OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Nanosystems and Structures Group

Optical Waveguide Sensors

Advanced Optical Sensors

Purpose: This technology combines the field of optical interferometry with optical fiber wave-guides for a very important Department of Defense application. The goal is to reduce firearm weight by using very lightweight barrels and compensating for any deflections.

Sponsors: Department of Defense, U.S. Army, and the Joint Service Small Arms Program.

Features: Real-time compensation, low-power operation, and significant weight reduction.

Users: Military, police, private security, sportsmen, and engineers and scientists as a laboratory diagnostic tool.

Contact Information:
Panos G. Datskos
Group Leader
Oak Ridge National Laboratory
P.O. Box 2008
Oak Ridge, TN 37831-6054
Phone: 865-574-6205
Fax: 865-574-9407
(datskospg@ornl.gov)

Oak Ridge National Laboratory has a distinguished history in optical waveguide sensors. A diverse number of physical parameters have been measured with these techniques for numerous applications such as novel radiation signature detection; telecommunications; and, most recently, rifle barrel deflection monitoring. This last application will is the subject of this fact sheet.

Example Application: Rifle Barrel Deflection Monitoring

Traditionally the methods to increase accuracy in a firearm, particularly at distance, have been to free float and substantially increase the thickness of the barrel. This barrel stiffening technique did not completely eliminate oscillations or deflections, but the amplitude was dramatically reduced for a given input energy—at a very high weight penalty. Obviously if ultralightweight barrels could be compensated for both the static and dynamic perturbations, the result would be very accurate yet significantly lighter weight weapons. Our phase I effort was aimed at demonstrating the feasibility of this real-time barrel deflection compensation approach. We used optical fiber sensors imbedded along the barrel to directly measure the stress-induced deflection. The sensitivity of the initial bench-top system was astonishing at approximately 1/10,000th of a minute-of-angle.

Technical Approach

In the ultimate embodiment of this concept (Figure 1), a barrel would be reduced in thickness to near its minimum diameter for safe operation at the designed pressure. The barrel would then be fluted with dovetailed microgrooves along the length (top, bottom, and both sides). Optical glass fiber would be attached along the grooves to act as longitudinal strain sensors (Figure 2). The fiber would be semipermanently positioned / captured in place with numerous high-temperature polymer materials such as Teflon or polyimide. Commercial optoelectronic sources (diode laser) and detectors (photodiode) would provide real-time interrogation of the optical fiber's changes in relative length when the barrel deflects (Figure 3). A second reference fiber positioned in a capillary sheath would be used to distinguish temperature-induced noise from the actual stress-induced barrel deflection signal. These fiber optic sensors along the barrel can

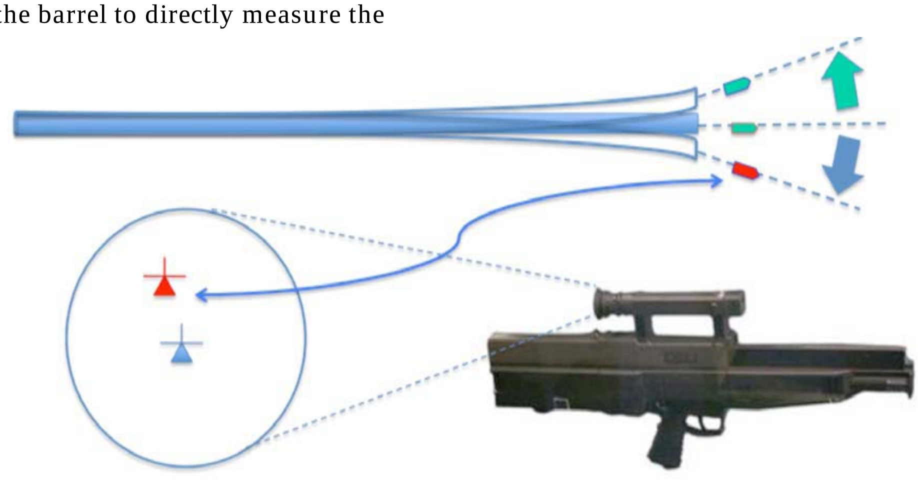

Fig. 1. System level concept depicting fiber-optical barrel deflection.

measure the magnitude and direction of both static (sling or forearm support) and dynamic (vibrational) induced deflections. These deflections would be represented in the form of plus and minus voltages in both the X and Y directions. A single application specific integrated circuit (ASIC) chip could compute the impact deviation and feed the information to one of many possible electronic sights. If process power is already available in a particular weapon system, then the computation of impact deviation could be accomplished with the native processor. The reticle would be electronically adjusted in position to compensate for the induced barrel deviation. This technique is particularly amenable to increasing the accuracy at extended ranges since these very small, yet measureable, displacement angles can represent significant deviation at impact. Since the position of the muzzle is determined continuously, it would theoretically be possible to shoot through the barrel resonance, further increasing the accuracy. Our approach could prove to be a significant weight reduction for the warfighter while simultaneously producing enhanced accuracy.

