Fiber Optics Instrumentation Development

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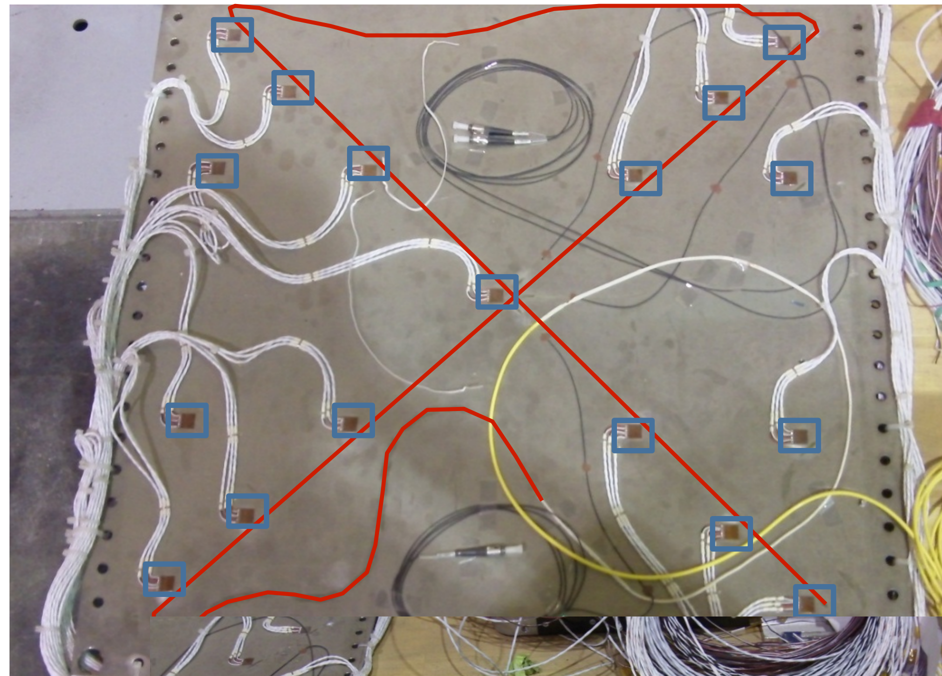
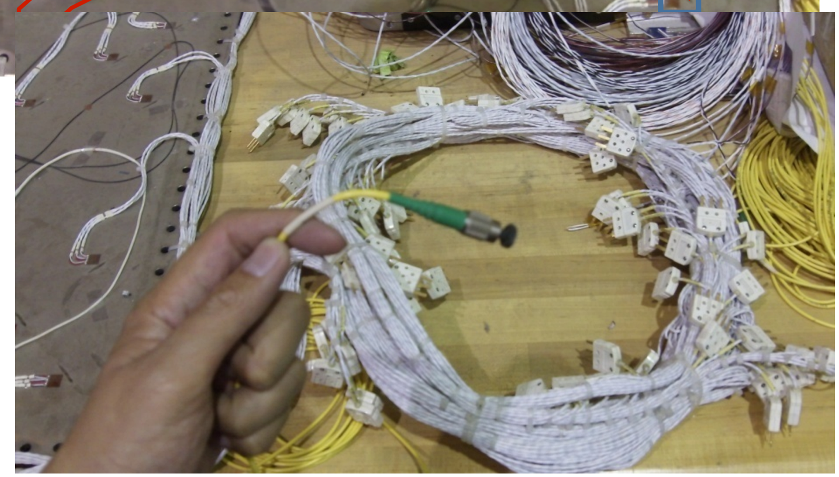
International Test and Evaluation Association (ITEA) Meeting
July 21st, 2010

National Aeronautics and Space Administration
Dryden Flight Research Center

Introduction: Why Use Fiber?

