

SHM System for Composite Structures



- **Motivation:**

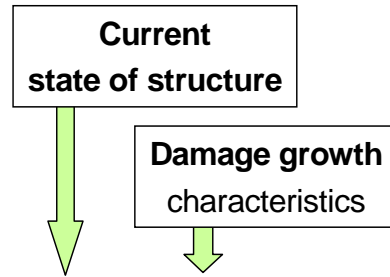
Impact damage in composite structures followed by continued cyclic loading can lead to structural failure and an SHM system to monitor these will be useful.

- **Objective:**

aModally-seleEMC / Lamb wa/ sensors0.0005 Tc 5.002 0 T



Structural Health Monitoring and Lifetime Prediction

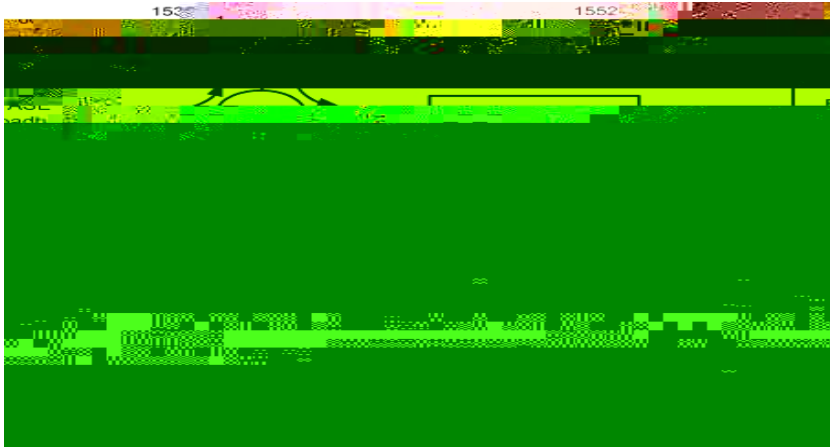


Structural Health Monitoring System

Inspection and Repairs

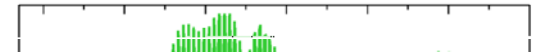
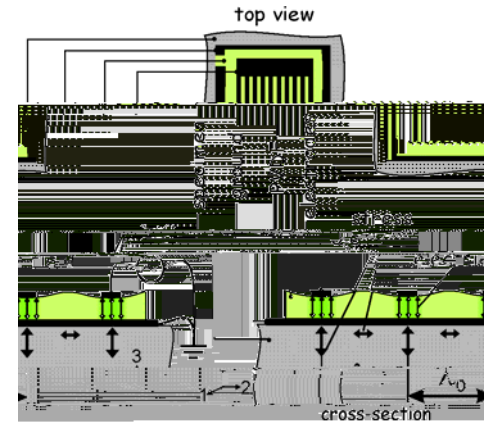


