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DEVELOPMENTS IN MILITARY INFRARED AND LASER TECHNOLOGY

by

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DEVELOPMENTS IN MILITARY INFRARED AND LASER TECHNOLOGY

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1. Introduction

Infrared and laser technology is widely used in aviation and space, in reconnaissance, remote sensing and remote metering, missile warning, aircraft night vision and night navigation, and plays an important role in target detection, identification and tracking, aiming and precision guidance as well as communications. Their application can greatly increase the precision of weapons systems, increase ECM capabilities, counter stealth capabilities, counter surface object interference capabilities, greatly reduce costs, and increase the effectiveness of weapons systems. Therefore, they are recognized as power multipliers for the weapons with which the military is equipped. The military of all countries are playing serious attention to developments in infrared and laser technology, especially the development of elements, components and their basic technology. For example, of the 11 different key technologies of the United States Defense Science and Technology, 1.162 billion Dollars was invested in optics and electronics (primarily composed of infrared and laser technologies) during the years 1992, 1993 and 1994 (not including SDI). This constituted 13 percent of all investments in key technologies during these three years.

Expenditures for 1992, 1993 and 1994 for item five of Optics and electronics technology, that is, electronic devices including microelectronic elements and devices and optoelectronic elements and devices and radio frequency devices are shown in Table 1.

Table 1.

表 1

1 时间	1992 年 2	1993 年 2	1994 年 2	3 年之和 3
4 微电子	312	256	236	804
5 光电子	210	211	143	564
6 射频器件	164	172	174	510
7 总计	686	639	553	1878

1. Date. 2. Year. 3. Total for three years. 4. Microelectronics. 5. Optoelectronics. 6. Radio frequency devices. 7. Total.

Optoelectronics constituted 30 percent of the overall total for the three years, and the ratio of optoelectronic devices to microelectronics was 0.7 to 1.

Expenditures for item number three which is sensor technology (detection technology), including radar detection equipment, optoelectronics detection equipment, acoustic detection equipment and multiple function detection systems technology are shown in Table 2.

Table 2.

表 2

1 时间	1992 年 2	1993 年 2	1994 年 2	3 年之和 3
4 无源光电	132	138	135	405
5 有源光电	50	54	44	148
6 总计	615	712	675	2006

1. Date. 2. Year. 3. Total for three years. 4. Passive optoelectronics. 5. Active optoelectronics. 6. Total.

Such a large proportion of the investment for the 11 key technologies going to infrared and laser technology fully demonstrates the importance of optoelectronic technology within national defense science and technology. Aviation and space are the primary users of optoelectronic technology, representing 60 to 70 percent of total applications. Therefore, infrared and laser technologies should be major developmental items in aviation and space.

In the past ten years, there have been startling developments in the military applications of infrared and laser technology. In infrared technology, using infrared detectors as a benchmark, the transition from linear to medium and small focal plane array (FPA) devices has been completed, and has moved from research models to production models. The cost has been reduced to one-tenth the original cost, and is on its way to one-hundredth original cost. The type of system is determined by the type of element. This has been the historical fact in the development of infrared technology, and there have been corresponding developments in infrared system technology, with the focal plane array imaging system having already been placed into use. In laser technology, because of industrial and military demands, major advances have been made in increasing power and use life of lasers and in reducing their cost. Tactical laser weapons have become a reality, and new laser wave lengths have appeared as well as new materials, new devices, opening up the way to new applications.

