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PORTABLE DOPPLER INTERFEROMETER SYSTEM FOR SHOCK DIAGNOSTICS AND HIGH SPEED MOTION

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(PRESENTATION ABSTRACT)

Velocity Doppler Interferometery is a technique that detects the frequency shift in monochromatic light reflecting off a moving surface. VISAR (Velocity Interferometer System for Any Reflector) is a system that uses the Doppler effect and is widely used for measuring the velocity of projectiles, detonations, flying plates, shock pressures (particle velocity) and other high speed/high acceleration motion. Other methods of measurement such as accelerometers and pressure gauges have disadvantages in that they are sensitive to radiation, electromagnetic pulses, and their mass can drastically alter the velocity of the projectile. Dent blocks are used to measure the final velocity of projectiles but the measurement has low accuracy and does not give a time-history of acceleration.

VISAR uses single frequency-single mode laser light focused onto a target of interest. Reflected light from the target is collected and sent through a modified, unequal leg Michelson interferometer. In the interferometer the light is split into two components which travel through the legs of the interferometer cavity and are then recombined. When the light recombines, an interference pattern is created which can range from dark (destructive interference) to bright (constructive interference). When the target moves, the reflected laser light experiences a frequency shift (increase) with respect to the frequency from the target in a static condition. Since the Doppler shifted light is split and routed through an **unequal leg** interferometer cavity, there is a time lag of the light containing the Doppler information at the recombination point in the interferometer. The effect of the time lag is to create a sinusoidally changing interference pattern (commonly called fringes). Since the interferometer time delay, laser wavelength, and the speed of light are known, an accurate measurement of target velocity/acceleration may be measured by analyzing both the number of fringes and the speed of fringe generation (system accuracy is 3-4%).

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* Presenter

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The unique method of measurement that the VISAR uses has some distinct advantages over more traditional methods of measurement:

- There is no mass loading of the projectile because light is the only component contacting the target.
- The system is based on light-speed measurements resulting in very high system bandwidths(VISAR can measure velocities from 20-10,000 meters-per-second.).
- The laser light is insensitive to radiation, electromagnetic fields, and explosive environments.
- VISAR tracks the surface from **initial** to **final** velocity giving the user a complete history of motion. This time-history of motion is invaluable for component modeling.

In the past, VISARs have been limited to laboratory-type conditions because of the size, complexity, and sensitivity of the interferometer cavity and electronic components. A new design of VISAR (called the Fixed Cavity VISAR) has been developed. The Fixed Cavity VISAR is smaller, requires little maintenance, and is much simpler to operate than its predecessor. The system is installed in a standard instrumentation rack and any occasional fine adjustments may be performed remotely. The traditional VISAR uses a 1 Watt argon-ion laser which has very high power and cooling requirements that restrict portability and remote operation of the system. Recent developments of solid-state lasers and detectors have allowed development of a portable VISAR. The Solid-State VISAR uses diode lasers or diode pumped crystal lasers for its light source. These lasers require minimal power and cooling and have lifetimes four to five times greater than an argon-ion laser. An added benefit of the longer wavelengths of the solid-state lasers is that they perform well with fiber optics. Many experiments require a measurement system capable of operating "in the field" or in inaccessible areas such as containment vessels, contaminated areas or tunnels. Also, there may be a concern for the safety of personnel working in the area of the laser beam which is hazardous to the skin and eyes. To meet those requirements, a VISAR with fiber optic coupled sensor(s) has been developed and rigorously tested in the field. The laser light is sent to and collected from the target with fiber optic cables. The fiber optic coupled sensors direct light to the target, collect the reflected light and have the option of intra-optic video imaging which allows for remote viewing and recording of the test. Since the video camera is imaging the target through the same optics as the laser, a magnified image of the target and the laser spot is produced. For small, inaccessible, or hazardous targets, remote video imaging is a valuable technique.

The presentation described by this abstract will include the concept of VISAR, method of operation, and techniques of measurement. Also, data from a variety of tests will be discussed as well as a unique large-scale underground detonation where ground shock was measured using a fiber optic coupled sensor a few meters from the device.

