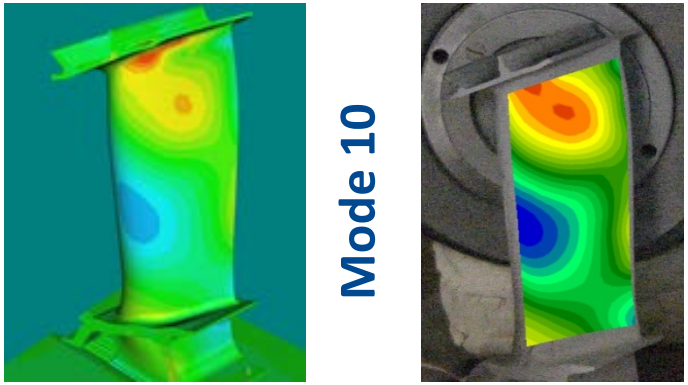
Results – Full Field Strain measurement

- IP Turbine Blade

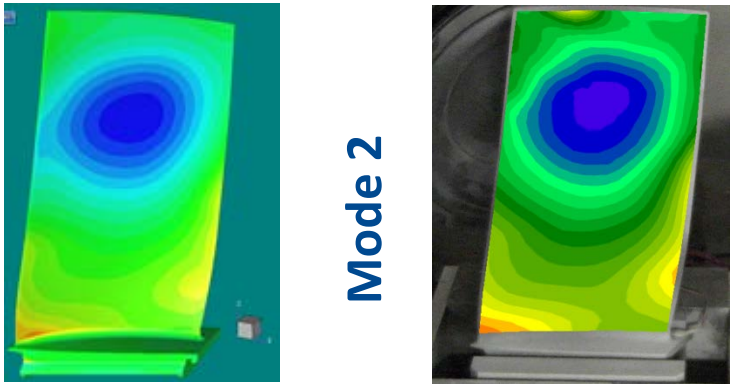


Mode 3

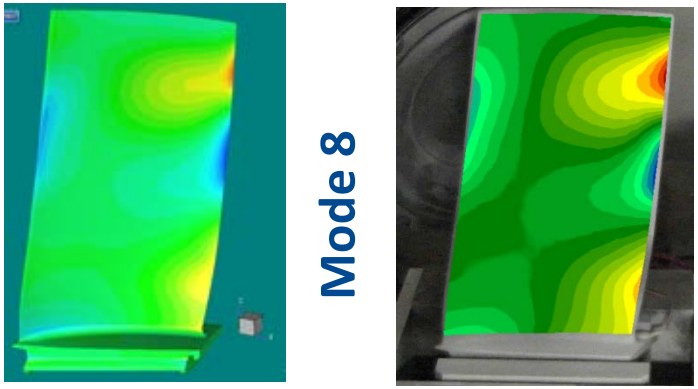


Mode 10

- IP Compressor Blade



Mode 2



Mode 8

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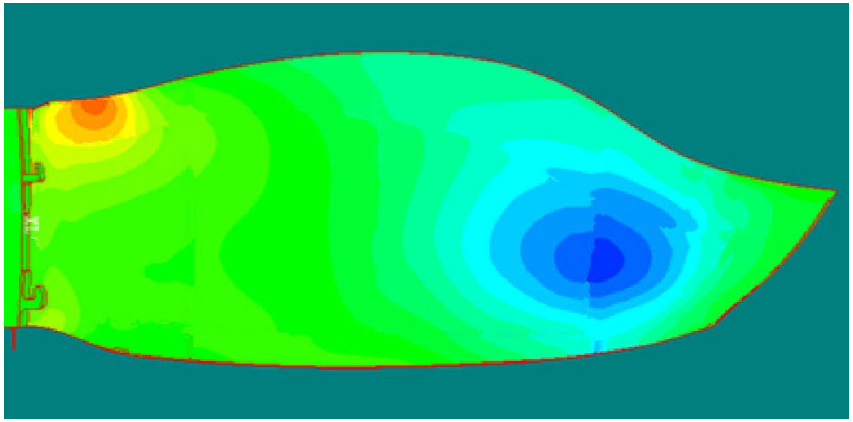
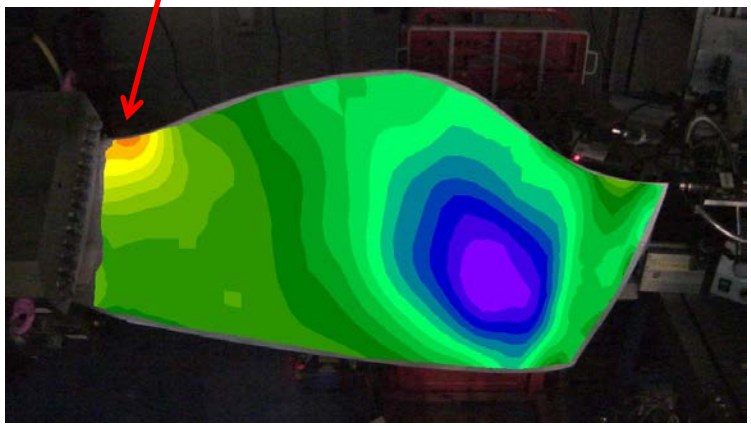
Results – Full Field Strain measurement