2. Advances over the last ten years

2.1. Infrared technology

The engineering for linear array detectors in the three primary bandwidths of 1-3μm, 3-5μm and 8-12μm as well as the British Sprite device was completed by the end of the eighties, and various infrared systems entered batch production and application in the early eighties. At the same time, a number of major United States Corporations launched widespread research of infrared focal plane array detectors, and was spurred on by the 1983 SDI plan, with dramatic increases in investment and with rapid developments. For example, the Rockwell Corporation developed 1-1.25μm 128 X 128, 256 X 256 and 512 X 512 mercury cadmium telluride composite focal plane arrays for the Hubbel Space Telescope, all of which were successfully developed and placed into use. There are three different types of intermediate range (3-5μm) infrared FPA components. These are the composite mercury-cadmium telluride composite single chip, the **PtSi/Si** silicate Shottky component and the **ZnSb** photovoltaic device, all of which have been successful. For example, the United States intermediate band mercury-cadmium telluride 256 X 256 high resolution product has a NETD of 0.009K. The 64 X 64 element has already been used in an anti-tank missile. It is inexpensive. The 512 X 512 component is technically very difficult, resulting in a low percentage of products meeting specifications and in high cost. England, France, Germany and Japan are also conducting research on similar components. **PtSi/Si** silicate Shottky infrared FPA devices have already been used to make up 256 X 256, 512 X 512 and 1024 X 1024 arrays. However their NETD is only 0.1 to 0.5K. Intermediate band **ZnSb** photovoltaic FPA elements, such as the United States Amber Engineering Corporations 128 X 128 in 1989 displayed mature CMOS composite element usage and has been produced. Its D^* was 74 X $10^{11}CmH^{1/2}W^{-1}$, and it only cost a few tens of thousands of Dollars. The infrared image equipment manufactured using these components had a NETD of as good as 0.001K. The frame frequency was more than 100Hz. There are now 256 X 256 and 512 X 512 components. The United States Houghes Corporation has already developed this type of product.

The long wave infrared FPA device: Current research is concentrating on Mercury Cadmium telluride, and 64 X 64, 128 X 128 and 256 X 256 elements have already been developed. However, only a low percentage of products meet specifications, the cost is high, and they have not yet become commercial products.

Non-cooled (or cold detection) focal plane elements are another type currently underdevelopment. These are very widely used in ground force light weapon sights, monitoring sensors, missile guidance heads and pilot goggles. The United States, England, France, Germany, Japan and Russia have all developed this type of pyroelectric devices. An example is the German pyroelectric camera which has a 270 line temperature resolution of 0.2K. The Japanese used lanthanum-doped lead titanate PLT pyroelectric transistor to achieve a temperature resolution of 0.1K. The Russians have used a networked style TGS with a frame frequency of up to 500 to 100 Hertz, which is being used on missiles.

In order to avoid the tremendous difficulty in the manufacturing processes and the high cost of long wave infrared mercury-cadmium telluride fixed vision focal plane arrays, search began in the late eighties for a new alternative long wave detector material and device structure such as the **AlGa As/GaAs** multiple quantum trap infrared detector, the **GeSi/Si** heterogeneous internal optoelectronic emission infrared detector, the **InGaSb/ZnAs** superlattice crystal infrared material device, and **HgZnTe** material. In summary, the transition has already been completed for moderate and short wave infrared detectors from linear arrays to focal plane arrays, as has the transition from research models to production models. The percentage of products which meet specifications is high, and the cost is now several U.S. dollars per element. Long wave focal plane arrays may see the same advances as those of the medium and short wave focal plane arrays in the near future. Also, currently under development are the multiple spectrum infrared detector, the laser infrared detector, and far infrared detectors used to detect low temperature targets and backgrounds.

Infrared system technology using thermal imaging as a benchmark has, in the past ten years, been widely applied to various types of sweep type thermal imaging devices. These primarily include: (1). Tank and vehicle observation, sighting and night vision and reconnaissance. (2). Surface and ship-borne search, surveillance, warning, tracking and sighting systems. (3). Airborne search, warning, guidance and tracking and sighting systems. (4). Various types of guidance heads. (5). Space, satellite reconnaissance, surveillance, measurement, resource surveys, meteorological measurements and pollution monitoring.

With the development of focal plane array devices, there has been a corresponding rapid development of focal plane array infrared imaging systems. Focal plane array image systems have been developed for all three wave bands, and the technology for 64 X 64. 128 X 128 and 256 X 256 medium waveband is fairly mature, and the cost is cheap, even cheaper than optical and sweep systems. The NETD has achieved 0.001K, and frame frequency over 100Hz, up to 1000Hz. The sweep model FPA imaging systems are currently being developed, and will primarily be used for large field of view search, monitoring and space vehicle systems. Ship-borne and airborne search and tracking system dual band (3-5μm and 8-12μm) infrared systems seem to have become a trend in development because they can increase system adaptability.