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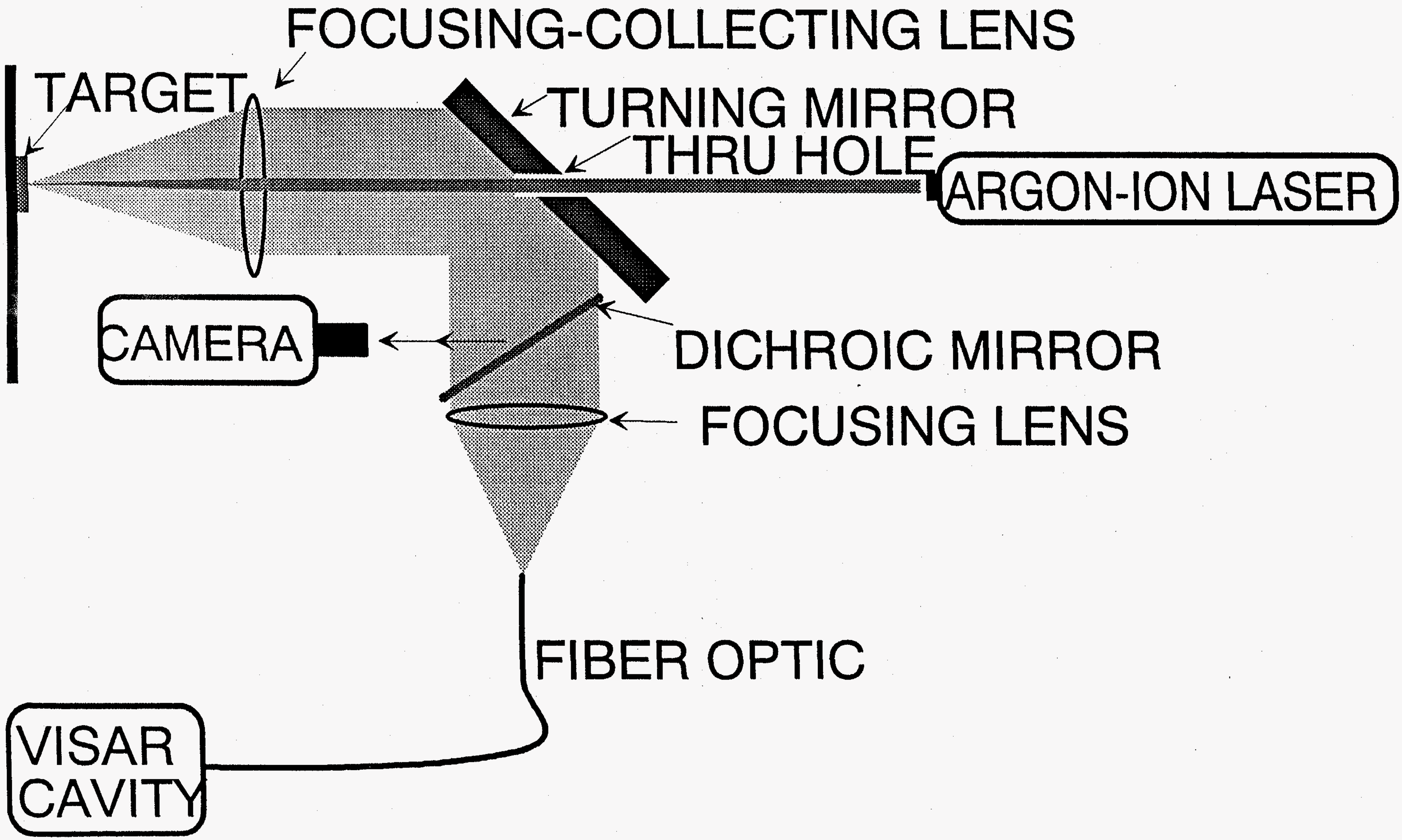
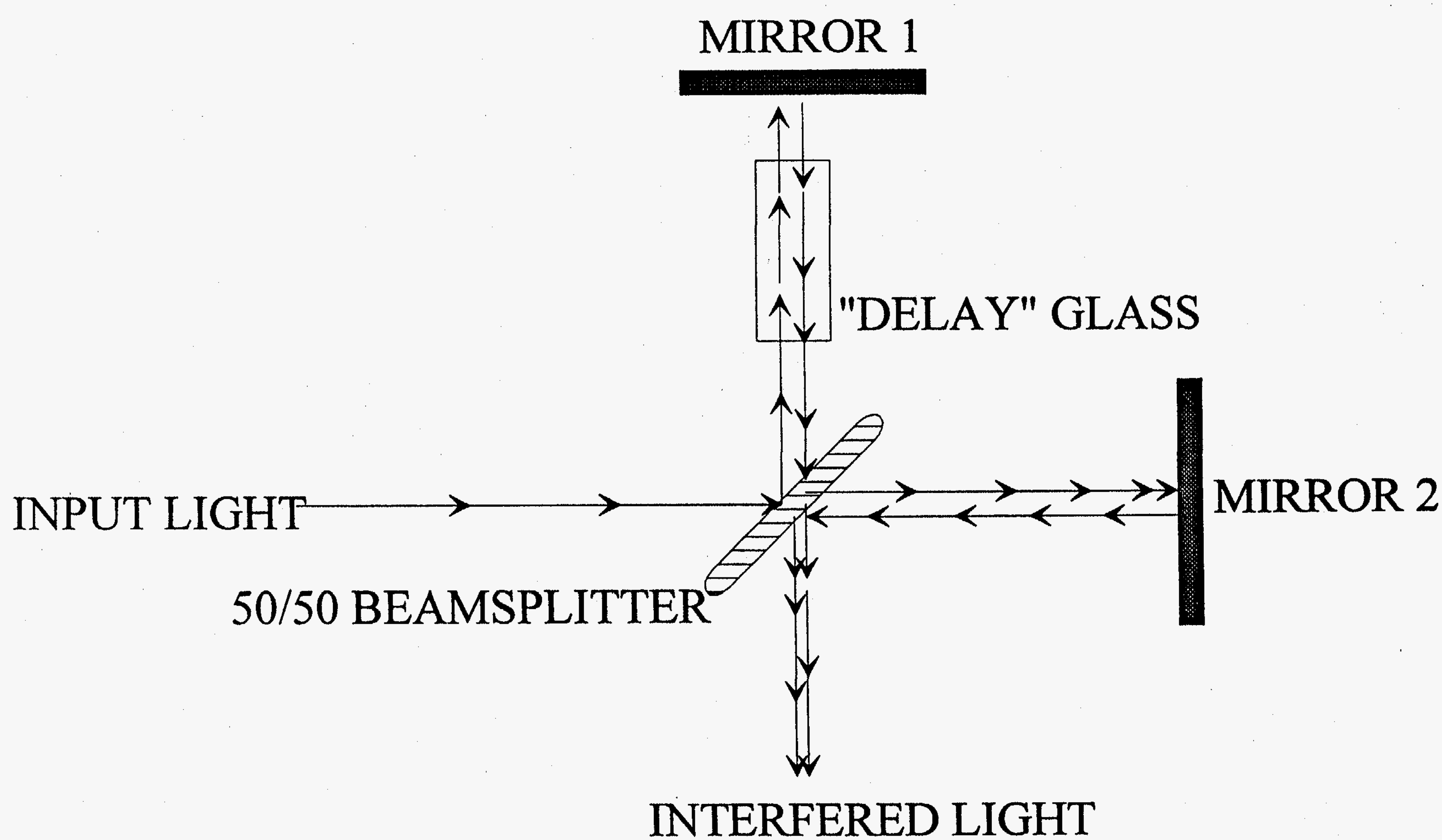
Velocity Interferometer System for Any Reflector (VISAR)

- SYSTEM IS BASED ON OPTICAL PHENOMENON
- SYSTEM CAPABLE OF MEASUREING VELOCITIES OF 20 - 10,000 METERS-PER-SECOND.
- ONLY LASER LIGHT IS TOUCHING TARGET
- MEASUREMENT ACCURACY IS +/- 2%
- VISAR MEASURES COMPLETE TIME-HISTORY OF MOTION