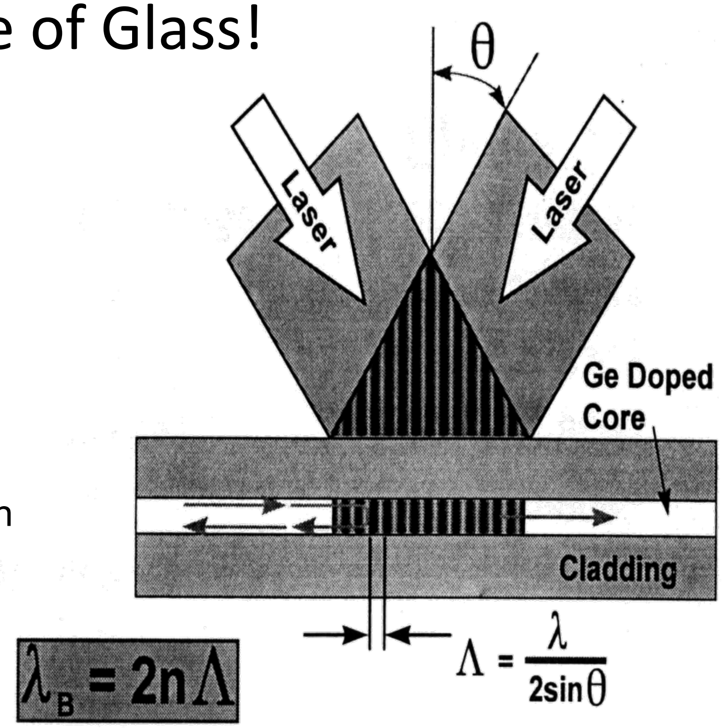
- Immunity to electromagnetic interference, radio-frequency interference, and radiation.
- Compact, lightweight, ruggedized device for smart structure
  - Embedded into structure
  - Harsh environment (under water)
- The ability to be multiplexed. (100s of sensors on a single fiber).
- Ease of installation and use (single fiber vs. multitude of lead wires).
- Potential low cost as a result of high-volume telecommunications manufacturing.
- WEIGHT SAVING vs Strain gauge



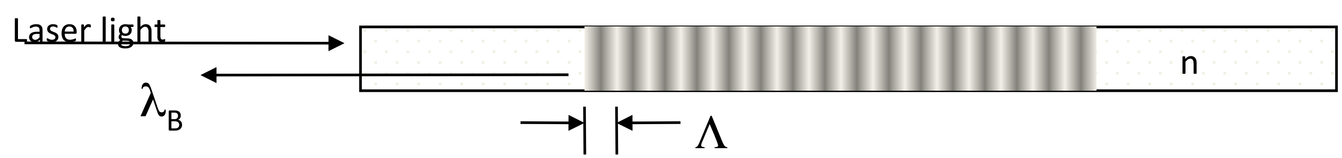


Background: A Piece of Glass!

- Fiber Bragg Grating (FBG) sensor is that a change in strain state will alter the center wavelength (λ) of the light reflected from an FBG.
- A fiber's index of refraction (n) depends on the density of the dopants it contains.
- FBGs are created by redistributing dopants to create areas that contain greater or lesser amounts, using a technique called laser writing or dopant modulation.
- The index of refraction is modulated throughout the length of the grating.
- This grating reflects a narrow spectrum of light that is directly proportional to the period of the index modulation (Λ) and the effective index of refraction (n).
- The Bragg wavelength (λ_B), is expressed by $\lambda_B = 2\,n\,\Lambda$. Because change in temperature (ΔT) and strain ($\Delta\varepsilon$) directly affect Λ and n, any change in temperature or strain directly affects the λ_B.