2.2. Laser technology

The primary characteristics in developments of laser technology (referring to moderate and small power) over the past ten years have been: (1), transistor lasers with tremendous advances in increased output power, increased life, increased efficiency (as high as 60 percent) and reduced cost. Quantum trap diode laser arrays have an average power of up to $100W/cm^2$; peak power of up to $3kW/cm^2$; and single chip surface emission diode laser array continuous output power has reached 50W, and single digit watt class transistor laser diodes have become practical and commercial products. Life expectancy has reached several tens of thousands of hours. (2). There has been rapid development of a new type of high efficiency, long life, small, totally solid state resistor diode pump laser. The strip laser with a transistor diode pump has an average output power of up to 1000W, and can be used for radars and machine processing. This type of laser is suited for environmental demands of field combat and aeronautics and space. It is one of the major developmental directions at the present time. Solid state laser with new wave lengths are the **NdEr** YAG laser at $2.9\mu m$, and the **ErYAG** at $1.7\mu m$ and $1.54\mu m$, the **HoYAG** at 2.1v. The adjustable laser using parameter oscillation YAG can adjust wavelength between 1.06 and $4.6\mu m$. (3), the CO_2 laser is still being emphasized in developments, primarily to solve the problems of small size, practicality and long life. Waveguide CO_2 lasers use an even discharge over a large area and diffusion cooling. They have a reduced cost and are smaller. The compact sealed CO_2 laser output power can reach 1500W, and have become practical at below 250W, being used in large numbers in material processing, becoming a product with excellent sales. Laser system applications are still concentrated in the following areas: Laser ranging, laser guidance, optical and electronic counter measures, laser firing, engagement simulation trainers, laser gyroscopes, optical fiber gyroscopes, tracking and metering, meteorological measurements, and pollution monitoring. Research and development in tactical laser weapon applications continues to be a major part of the development of laser technology. Solid state lasers, gas lasers and chemical lasers can all be realized. The present problem is which type of laser is most suited to practical requirements, and best meets the requirements of different tactical conditions.

2.3. Developments by the year 2005

Predictions for future developments involve political, economic, military and technical factors. It is very difficult to come up with an accurate prediction. However, as far a technology is concerned, we can only present some imprecise views. For infrared technology, it may be stated that the "the era of focal plane array has arrived". The question now is not whether or not it is possible to build an infrared focal plane device, but what percentage of the products must meet specifications, how much will it cost, what is the quality of the product, and how many can be provided. The development of focal plane technology has allowed for a large increase in the temperature resolution of new infrared image system, for increases in spacial resolution, a drop in system cost, a reduction in size, further increases in useable range and cheaper cost. It is predicted that between 1995 and 2005 current first generation thermal imaging devises will gradually be replaced by second generation (focal plane) thermal imaging devices. New FPA and multiple light spectrum FPA with more elements and higher sensitivity will be developed. There will not be decreases in cost of several magnitude. There will be wide use of thermal imaging devices which operate at room temperature and will not use deep cold. Super lattice crystal materials and quantum trap devices will become practical. There will be a new stage of development in lasers, with transistor lasers at the forefront of laser development. Sales will increase, and applications will become broader, costs will decrease, array laser devices will have increases in power of several magnitude, continuous operating live will reach 100,000 hours or more, electricity to light conversion efficiency will generally reach 50 percent, wave lengths will move toward short and medium wave lengths. Diode tube pump solid state lasers will become the primary direction in the development of solid state lasers. High repetition frequency (5K-10K) laser out put power will approach 10MW. Large area discharge waveguide CO_2 lasers will repeat the development of CO_2 lasers. Laser emission power and reliability will be increased, and the cost will decrease. This will promote their applications in various areas. Because of the development of corresponding laser technology, units will be equipped with tactical laser weapons (anti-aircraft, air-to-air).

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