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National Defense Industrial Association

Salt Lake City, Utah

Simple Optical Sensors for Firing Tests

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

May 25, 2011

Presented by:

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Presentation Outline

- Background & Requirements
- Potential Solutions
- Approach
- Apparatus
- Findings
- Future Work

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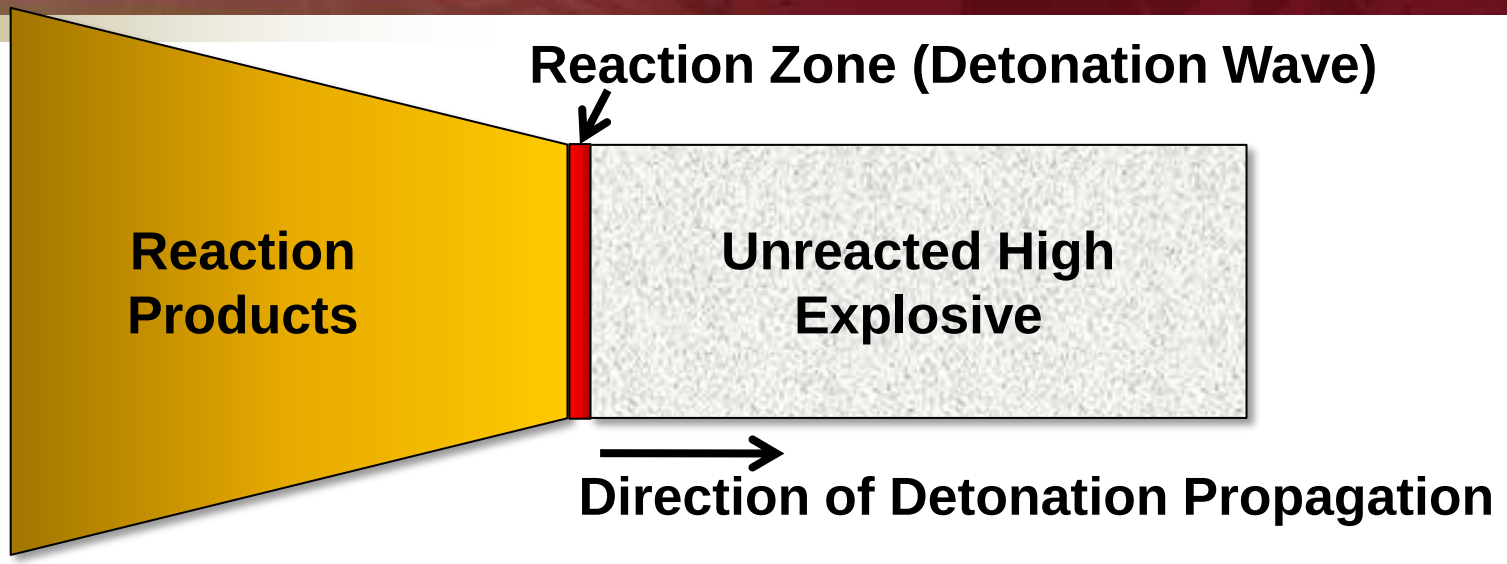
Explosives Firing Tests



What can we measure?

- **Sensitivity**
- **Combustion**
- **Working Capacity**
- **Detonation**

Refs: Test Methods for Explosives [Suceska1995]
Tactical Missile Warheads [Carleone1993]

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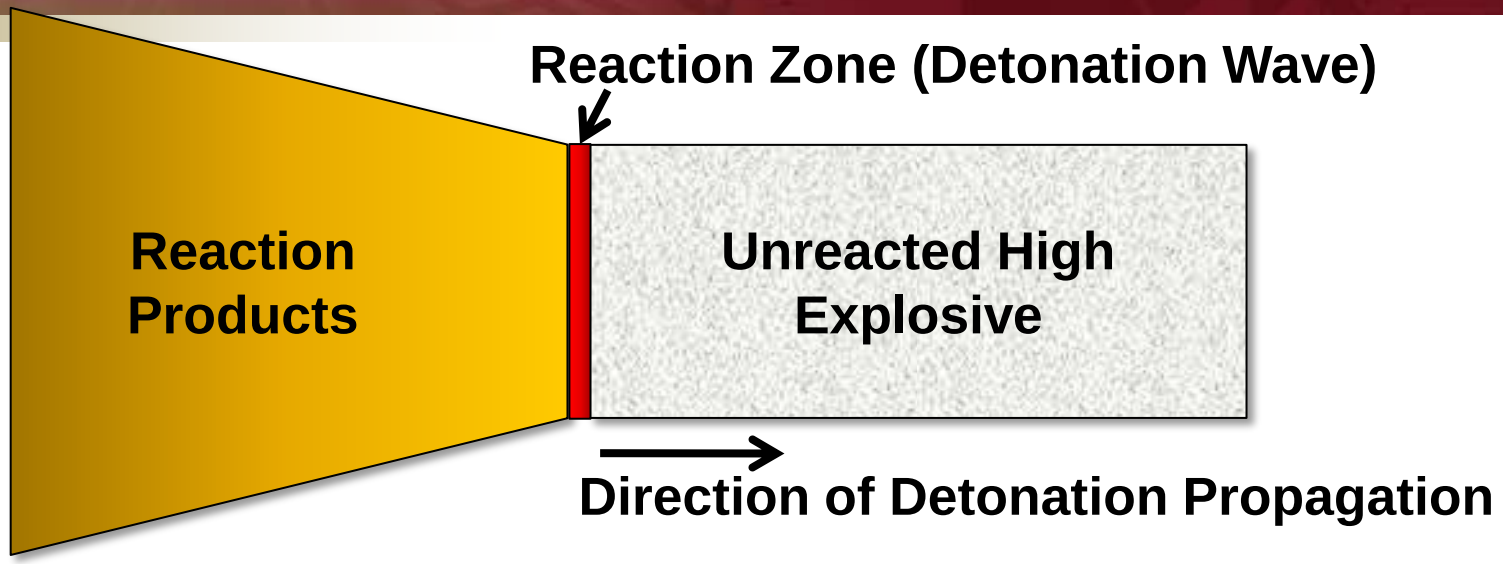