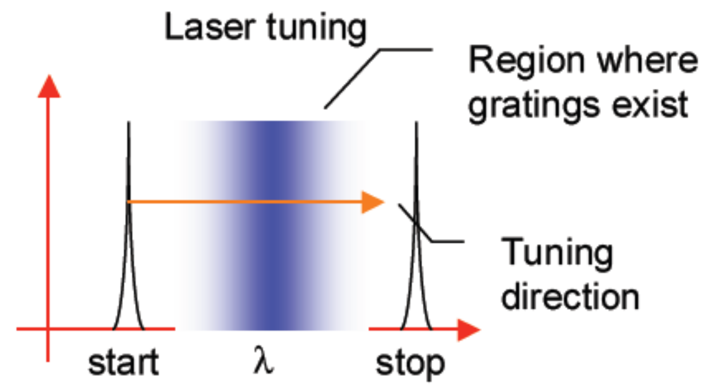


$$\frac{\Delta\lambda_B}{\lambda_B} = K\varepsilon$$



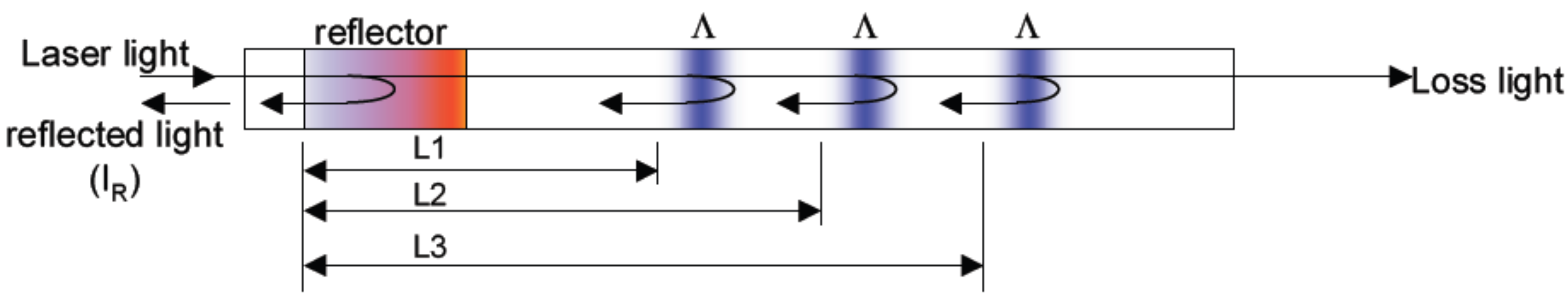
NASA Grating Modulation Multiplexing Method

- Multiplex 100s of sensors onto one fiber.
- All gratings are written at the same wavelength.
- A narrowband wavelength tunable laser source must be used to interrogate sensors.
- Sensor size can be from 0.1mm to 100mm gage lengths.