Monitor / Identify Impact Location

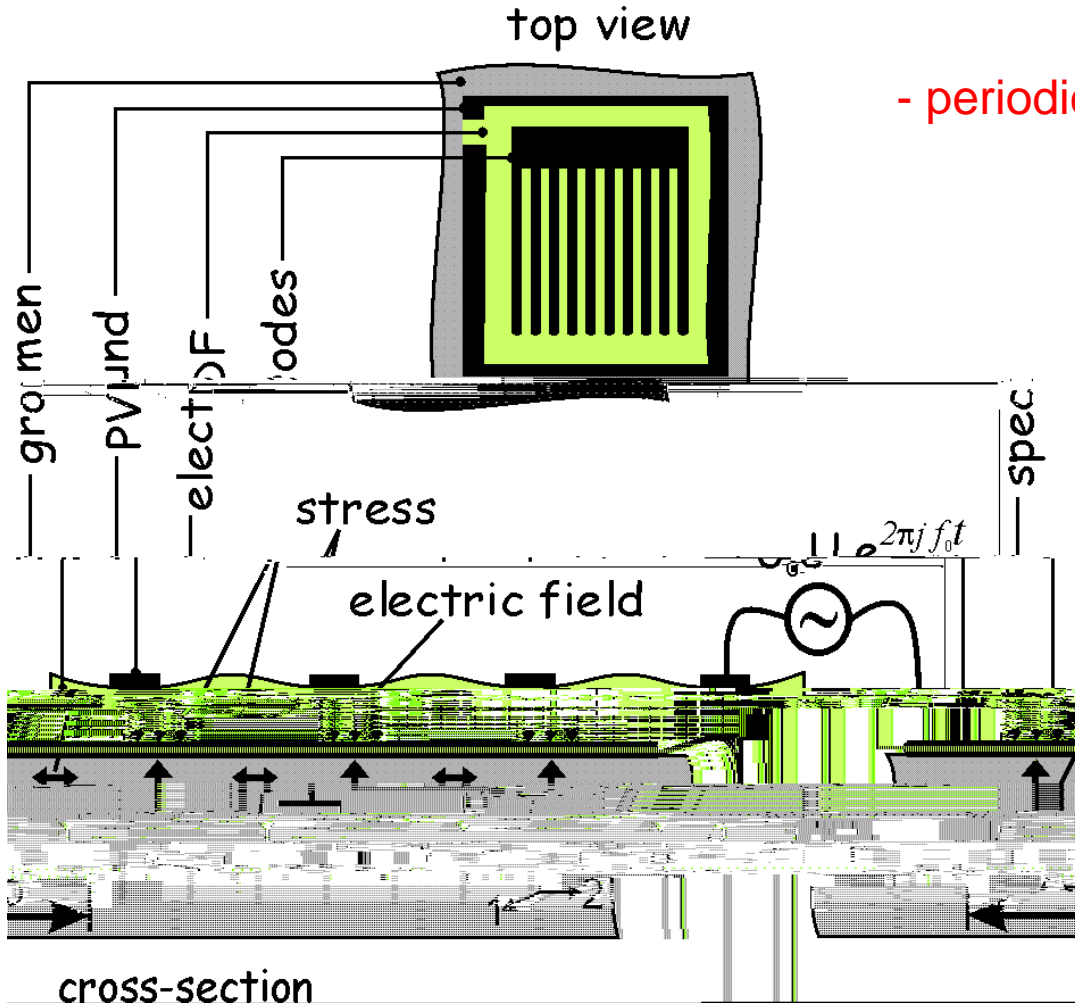


-0.001 0.000 0.001 0.002
Time(s)





Mode-Selective Lamb-Wave Sensors

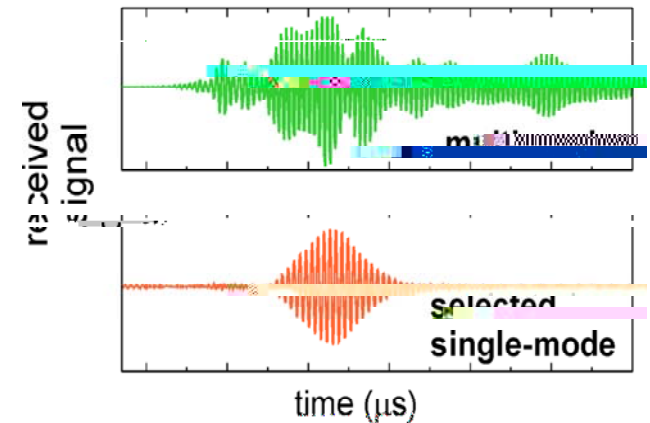


The comb design:

- periodic array of sources (period= λ_0) -

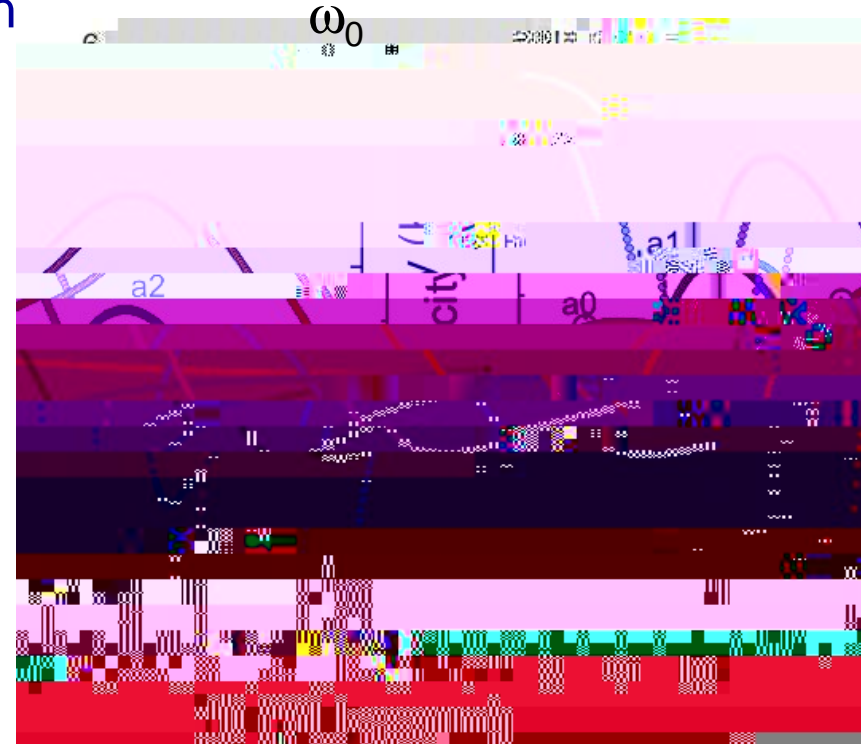
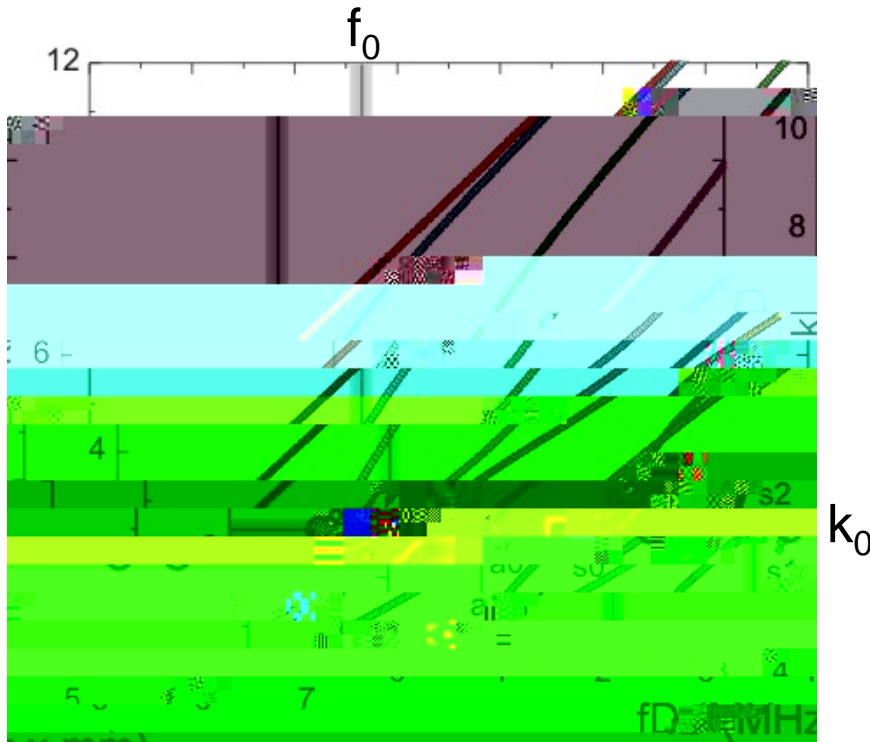
Characteristics:

- unobtrusive: 0.3 mm thick
- malleable
- inexpensive
- mode-selective



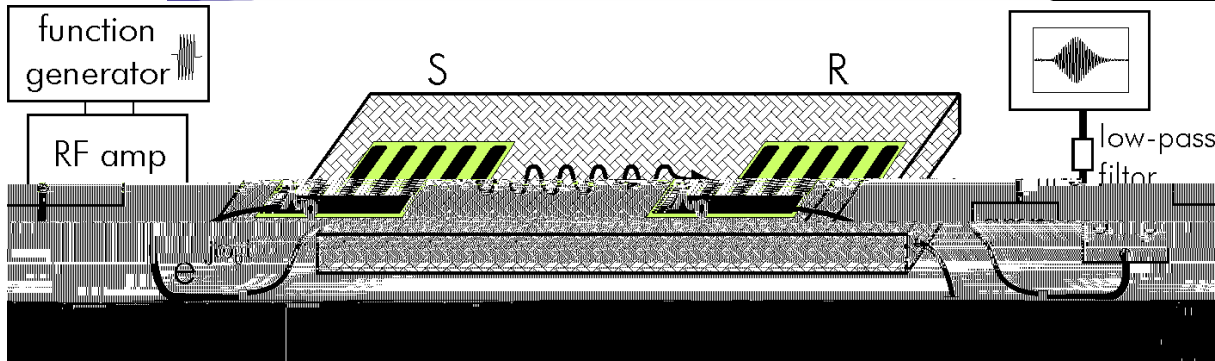


Wavelength λ_0 ($2\pi/k_0$) imposed by design
 \Rightarrow only one mode can satisfy $c_0 = \omega_0/k_0$.

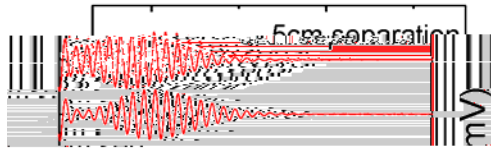


Excitation: in a low-dispersion domain

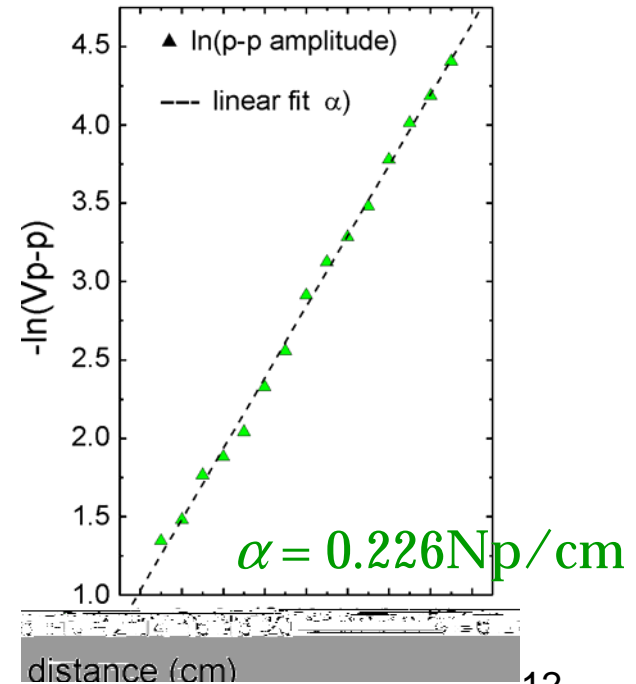
Mode Propagation (minimal dispersion)