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- **Sensitivity**
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Parameters

- **Reaction or no reaction.**
- **Velocity**
- **Pressure**
- **Temperature**
- **Products' Composition**

Refs: Test Methods for Explosives [Suceska1995]
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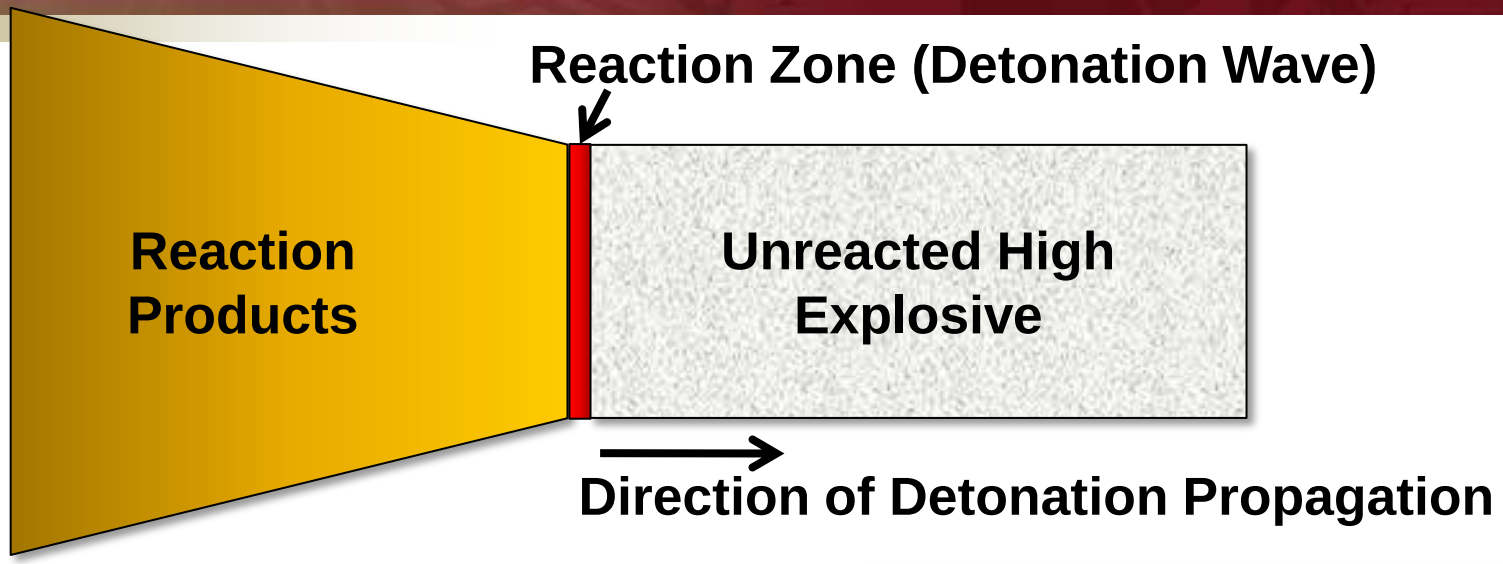
Explosives Firing Tests



What can we measure?

