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An Application of Optical Fiber in Defense and National Security

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Abstract
Distributed Fiber Optic Sensing is a powerful technology with wide spread use in applications from down-hole oil & gas wells to environmental monitoring of streams. This paper will highlight some of the various technologies and applications. Recent advances in multi wavelength Raman systems will also be discussed.

I. INTRODUCTION

Many technological opportunities have been made possible by the advances in optics and photonics since the National Research Council's (NRC's) publication in 1998 of Harnessing Light: Optical Science and Engineering for the 21st Century. Because optics and photonics are playing an increasingly important role in national Defense, the United States is at a critical juncture in maintaining technological superiority in these areas. The gap between sophisticated and less sophisticated adversaries is not as large as it once was, and provides little or no advantage in several key technical areas, such as conventional night-vision equipment.

Sensor systems are becoming the next "battleground" for dominance in intelligence, surveillance, and reconnaissance (ISR), with optics-based sensors representing a significant fraction of ISR systems.In addition, laser weapons are poised to cause a revolution in military affairs, and integrated optoelectronics is on the verge of replacing many traditional integrated circuit functions. Sophisticated platforms have reduced the need for a large set of traditional war fighters, but there is an increased need for a high-tech workforce to support those platforms. This workforcerelies on advanced training in technical areas with a basis in science, technology, engineering, and mathematics (STEM), which are precisely the areas in which it is becoming more difficult to find continued optics and photonics education in the United States. The ability of U.S. Defense forces to leverage technology for dominance while using a small force is also threatened by an ongoing migration of optics and photonics capabilities to offshore manufacturing sites. This means that the United States may lose both first access and assured access to new optics and photonics Defense capabilities.

Although conventional night-vision imagers have become commodities available to anyone with money, more sophisticated optical-based surveillance systems have made major progress in the past decade and provide a great opportunity. A number of very-wide-field-of-view passive sensor systems have been developed and are discussed in this chapter. It is now possible by using such systems to view large areas with moderate to high resolution, especially during the day. Large portions of a city can thus be continuously monitored and the data from the system stored. If something of interest occurs, it is possible to re-examine that event to determine exactly what happened. Once areas of interest have been detected, it would be useful to have exquisite detail in certain critical areas, highlighted by the wide-area detection sensor. There have recently been long-range identification demonstrations using active electrooptical (EO) systems called laser radar, or ladar. Although synthetic aperture radar (SAR) has been around for decades, it is only recently that synthetic aperture ladar systems have been flown. These are briefly discussed below. Multiple sub-aperture-based, potentially conformal, active sensor developments are also discussed. This is a developing technology that will allow lighter-weight, long-range imaging systems that can also be applied to laser weapons. After an object has been detected and identified, it may be recognized as a threat that has to be dealt with. "Speed-of-light" weapons are ideal choices for certain applications, such as for a boosting missile. These laser weapons can destroy a boosting ballistic missile, causing whatever warhead is on the missile to fall back on the nation that fired the missile. Recently the Airborne Laser Test Bed (ALTB)shot down a boosting ballistic missile with an onboard laser for the first time. Although this was a highly successful test, it was done with a chemical laser, using a mixture of oxygen iodine as the gain medium. There is strong interest in and great potential for laser weapons that run on electricity. If sufficient electricity can be generated from onboard fuel, one could use the same fuel.

Technical Point of View

Night Vision

The proliferation of night-vision equipment over the past few decades has led to a significant amount of surplus equipment available at very low cost. This equipment has eroded the tactical advantage that the United States previously had in this area of warfare during the night.