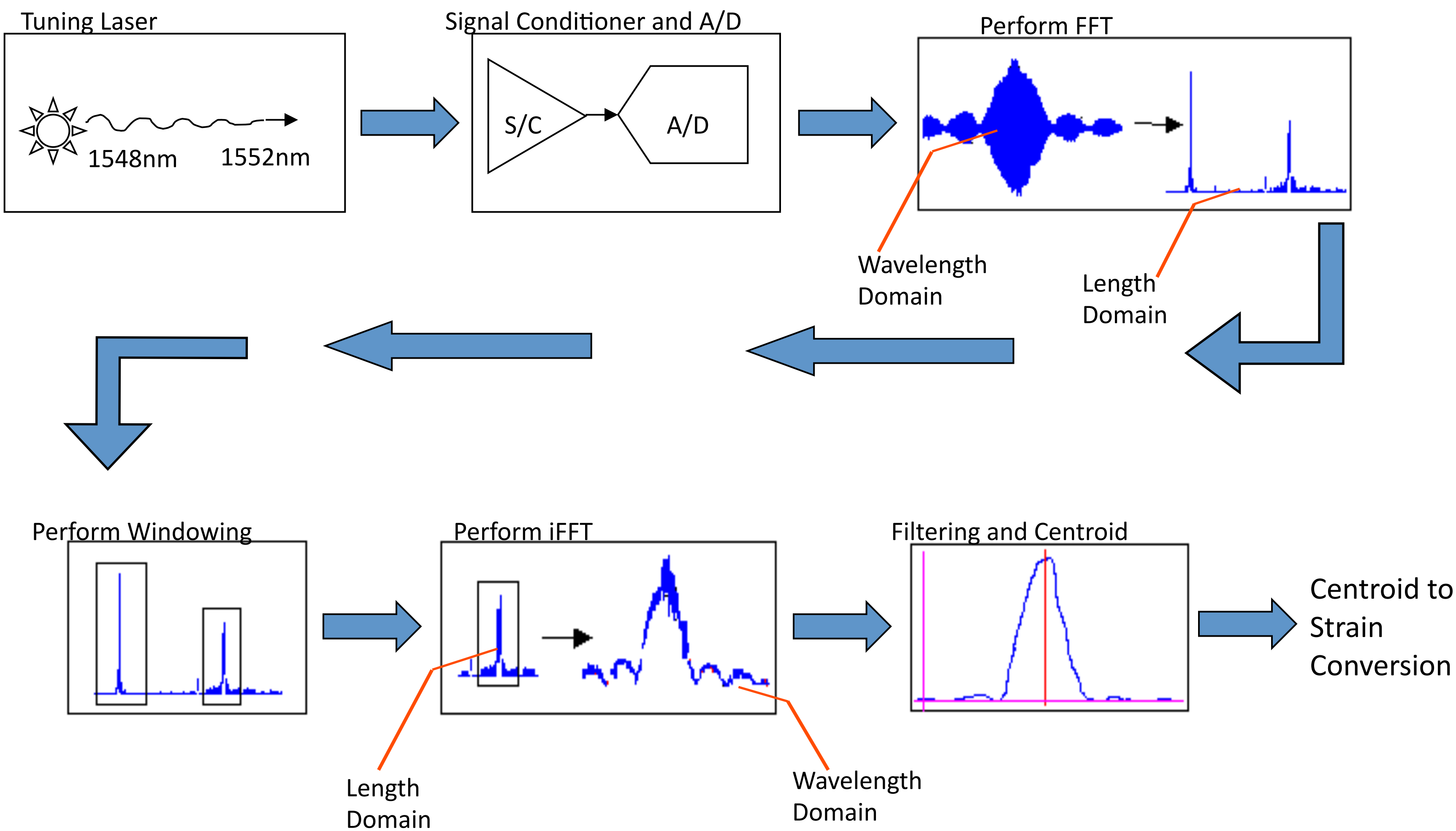


$$I_R = \sum_i R_i Cos(k2nL_i) \qquad k = \frac{2\pi}{\lambda}$$

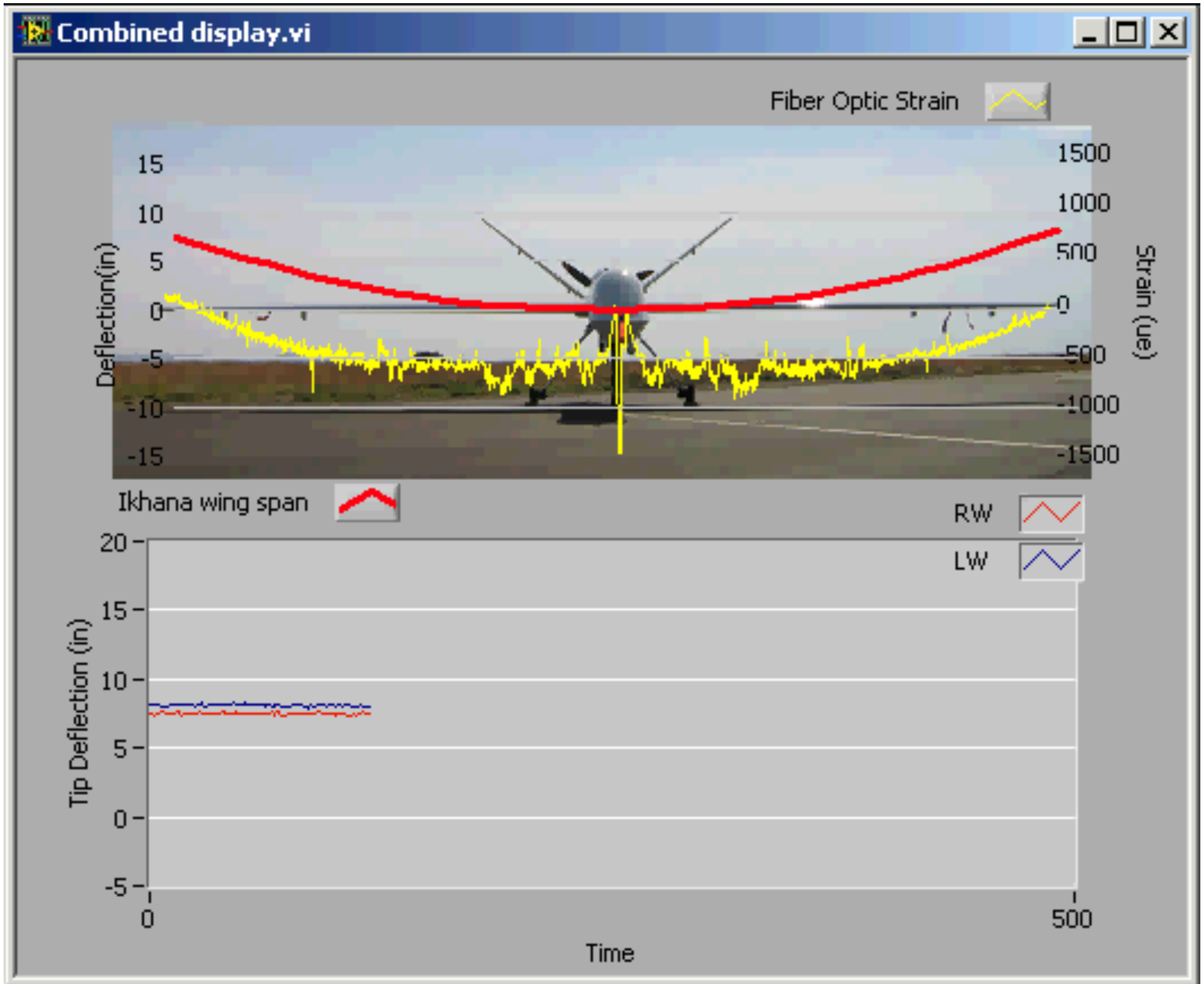
R_i – spectrum of i^{th} grating
n – effective index
L – path difference
k - wavenumber



Processing Procedure



Fiber Strain Sensors in Action



Fiber Optics Wing Shape Sensing System (FOWSS) for Ikhana

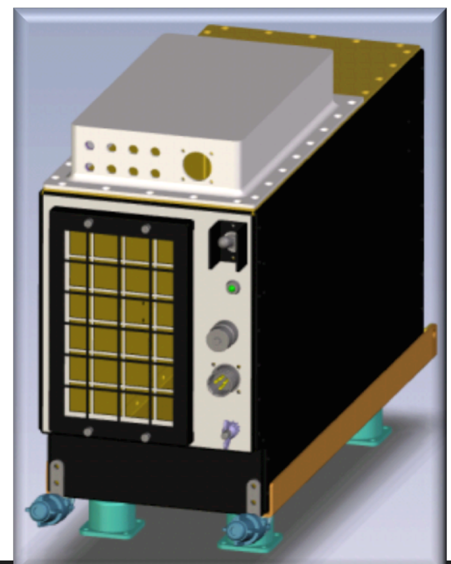
• Fiber count:	4
• Max Fiber length:	40 ft
• Max sensing length:	20 ft
• Max gages/fiber:	480
• Total gages/system:	1920
• Sample rate:	50 Hz @ 2 fibers
	30 Hz @ 4 fibers
• Power:	28Vdc @ 4 Amps
• Weight:	23 lbs
• Size:	7.5 x 13 x 13 in

Fiber Optics Instrumentation Development System for NASA Composite Crew Module

Fiber count	4
Max. fiber length	40 ft
Max sensing length	20 ft
Max. sensors / fiber	480
Total sensors per system	1920
Min. grating spacing	0.5 in
Sample rate	2 fibers @ 50 sps 4 fibers @ 24 sps
Interface	Gigabit Ethernet
Power	120 VAC
Weight	12 lbs
Size	9 x 5 x 11 in