- Sensitivity
- Combustion
- Working Capacity
- Detonation

Some Techniques

- Streak / Framing Camera
- Schlieren / Shadowgraph
- Flash X-Ray Radiography
- VISAR
- PDV
- Fabry-Perot
- Conductive Probes
- Piezoelectric Probes
- Optical Fiber Probes

Refs: Test Methods for Explosives [Suceska1995]
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Tradeoffs

Want to measure:
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"Intrinsic" Requirements
- Accuracy
- Precision
- Sensitivity & Dynamic Range
- Calibration
- Channel Independence
- Intrusiveness
- Data Requirements

"Extrinsic" Requirements
- Cost (initial & recurring)
- Compatibility w/ existing equip.
- Skills required to use & maintain.
- Experimental Environment(s)

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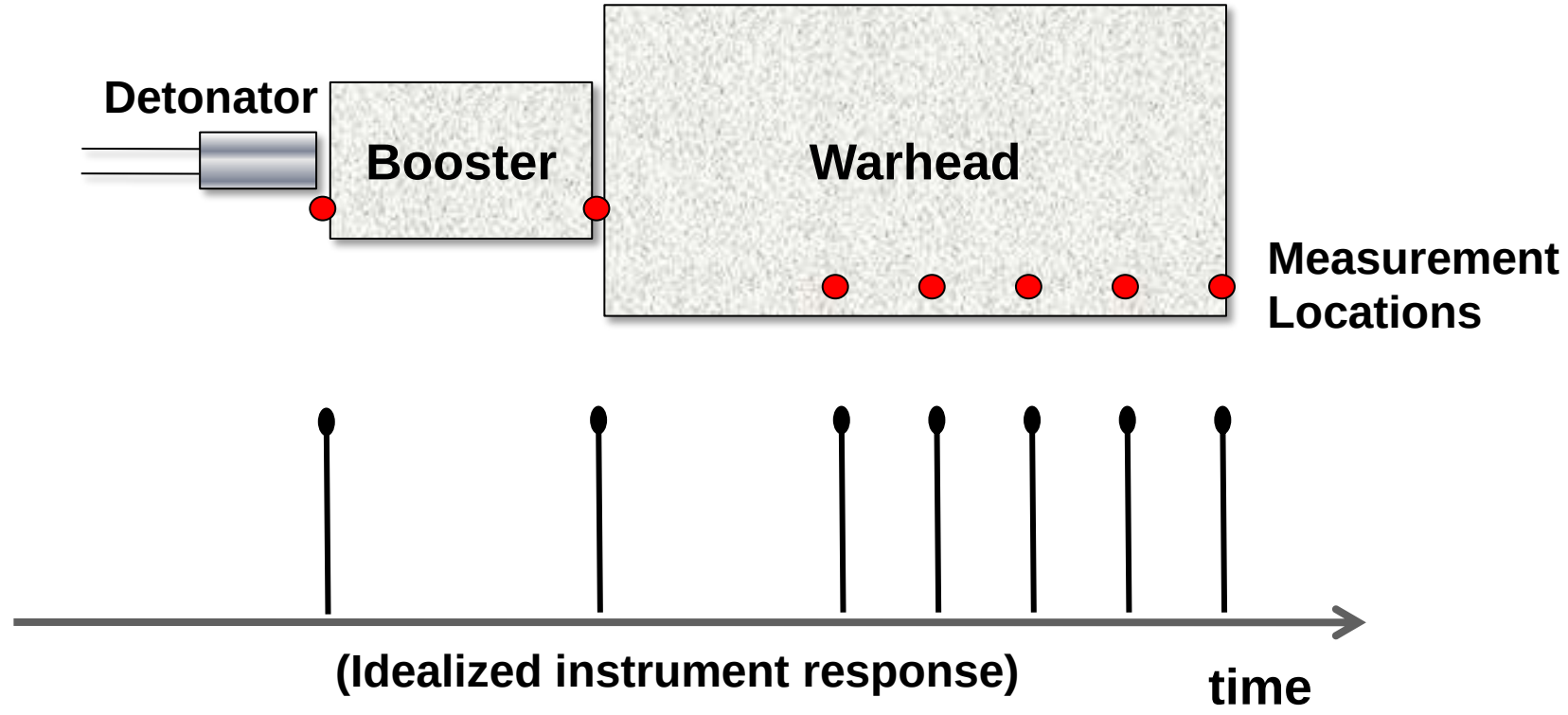
Probes

Measure the timing of the detonation wave as it propagates through the experimental specimen.