- Large Fan Blade – mode 2



Location of strain gauge



- 2% difference in με between 3D SLDV and strain gauge values

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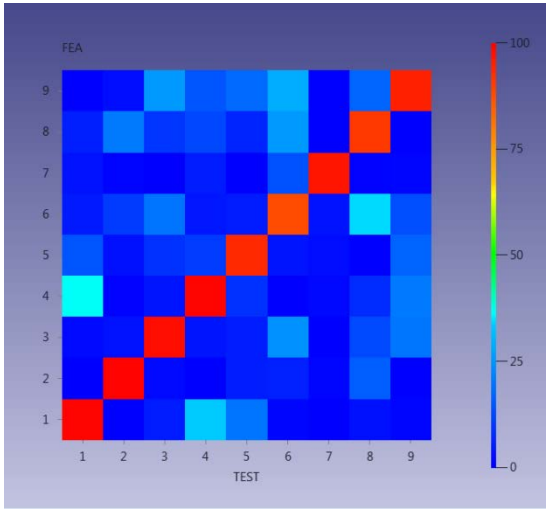
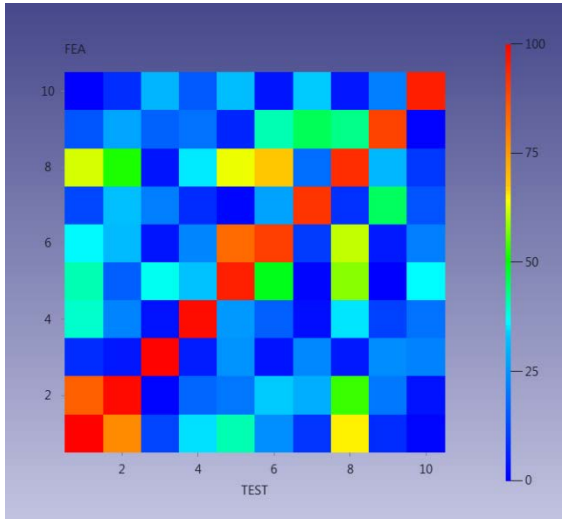
Correlation - Displacement