Laser Rangefinders, Designators, Jammers, and Communicators

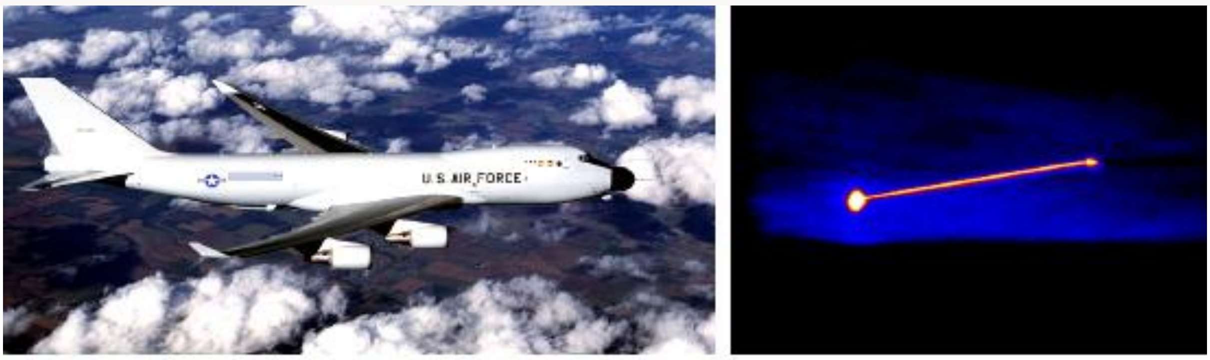
The significant increase in laser diode efficiency coupled with the decrease in cost has enabled recent advances in the area of laser designators. One of the key motivators for moving to, for example, optical communications, is that they minimize the probability of interception, jamming, and detection, while dramatically minimizing the power needed. The improved efficiency and availability of high-powered lasers at a broader range of wavelengths has also enabled the development of countermeasure systems for several applications, including Défense against the now-prolific man portable air Défense systems (MANPADS) capabilities that threaten commercial and military aircraft. The specific developments are not covered in detail in this report.

Laser Weapons

The Missile Défense Agency demonstrated the potential use of directed energy to defend against ballistic missiles when the Airborne Laser Test Bed successfully destroyed a boosting ballistic missile on February 11, 2010. As discussed in a Missile Défense Agency news release,this revolutionary use of directed energy is very attractive for missile Défense, with the potential to attack multiple targets at the speed of light, at a range of hundreds of kilometres, and at a low cost per interception attempt compared to current technologies. Since publication of the 1998 NRC report, there have also been other successful demonstrations, including the Tactical High Energy Laser (THEL),the Mobile Tactical High Energy Laser (MTHEL), and the Maritime Laser Demonstrator (MLD).over level for 6 hours.The goal of the High Energy Liquid Laser Area Défense System (HELLADS) is to demonstrate 150 kW of power in a lightweight package. In June 2011, DARPA completed the laboratory testing of a fundamental building block for HELLADS, a single laser module that successfully demonstrated the ability to achieve high power and beam quality from a significantly lighter and smaller laser.Another DARPA program that is developing an approach to laser weapons is the Adaptive Photonic Phase Locked Elements (APPLE) program.APPLE uses a modular system to scale the available power, which requires high-powered lasers with sufficiently

Hyper-Spectral Sensing

Hyper-spectral imaging is an extreme form of colour imaging. People are very familiar with colour imaging. We all know that spotting a bright red object lying on a green lawn is much easier than seeing a green object on a green lawn. Colour in an image can be divided into many wavebands for more resolution. One of the significant issues associated with multi- or hyper-spectral imaging is whether or not one needs to see at night. Daytime viewing uses the visible and near-infrared regions of the spectrum,whereasnight-time viewing requires detectors for longer wavelengths. Although there is a phenomenon called night glow in the near-infrared, and often in man-made lighting or light from the Moon, reliable viewing requires moving to the mid- or long-wave infrared (IR). Most of the current commercial applications of spectral, or hyper-spectral, imaging use the visible and near-IR regions.



(a) (b)

Défense Systems

Défense systems (laser weapons) have made great progress since the 1998 NRC report was issued. The Airborne Laser Laboratory (ABL) intercepted two ballistic missiles in February 2010 with the megawatt-class oxygen iodine laser emitted from the nose of the aircraft. After this successful test, ABL was converted to the

Airborne Laser Test Bed to explore issues associated with potential follow-on activities. As of this writing, no follow-on activity has been identified. Until April 2009, ABL was on a path to deployment in small numbers. However, at that time the second ABL aircraft was recommended for cancellation, with the program to return to a research and development effort.

Another major laser weapons effort was the advanced tactical laser (ATL), a short-range weapon for use on a gunship-like aircraft, with the laser replacing a gun. In August 2008, the first test-firing of the “high-energy chemical laser” mounted in a Hercules transport plane was announced. In August 2009, a ground target was “defeated” from the air with the ATL aircraft.[50] This laser weapon is also based on an oxygen iodine laser, requiring hauling hazardous chemicals to the field. At the time of this writing, there is no planned follow-on effort.

II. CONCLUSION

The findings of previous National Research Council studies reporting the potential workforce shortages for the United States in the areas of science, technology, engineering, and mathematics are consistent for the areas of optics and photonics in relation to Défense and security. There are additional constraints for the Défense workforce, which requires either a sufficient number of qualified U.S. nationals or a new way of leveraging uncleared individuals in the U.S. Défense workforce, and will be significantly impacted by a decrease of senior personnel due to the retirement of a disproportionately older workforce over the next 15 years.

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