Possible Solutions

Conductive Probes
- Make / Break Switches
- Nichrome Wire
- Ion Pins

Piezoelectric Probes
- PVDF
- PZT

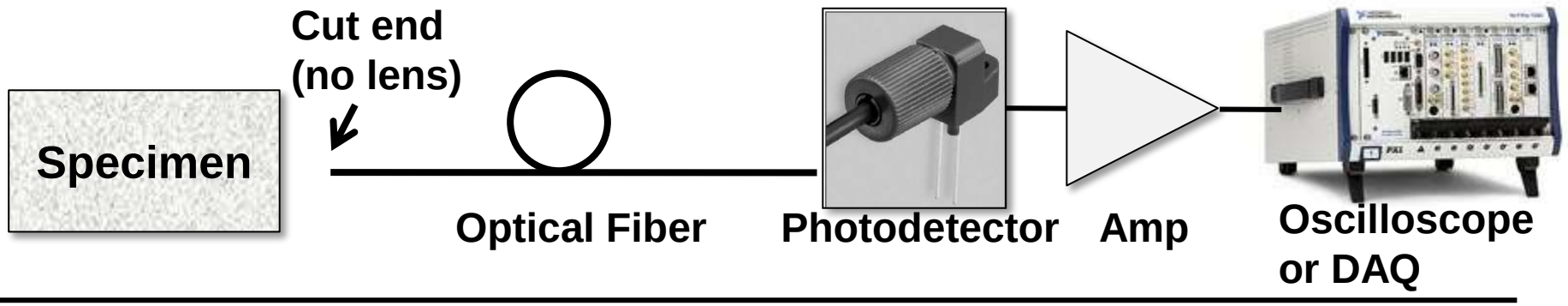
Optical Fiber Probes
- Optical Fiber
- Optical Fiber with Lens
- Modified Fiber

Potentially offers:
- Accurate, fast response.
- Channel independence.
- Scalability.
- Favorable Electromagnetics.

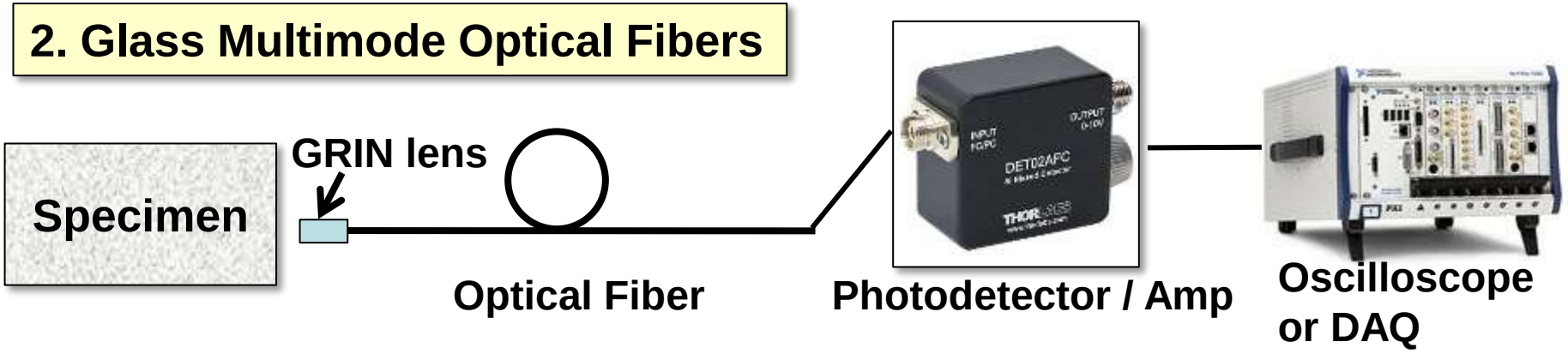
Refs: Test Methods for Explosives [Suceska1995]
High speed velocity measurements on an EFI-system [Prinse2007]
Dynasen, Inc., http://www.dynasen.com
Measurement Specialties, Inc., http://www.meas-spec.com/