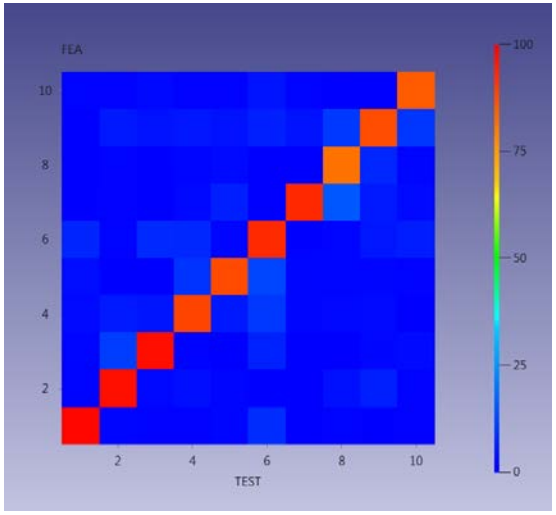


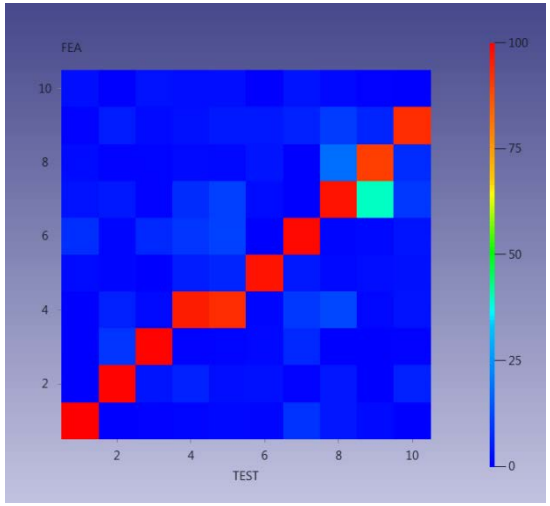
3D SLDV



1D SLDV

IP Turbine Blade





IP Compressor Blade

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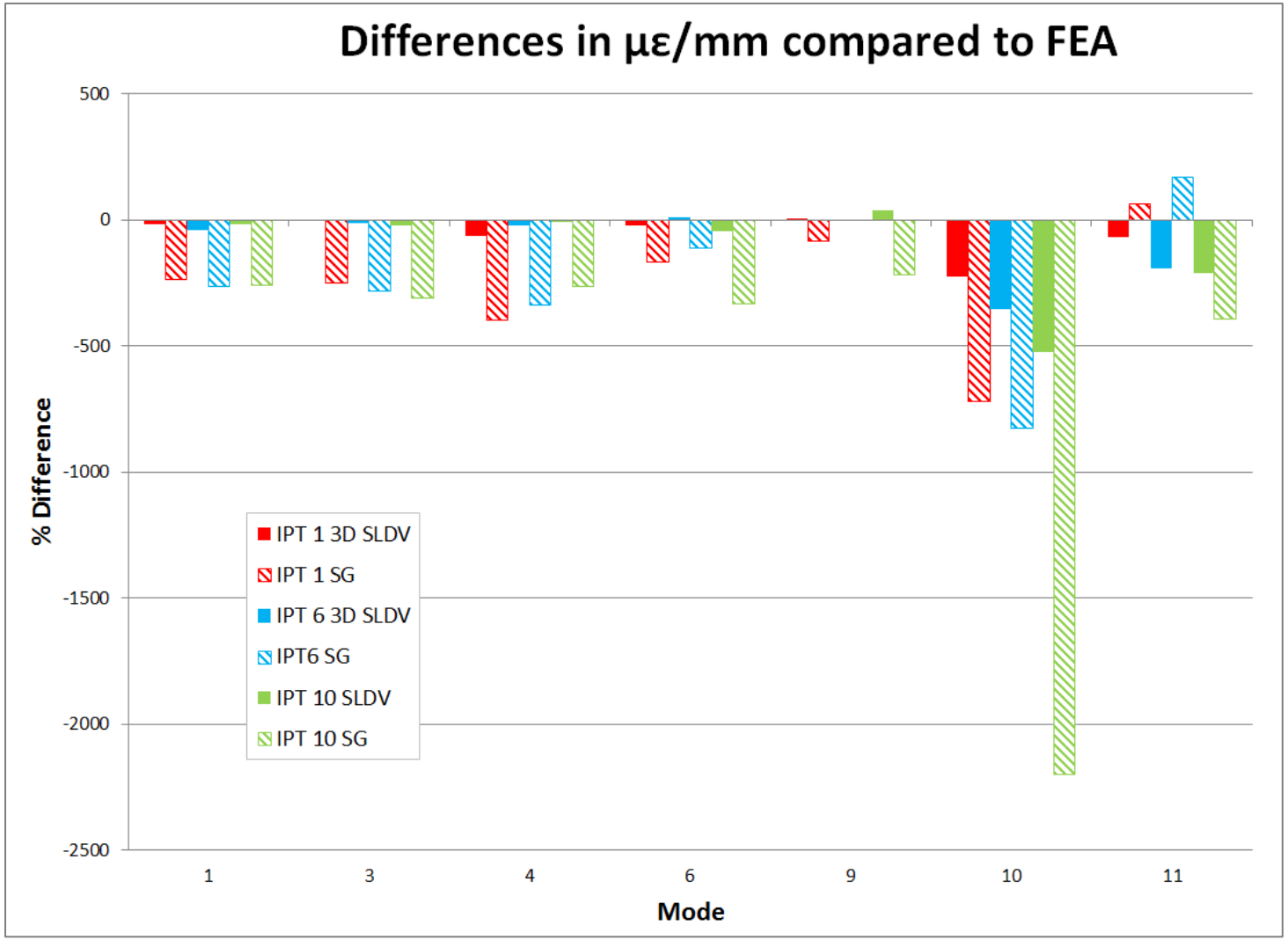
Correlation – strain values



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Conclusions

- 3D ODS have been measured for a variety of turbomachinery components and a large range of modes.
  - Visual comparison and numerical correlation show 3D data to be an improvement over the 1D case.

- Full Field surface strain maps have been produced that show good visual comparison with the FE counterparts.
  - Numerical correlation of ‘point’ data shows better agreement between SLDV and FE, than strain gauge and FE.

- Future Work
  - Full-field strain correlation
  - Efficacy of the method at operational and abnormal levels
  - ‘Productionisation’ of the process.

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Questions?

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