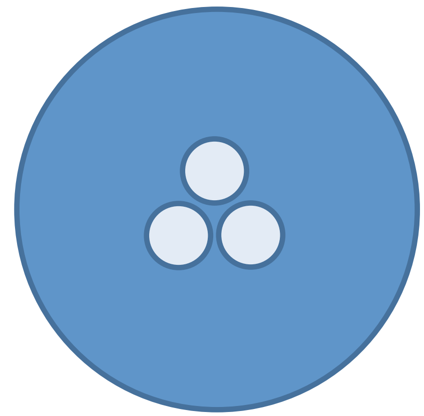
Fiber Optics Instrumentation Development System for Global Observer

- Fiber count: 8
- Max Fiber length: 80 ft
- Max sensing length: 40 ft
- Max gages/fiber: 1000
- Total gages/system: 8000
- Sample rate: 0-50 Hz
- Power: 28Vdc
- Weight: 28 lbs
- Size: 7.5 x 13 x 18 in

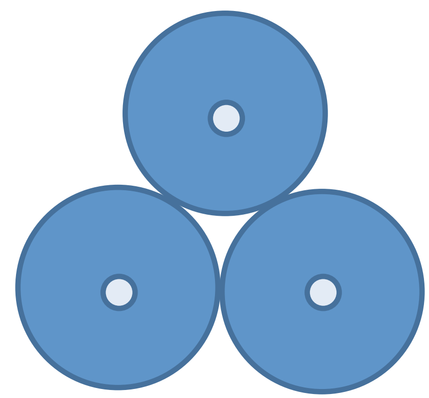


Recent Development
Shape Sensing using fiber strain sensors

- From collaboration with NASA LaRC, shape sensing using fiber strain sensors has been realized
  - Initial research focuses upon 3-core fiber
  - This speciality fiber can be replaced with 3 conventional fibers superposition from one another at 120°
- From knowing the strain value of each fiber, the 3-dimensional position of the fiber can be accuracy rendered in real-time
  - Strain → 3D Position



3 core fiber



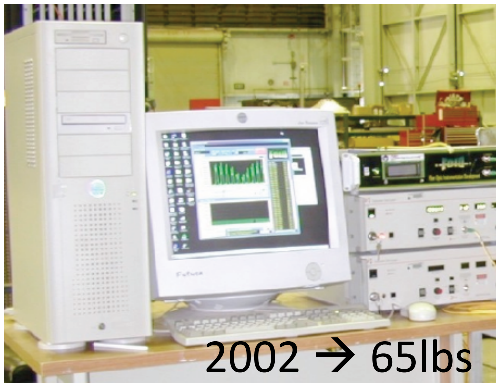
3 SMFs aligned in 120°

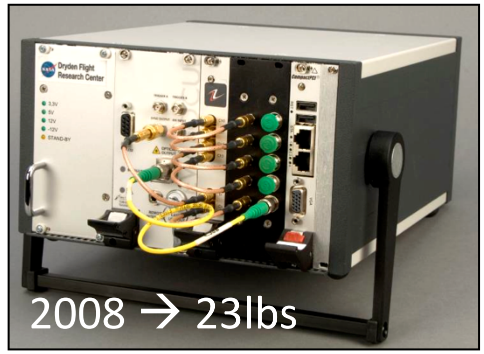
Prototype – Hexagon strain rod

Prototype – Shape sensing fiber

Conclusion

- NASA DFRC has successfully develop fiber optics strain sensors technology from laboratory to real-world application





2010 and beyond
8-channel system
>100Hz
~30lbs

2-channel system
~50Hz
~10lbs

- Current status
  - Dryden FBG system are installed on Ikhana and Global Observer UAV for real time strain sensing
  - Real-time fiber shape sensing is currently being developed
- Potential application of technology beyond aeronautics
  - Automotive Sector
  - Energy Sector
  - Biomedical Sector