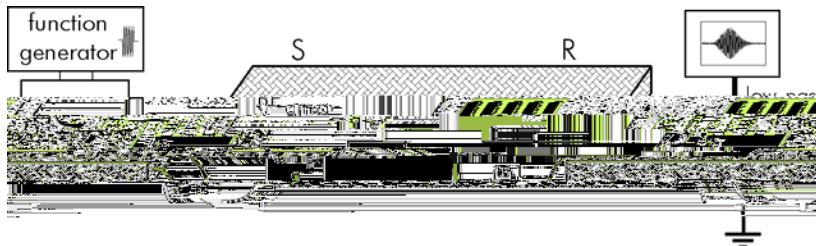
- 16 ply carbon-epoxy woven composite
- a_0 mode ($f=0.31\text{MHz}$, $\lambda=4.5\text{mm}$)



$$c_g = 1.59 \text{ mm/ms}$$



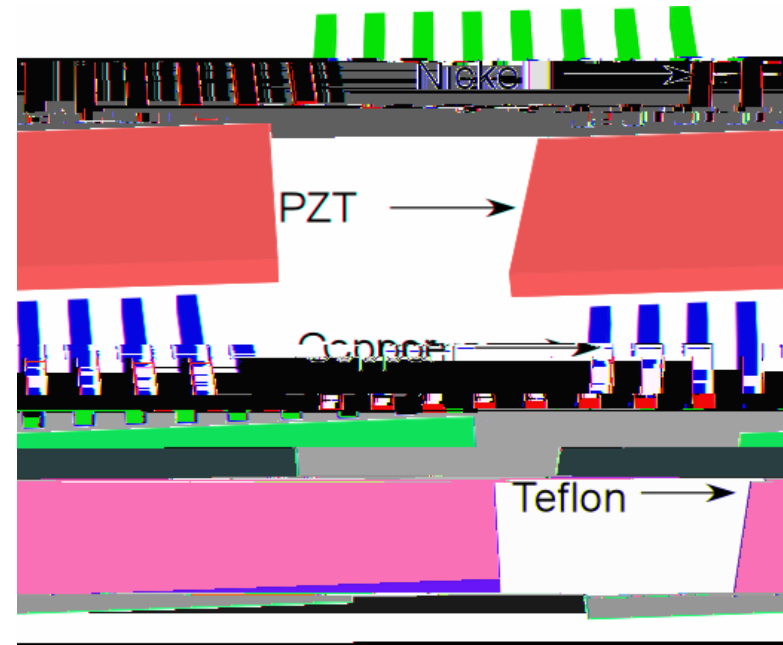
Array Design Configurations



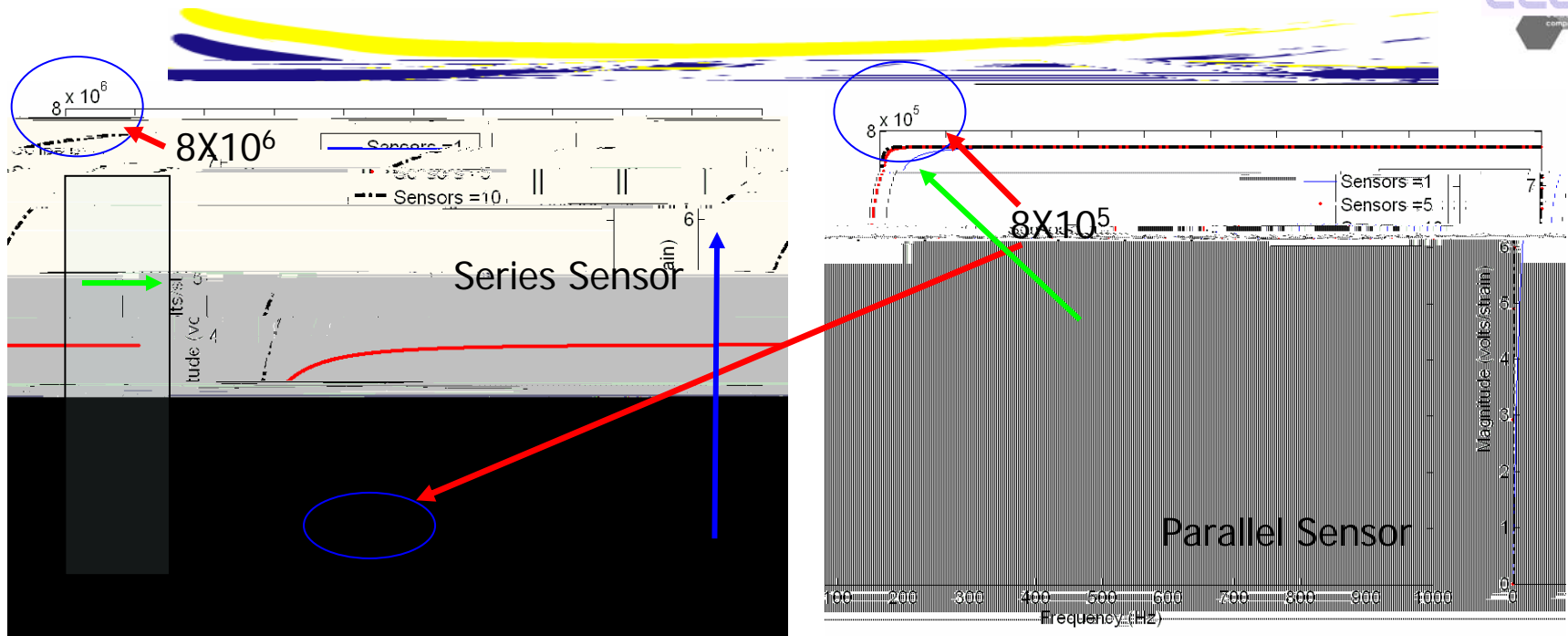
- Generator array is best connected in parallel.
- Receive array is best connected in series.