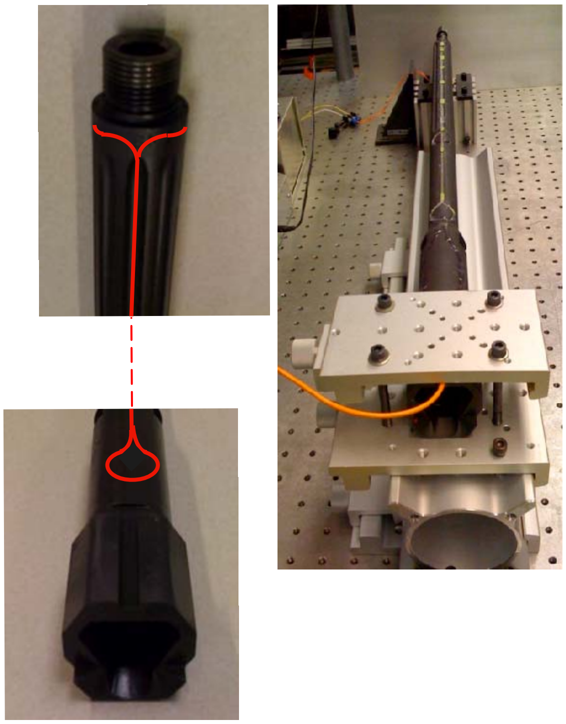

Fig. 2. Images of the laboratory test setup showing different views of the test barrel. The red lines depict the geometrical path of the optical fiber along the barrel.

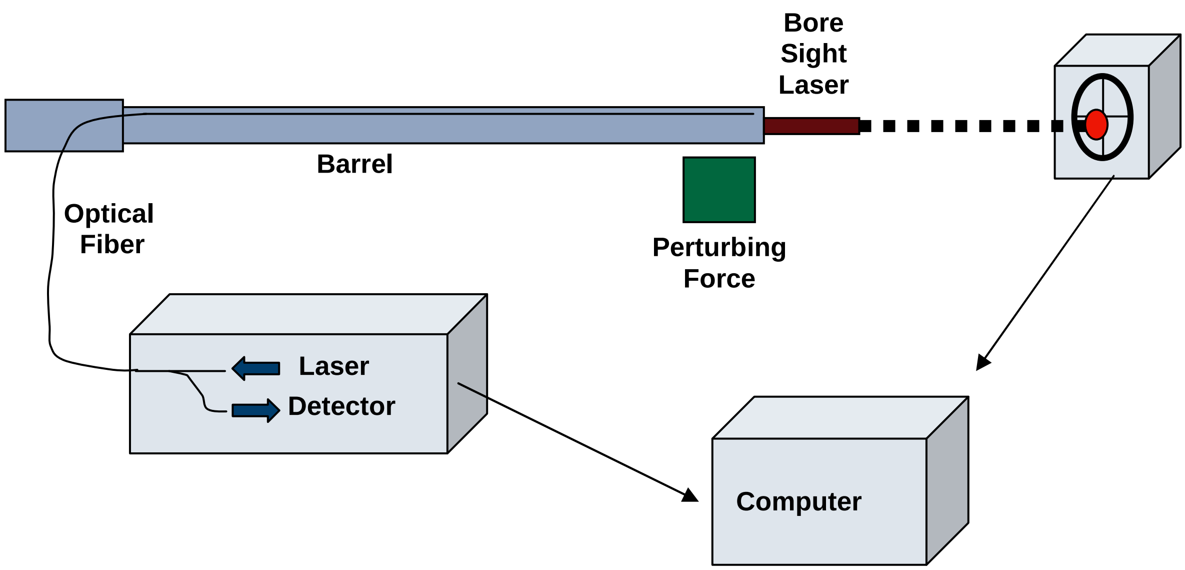

Fig. 3. Diagram of the testing configuration showing the bore-sight laser used as a calibration source for the stand-alone fiber-optic sensor.