Approach

1. Plastic Multimode Optical Fiber Probe

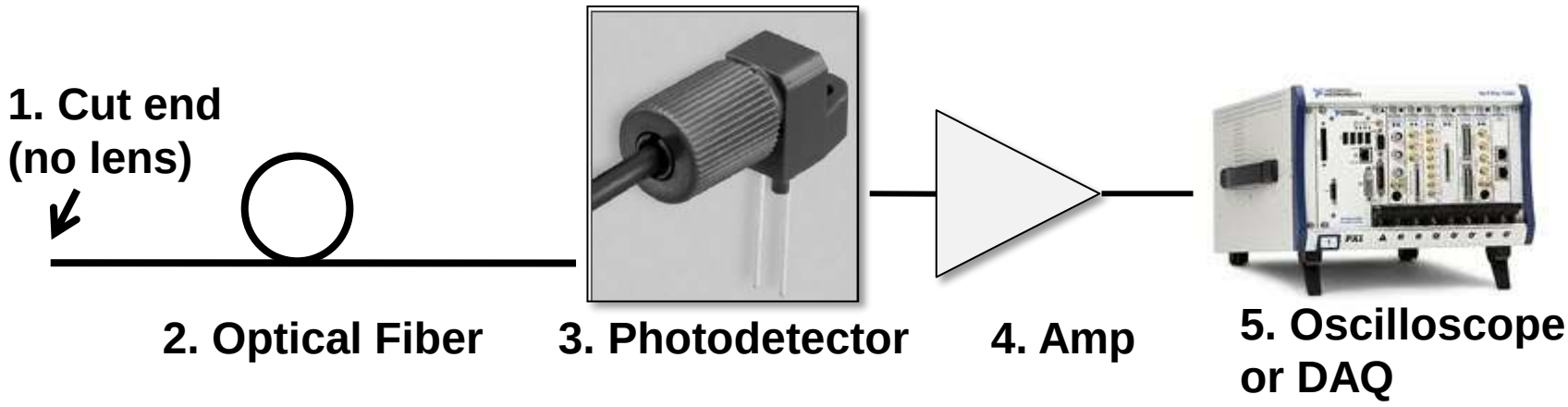


2. Glass Multimode Optical Fibers



Refs: Laser Light Scattering: Principles and Practice, Second Edition [Chu2007]
High speed velocity measurements on an EFI-system [Prinse2007]
Fiber Optic Sensors: An Introduction for Engineers and Scientists [Udd1991]
Electro-Optics Handbook, Second Edition [Waynant2000]

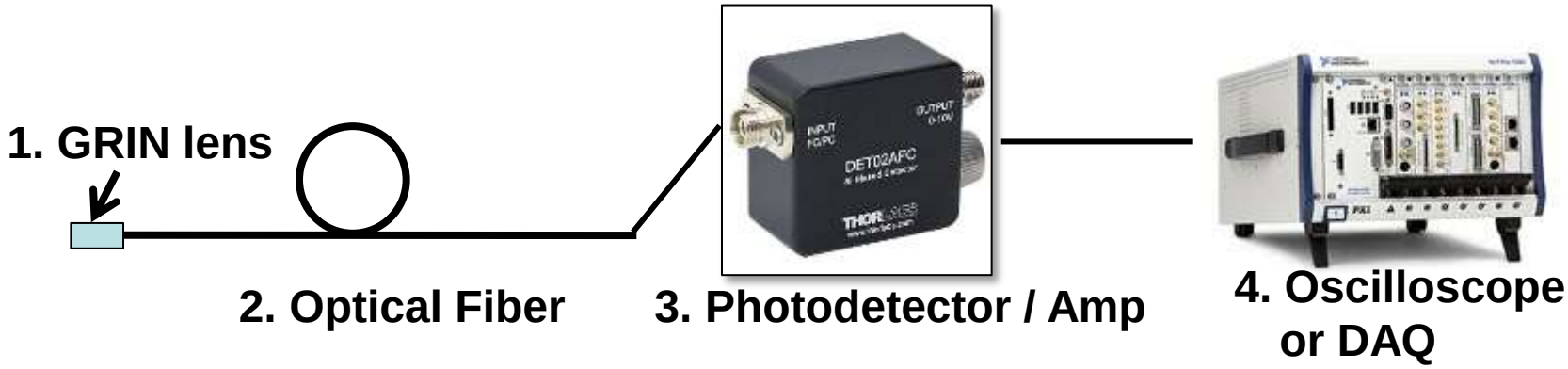
Apparatus – Plastic Fiber



1. Use a razor or craft knife to make a clean cut perpendicular to jacket.
2. Tyco Electronics, p/n 501232-4, step index multimode fiber, polyethylene jacket, PMMA fiber: n.core=1.49, n.clad=1.42, NA=0.46, Max atten 150db/km.
3. Industrial Fiber Optics IF-D91, tr=5 ns.
4. Amplifier as needed for signal conditioning.
5. Oscilloscope or Data Acquisition System (DAQ) as needed for data requirements.

Refs: Tyco Electronics, http://www.tycoelectronics.com
Industrial Fiber Optics, http://www.i-fiberoptics.com/