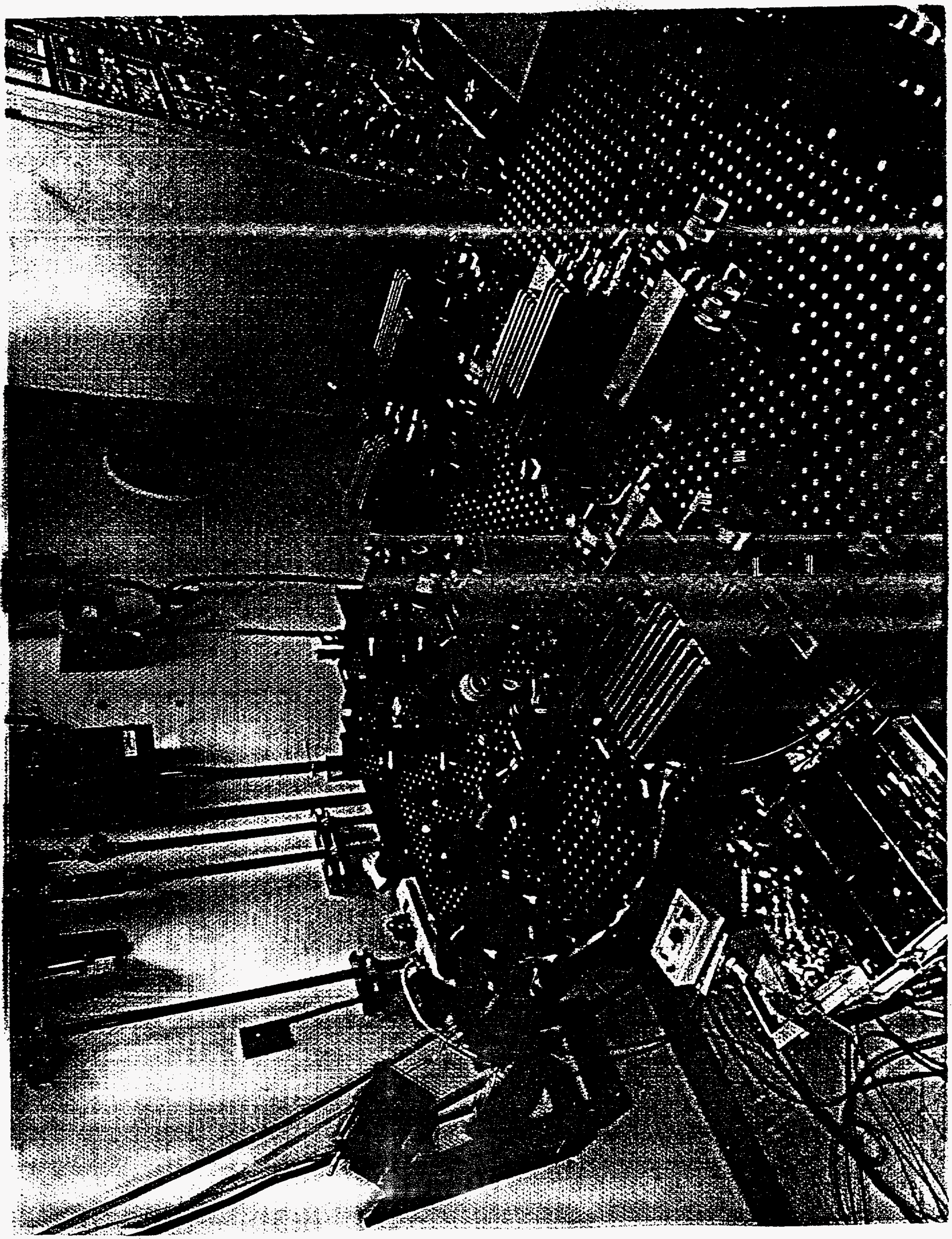
CONVENTIONAL VISAR



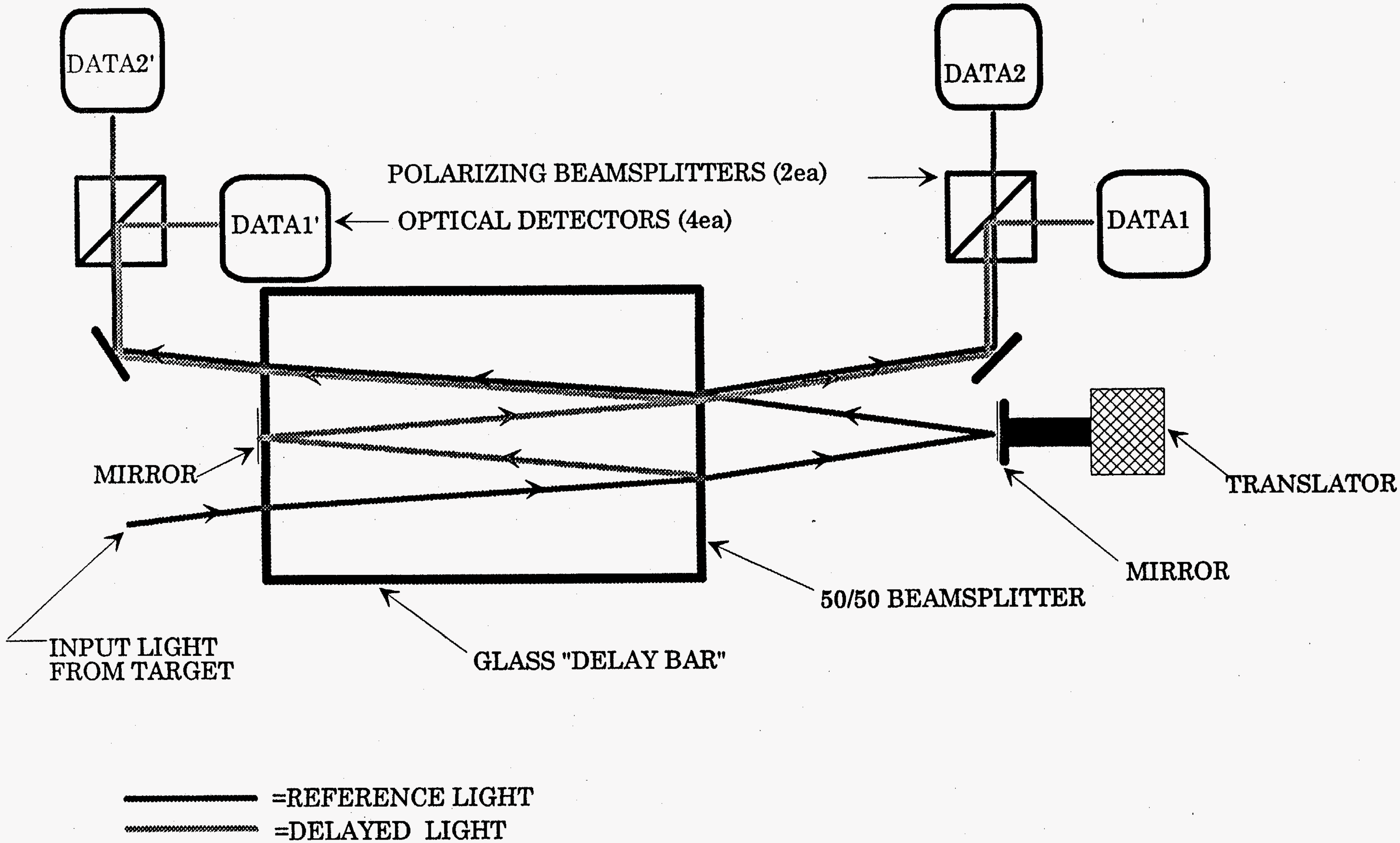
MICHELSON INTERFEROMETER CAVITY



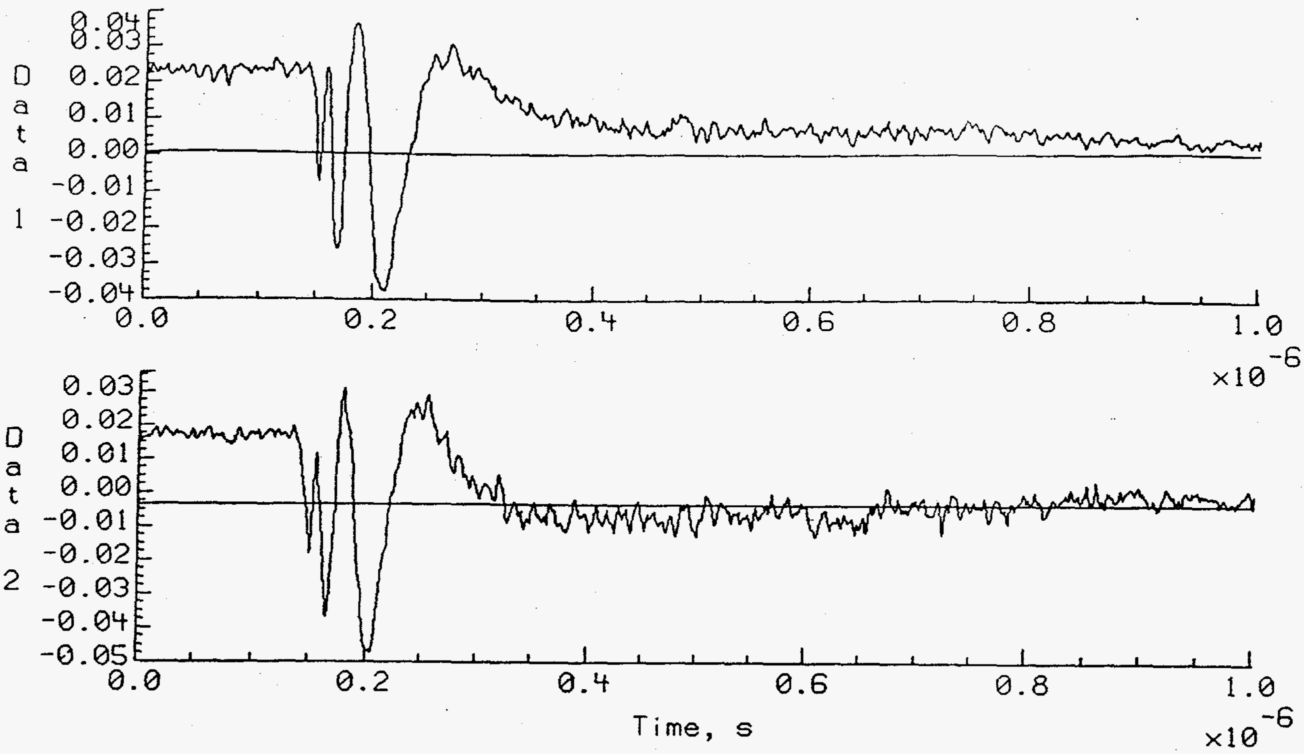
USSR BLK5