Generation Transducer array

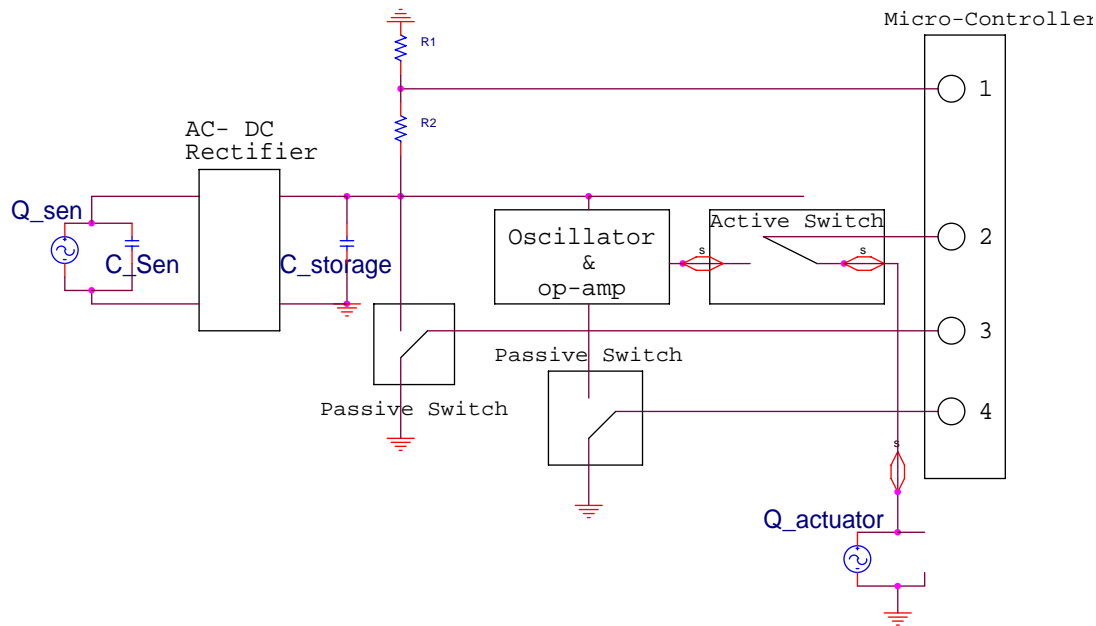


Receiver Transducer array



$$\frac{V_o}{S} = \frac{(e * A_e * R_o * n * j * \omega)}{n + (j * \omega * C * R_o)}$$

$$\frac{\begin{pmatrix} * & * & * & * & * \end{pmatrix}}{1 \begin{pmatrix} * & * & * & * \end{pmatrix}}$$