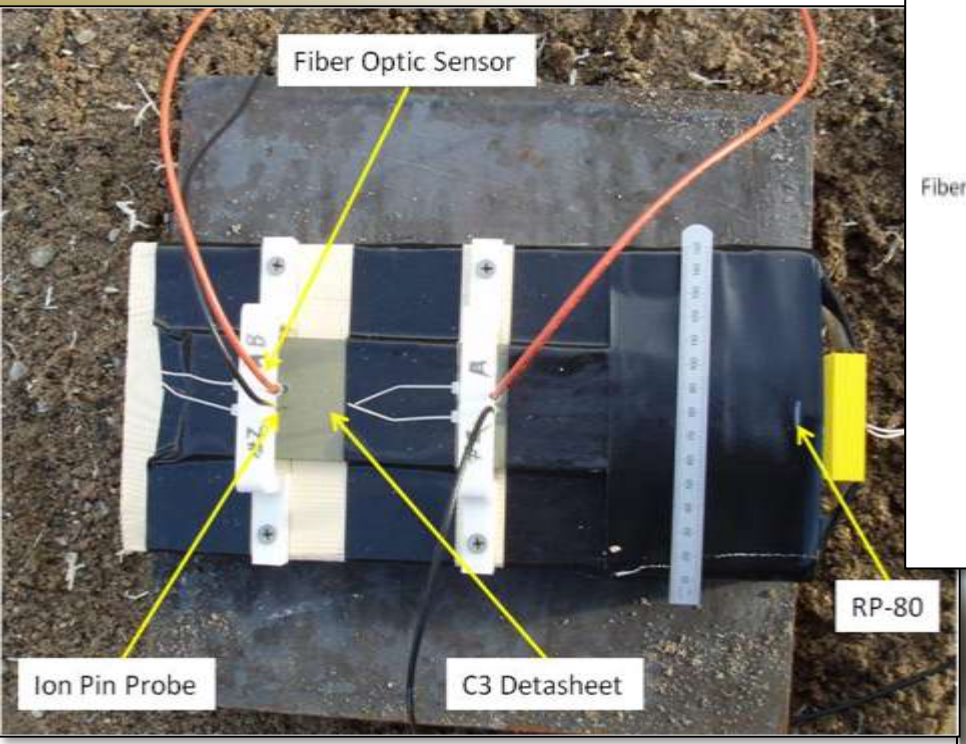
Apparatus – Glass Fiber

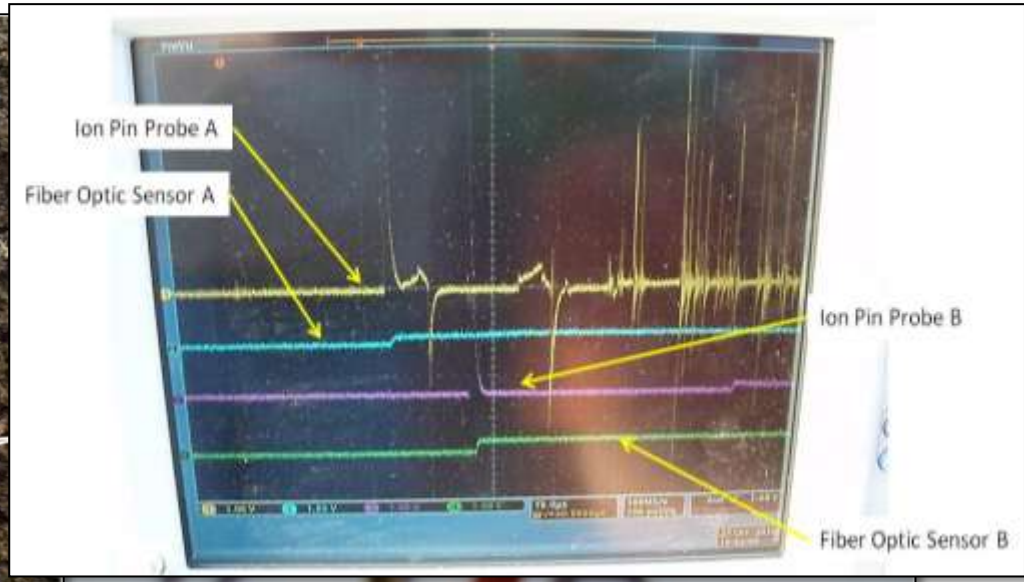


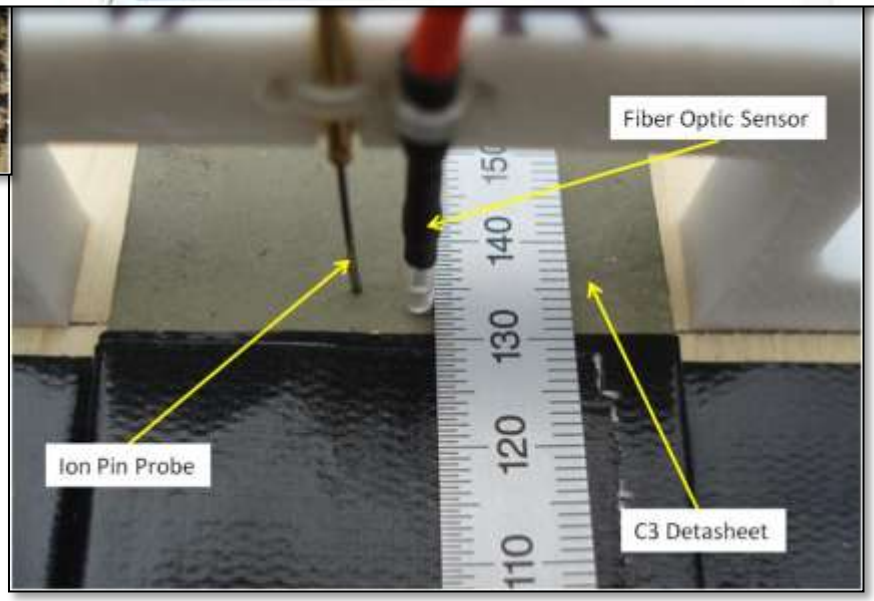
1. GoFoton (formerly NSG America) SELFOC(tm) Gradient Index Lens, p/n SLW-180-023-SBC. Oxide glass, 0.23 pitch, gradiant constant 0.332, N0=1.5986.
2. Fiber Pigtail and Patch Cable. Optequip p/n A10006 and A20182. The fiber itself is Corning Infinicore 300 62.5/125 micron glass multimode fiber. Fiber end is first cleaved, inserted in ferrule (Thorlabs p/n 50-1800-126), and polished, and then the lens is attached using Norland optical adhesive number 61 (NOA-61), which is cured using a UV light source. Polished fiber NA=0.27. FC connectors used.
3. Thorlabs DET02AFC photodetector/amplifier. Si photodetector, tr < 1ns.
4. Oscilloscope or Data Acquisition System (DAQ) as needed for data requirements.