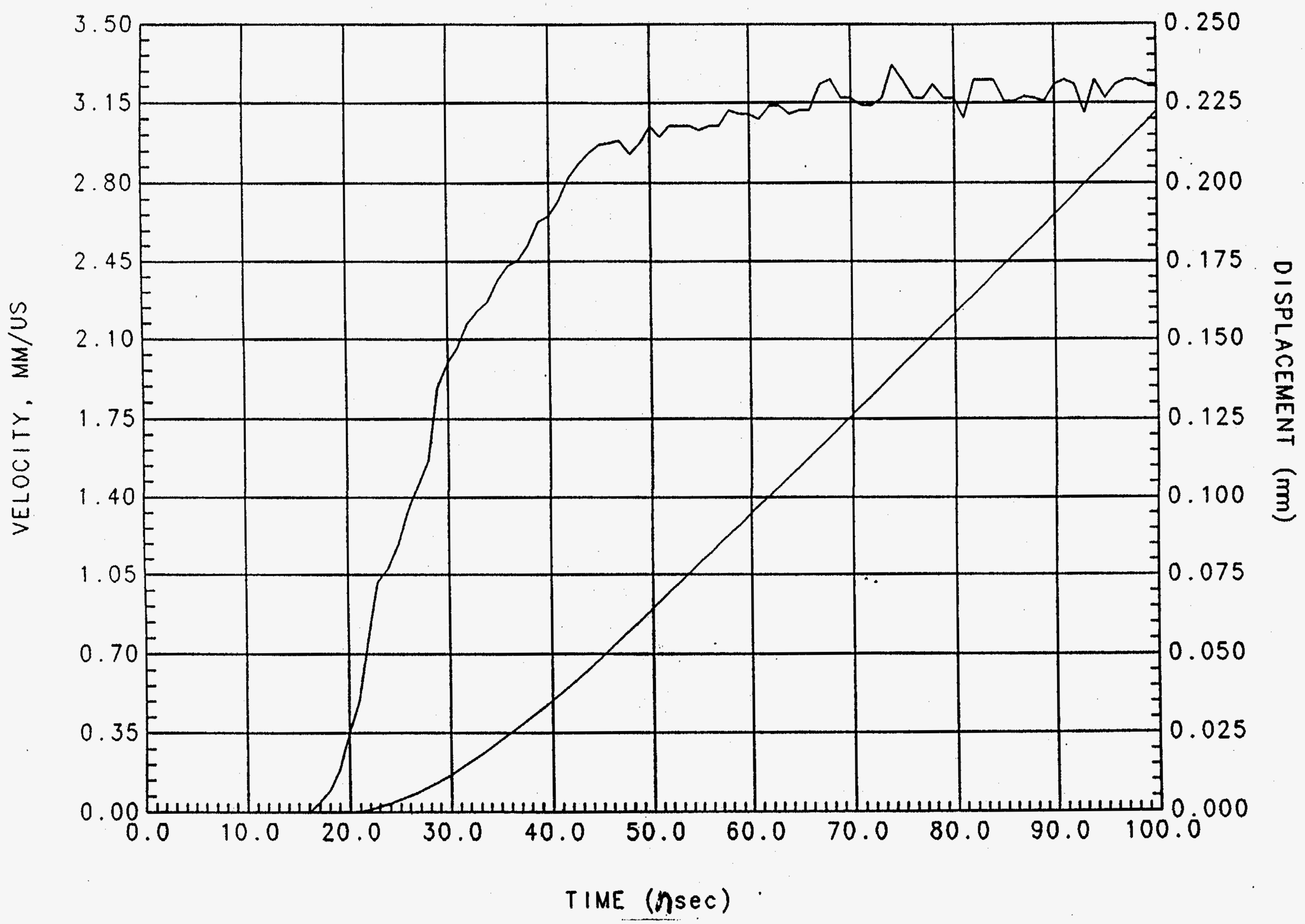
FIXED CAVITY VISAR

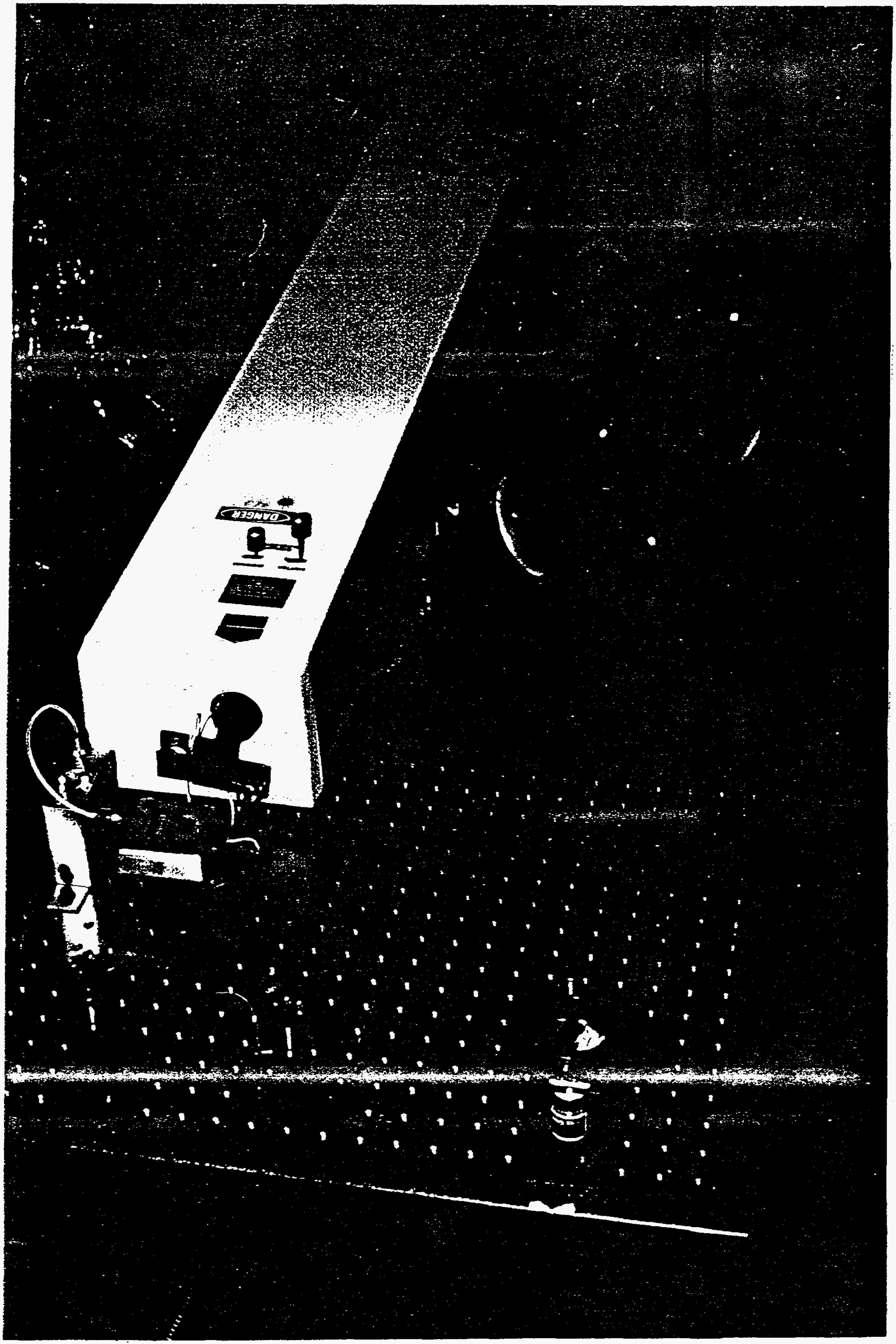


USSR B1153

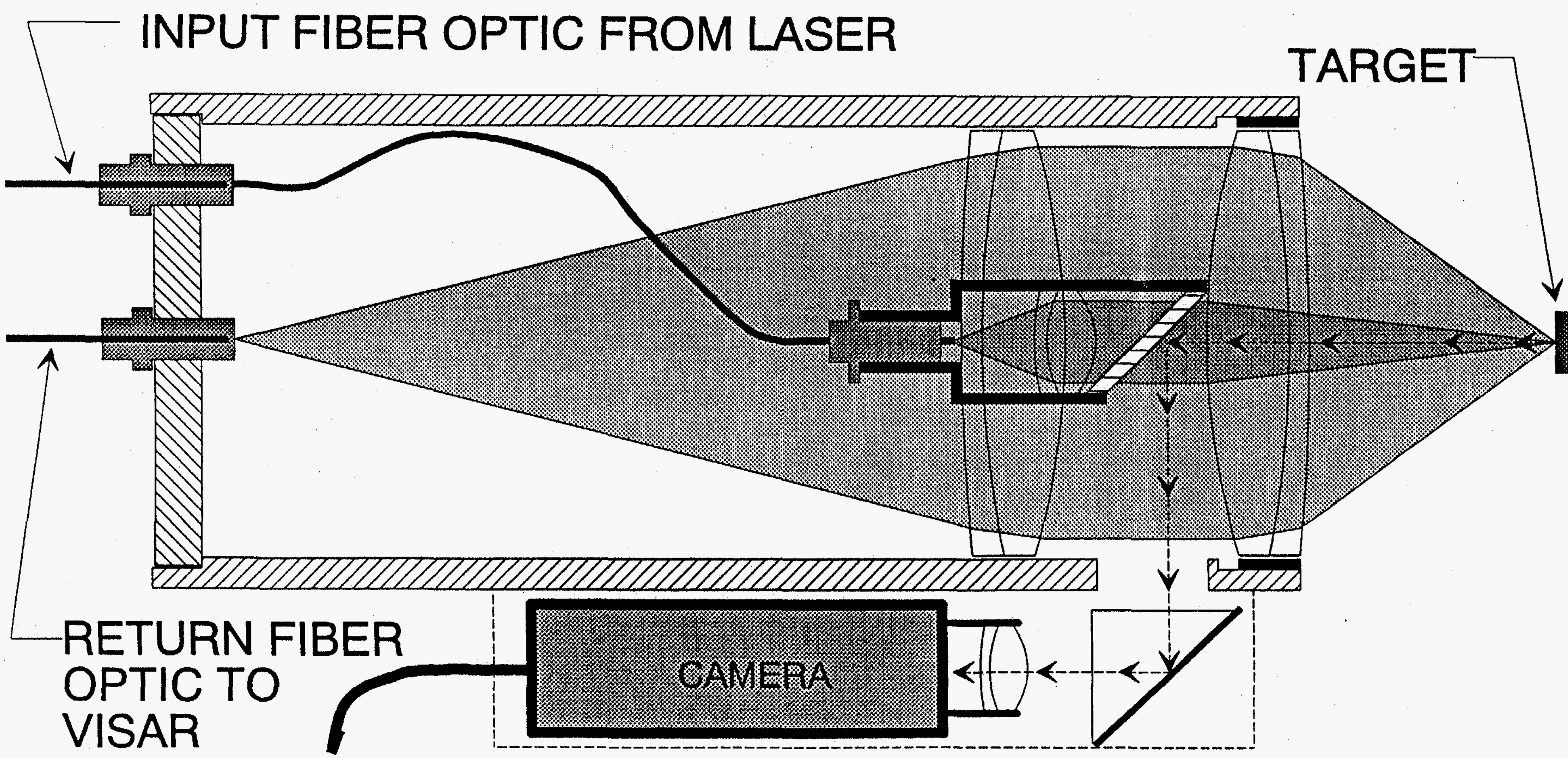


Data 1
0.04
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
0.0
0.2
0.4
0.6
0.8
1.0
×10^-6
Data 2
0.03
0.02
0.01
0.00
-0.01
-0.02
-0.03
-0.04
-0.05
0.0
0.2
0.4
0.6
0.8
1.0
Time, s
×10^-6


VELOCITY, MM/US
3.50
3.15
2.80
2.45
2.10
1.75
1.40
1.05
0.70
0.35
0.00
DISPLACEMENT (mm)
0.250
0.225
0.200
0.175
0.150
0.125
0.100
0.075
0.050
0.025
0.000
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0
TIME (sec)