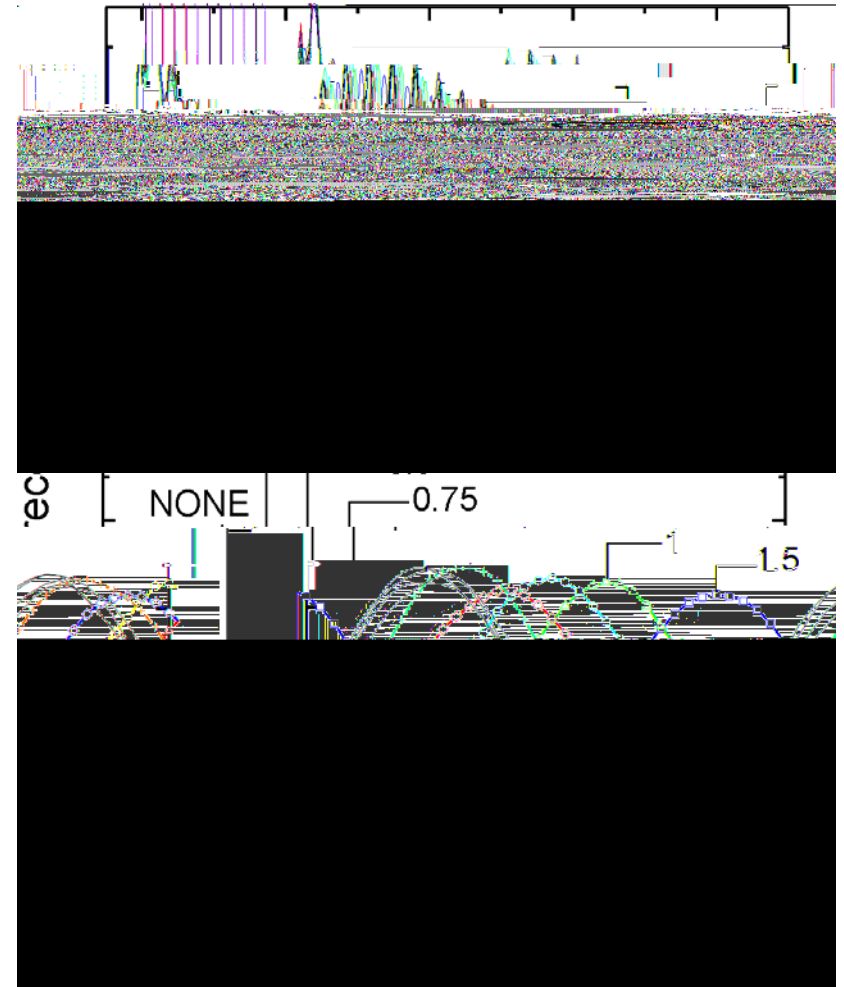
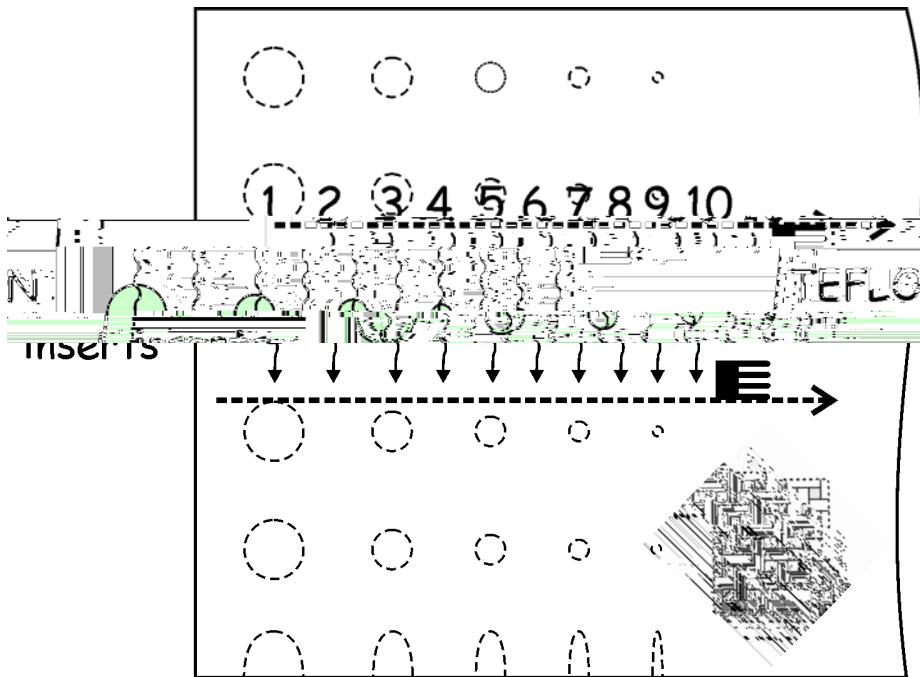