Refs: Corning, http://www.corning.com/index.aspx
GoFoton / NSG America http://www.nsgamerica.com/
Norland Products, Inc. http://www.norlandprod.com/
Optequip, http://www.optequip.com/
Thorlabs, Inc., http://thorlabs.com/

Findings





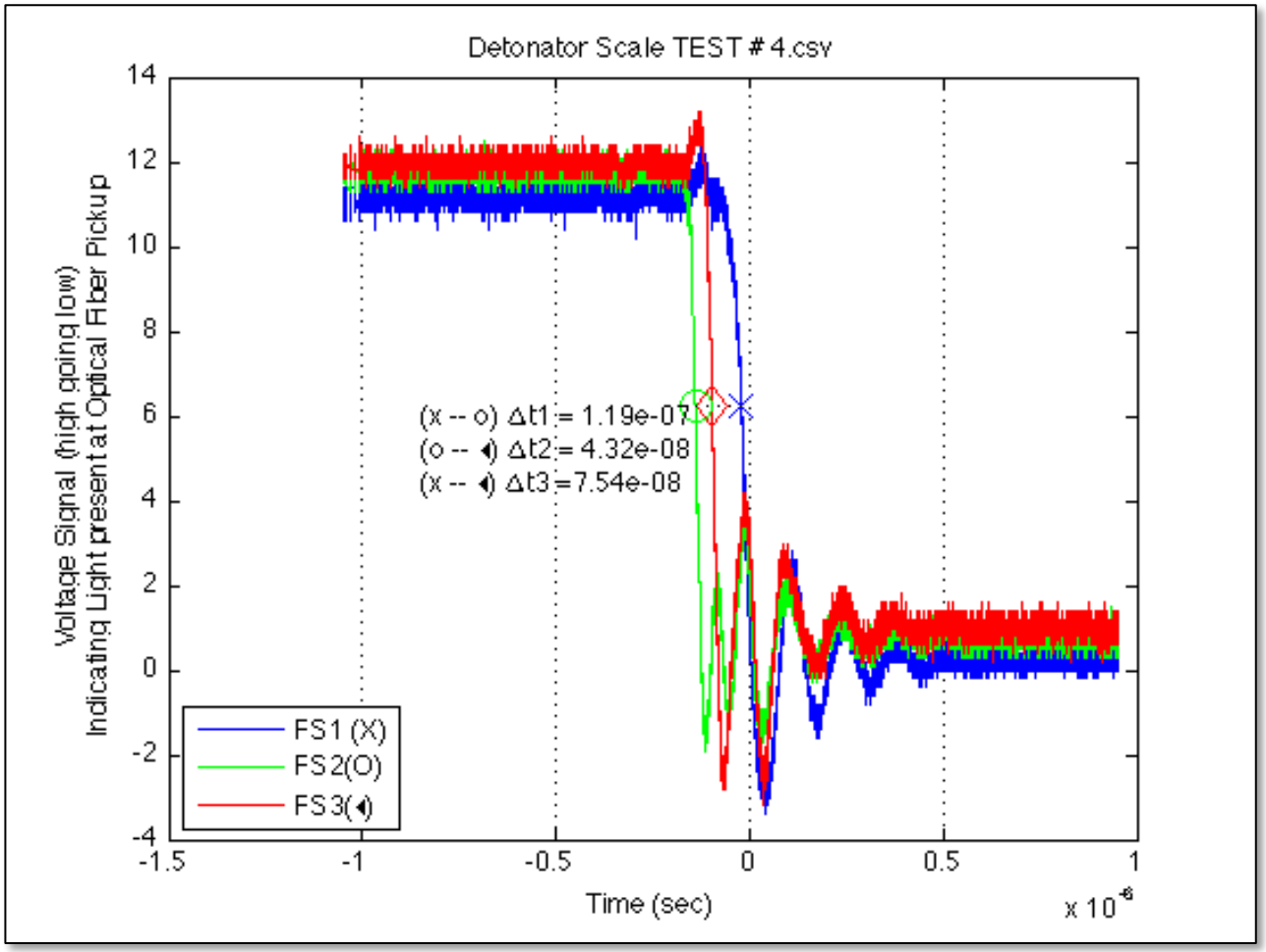


Test equipment included Tektronix DPO4101 Oscilloscope, a Dynasen model CS2-50-300 Pin Mixer to power the Ion Pin Probes, Two (2) Dynasen CA-1041 Ionization Pins, a laptop computer to record the data from the oscilloscope, two (2) Thorlabs DET02AFC Photodetectors, two (2) Fiber Optic Flash Sensors, and one (1) 100 meter multi-mode patch cable.

Courtesy of John Dunbar and Devin Chamness

Findings (cont'd)

Need to optimize system for fast, clean pulse response.



Total Delay T_D

$$T_D = \sum_{i=1}^{n} T_{Di}$$

Total Rise Time T_R

$$T_R = \sqrt{\sum_{i=1}^{n} T_{Ri}^{\,2}}$$