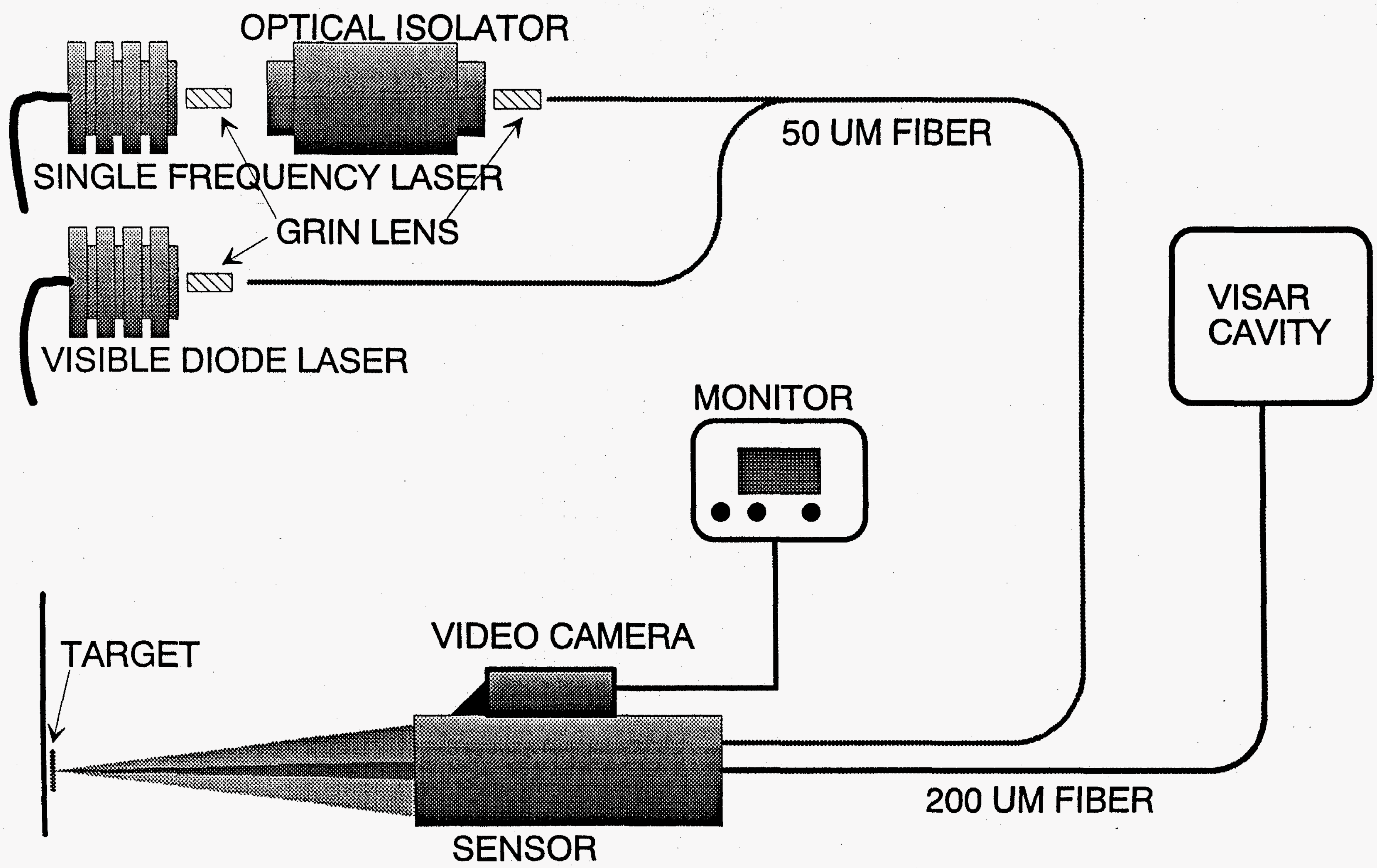

DANGER

IMAGING FIBER OPTIC COUPLED SENSOR

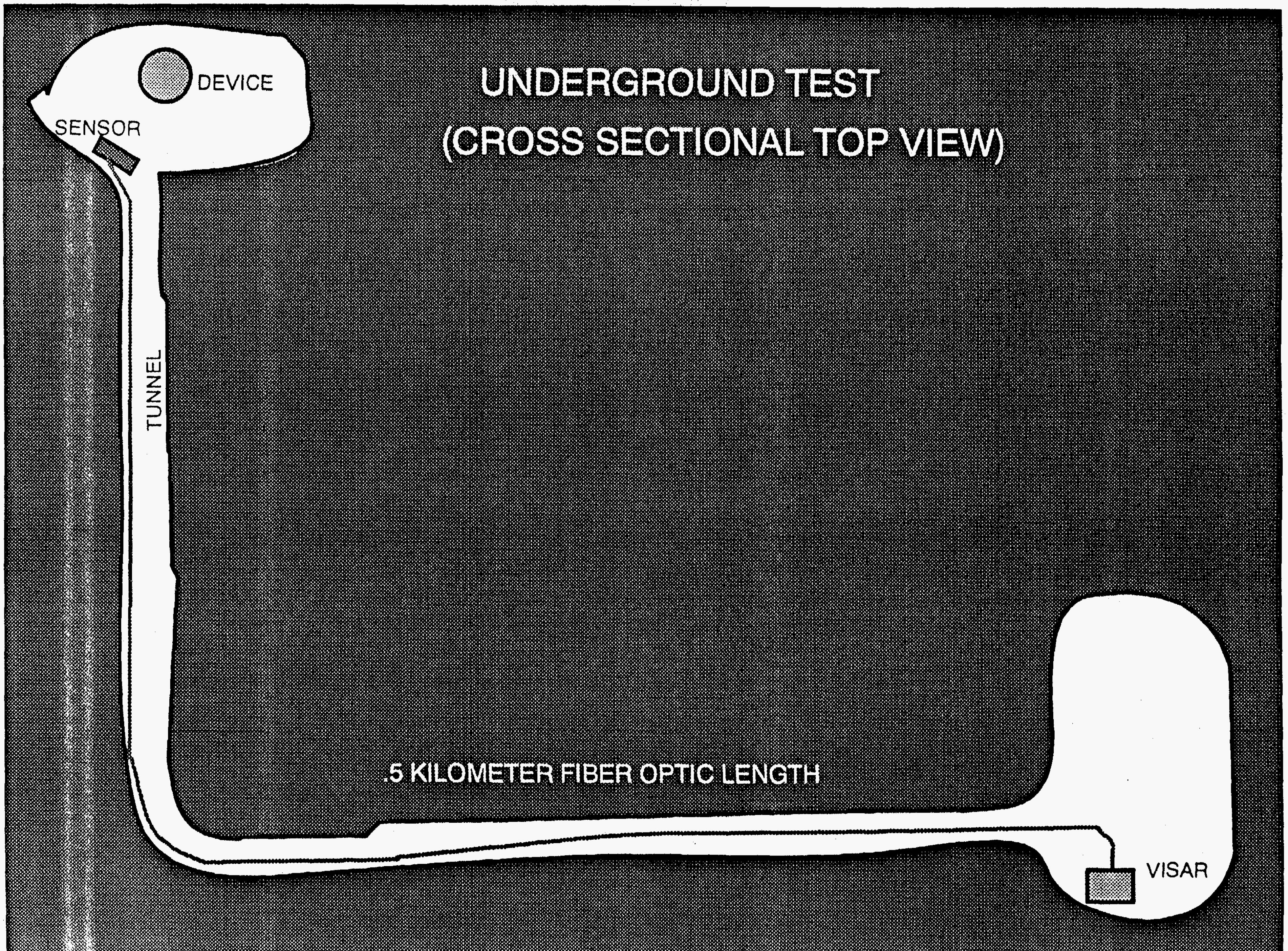


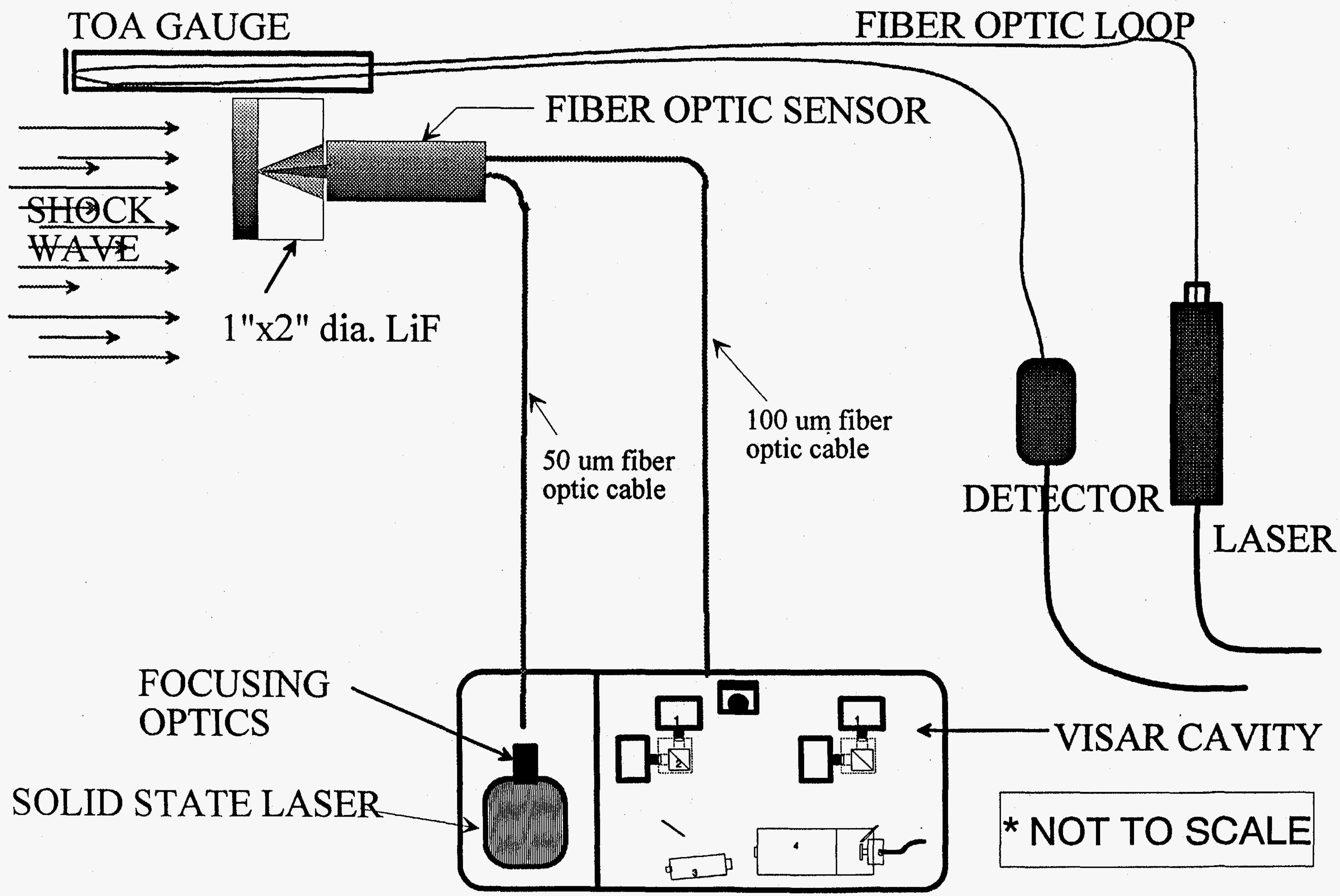
USSR BLK4

SOLID STATE FIBER OPTIC COUPLED VISAR



USSR BLK6


UNDERGROUND TEST
(CROSS SECTIONAL TOP VIEW)
DEVICE
SENSOR
TUNNEL
.5 KILOMETER FIBER OPTIC LENGTH
VISAR



TOA GAUGE
FIBER OPTIC LOOP
FIBER OPTIC SENSOR
SHOCK WAVE
1"x2" dia. LiF
50 um fiber optic cable
100 um fiber optic cable
DETECTOR
LASER
FOCUSING OPTICS
SOLID STATE LASER
VISAR CAVITY
* NOT TO SCALE

CHARACTERISTICS OF LASERS USED FOR VISAR

LASER\ WAVELENGTH	INPUT POWER	OUTPUT POWER	DETECTOR TYPE
ARGON-ION 514nm	35,000 W	1,000 mW	Si, PMT, STREAK
DIODE 830nm	150W	120 mW	Si, PMT
DIODE PUMPED Nd:YAG 1319nm	175 W	160 mW	InGaAs
DIODE PUMPED, FREQUENCY DOUBLED Nd:YAG 532nm	200 W	400 mW	Si, PMT, STREAK

CONCLUSION

- VISAR IS PORTABLE AND FIBER OPTIC COUPLED
- SYSTEM HAS BEEN TESTED IN HARSH CONDITIONS
- REMOTE SENSOR ALLOWS TESTING IN HIGH RADIATION, TEMPERATURE, ELECTRO -MAGNETIC ENVIRONMENTS
- VISAR MAY BE NETWORKED