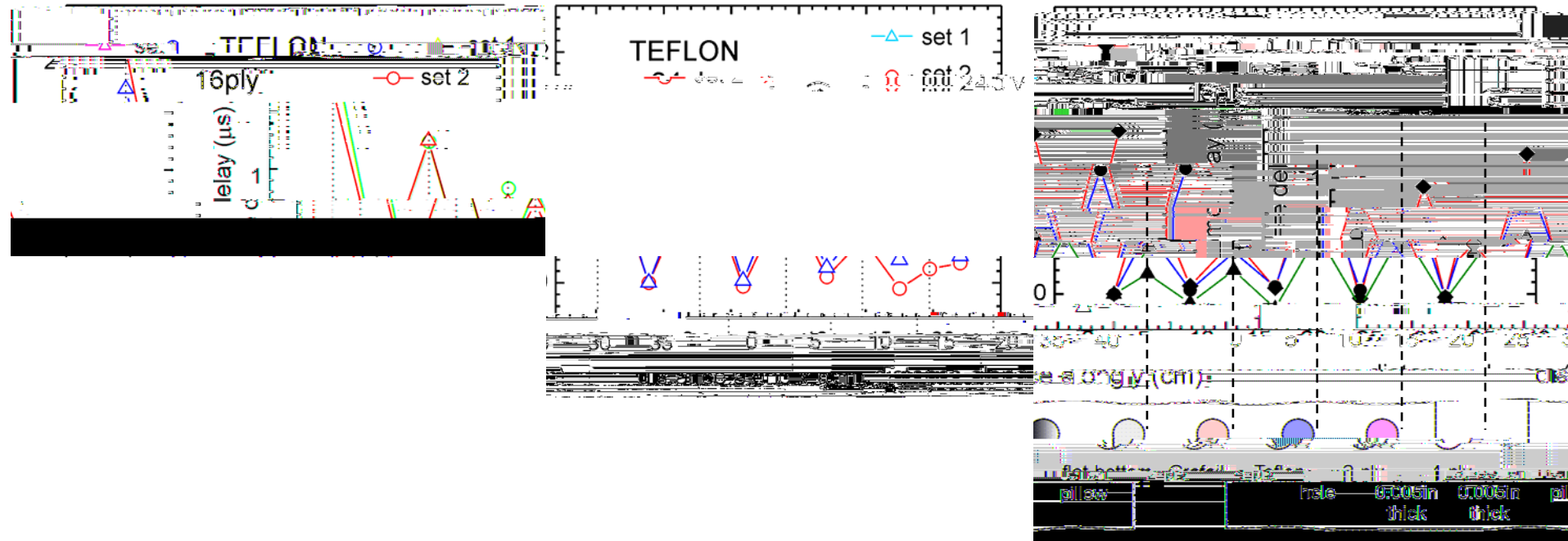
Delamination Signature

(decrease in group velocity)

single mode (a_0) tone-burst propagation



Delamination Signature Time-Delay





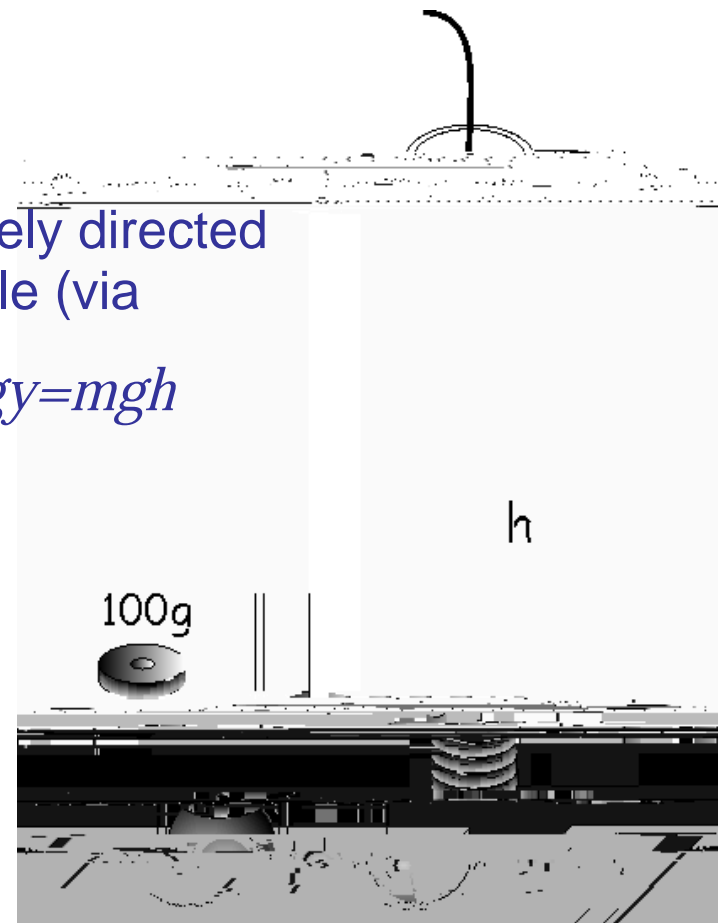
Material:

Toray T800 BMS 8-276
manufactured by:
NIAR, Wichita, KS

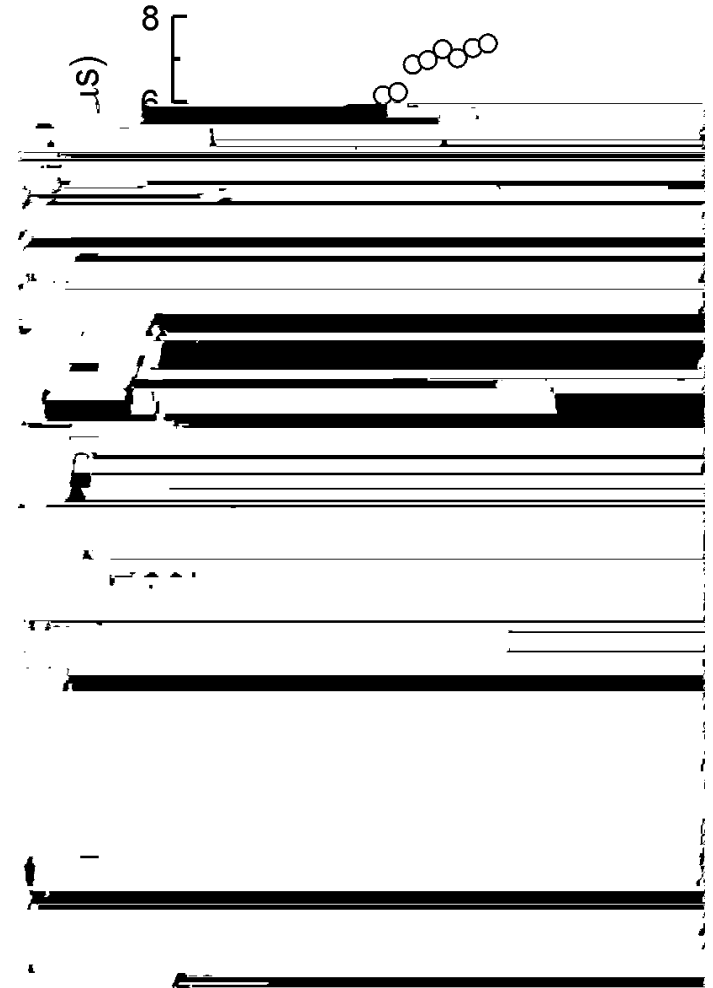
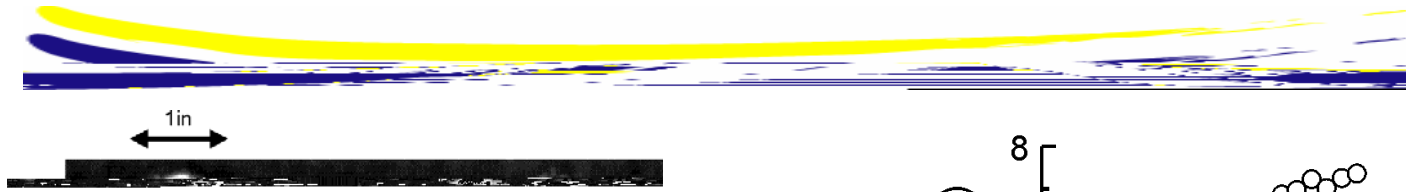
cross-ply $[0/90]_{6S}$
carbon-epoxy composite
4.6mm thick (24 plies)

- precisely directed
- variable (via

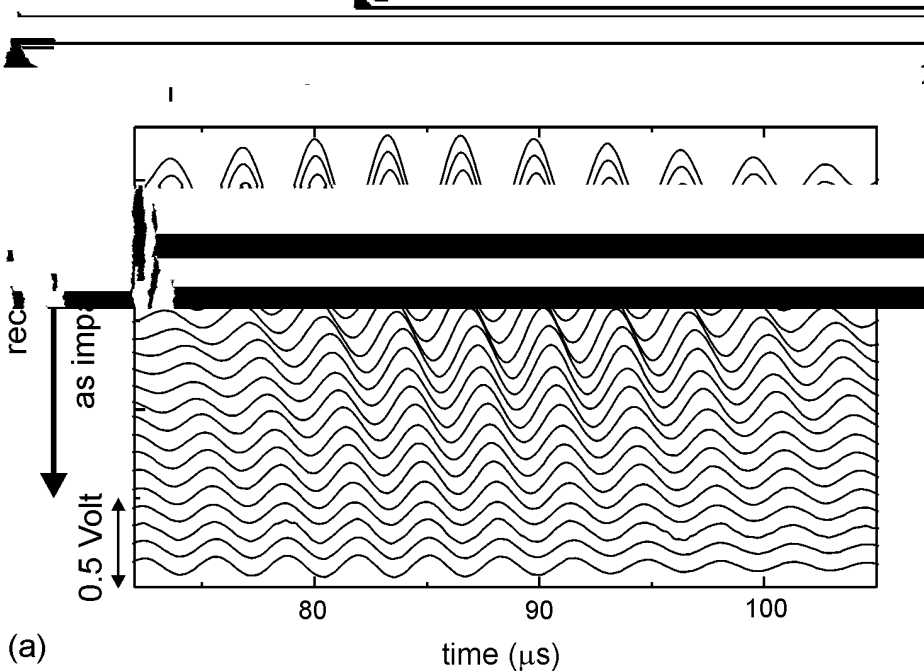
$$Energy = mgh$$



Impact Delaminations



time traces for the 22.1 impact data



(a)

- i) composite part suffers an impact and is monitored with sensors;
- ii) velocity changes

+

$$S(\tau) = a + b\tau^m$$

- Benefit to Aviation
 - Maintenance calls based on need
 - Cost saving
 - Reduced downtime
- Future needs
 - efficient wireless sensor systems for autonomous data acquisition and data management
 - damage growth laws