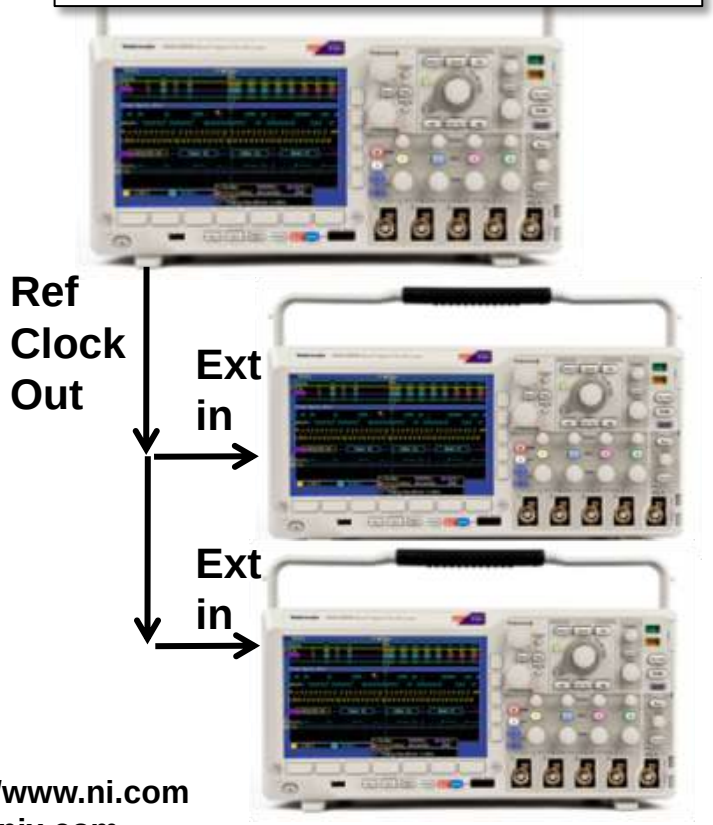
Refs: Elmore1948, Kennedy1988

Findings (cont'd)

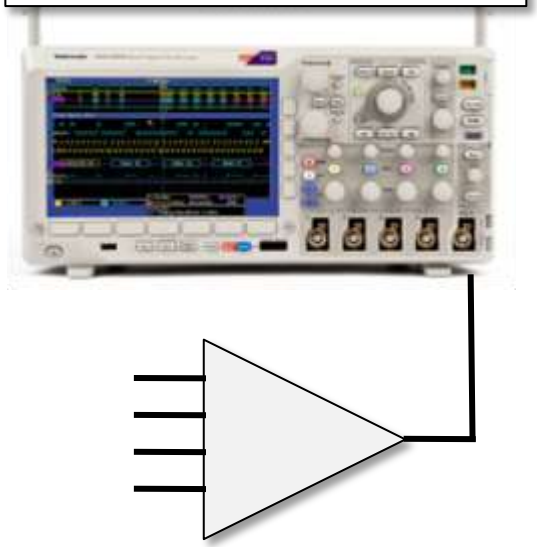
Scalability depends on common time reference across data record.

DAQ with many channels sync'd across bus.

Distribute common timing/trigger reference



Sum multiple inputs per channel



Refs: National Instruments, http://www.ni.com
Tektronix, http://www.tektronix.com
Operational Amplifier Circuits: Theory and Applications [Kennedy1988]

Future Work

- More firing experiments (Summer 2011).
- Develop calibration / channel equalization technique.
  - Suitable for field as well as lab.
- Obtain or design high-speed amplifier with compensation for high-speed pulses.
  - Lowpass filter with Thomson/Bessel linear phase
- Survey alternative parts/suppliers.

Questions?

Thank you!

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