From Terahertz to Deep UV, Science and Technology for Space Applications

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Exploration is certainly part of the human being character, and it has been a significant part of human history. It stated by land exploration; but human found a new one in space. Space, as a new frontier for exploration, has always been a driver of the modern human. Electromagnetic waves have been mainly used in space exploration from the very first day, even before human can fly. Once in space the information of the universe appears to man or his spacecraft in the form of electromagnetic radiation: light. Using light, one can see deep space and discover new objects and cosmic events. We can also look down to the earth and monitor the weather, gather information about natural resources, monitor the activity of other humans, and etc. For each of this application different types of light, such as terahertz (THz), infrared (IR), and ultraviolet (UV), are needed. For example, when looking at the earth, we can observe the complex and evolving weather patterns but for this we need the right detectors. The thermal or infrared images recorded by sensors called scanning radiometers enable a trained analyst to determine cloud heights and types, to calculate land and surface water temperatures, and to locate ocean surface features. Weather observation is typically made via different 'channels' of the infrared: 3.9 µm – 7.3 µm (Water Vapor), 8.7 µm, – 13.4 µm (Thermal imaging). In space, there are many regions which are hidden from optical telescopes because they are embedded in dense regions of gas and dust. However, infrared radiation, having wavelengths which are much longer than visible light, can pass through dusty regions of space without being scattered. This means that we can study objects hidden by gas and dust in the infrared, which we cannot see in visible light, such as the center of our galaxy and regions of newly forming stars.

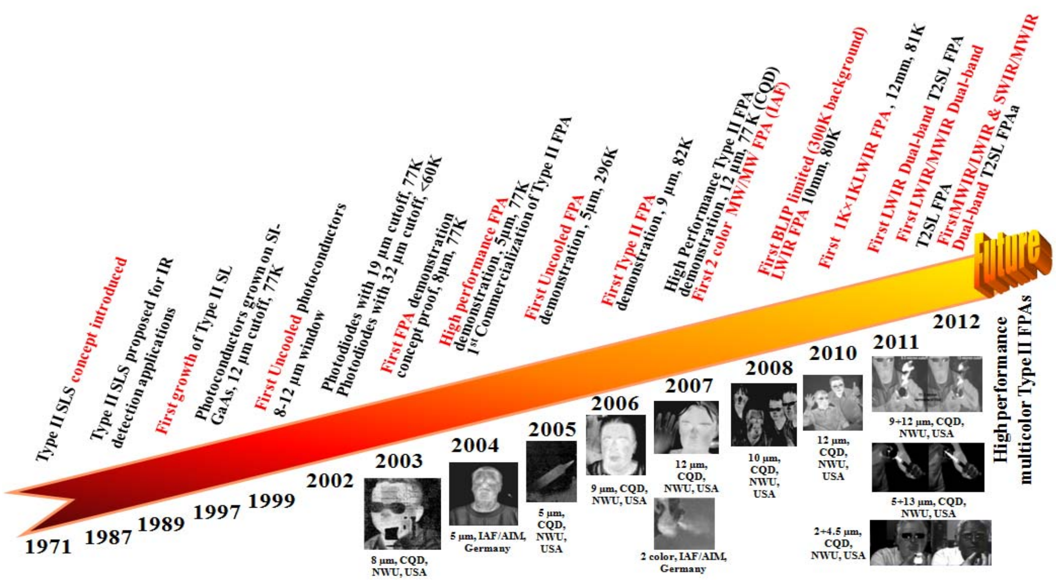

Figure 1. Historical development of Type-II superlattice photodetectors and imaging.

Depending almost exclusively on imaging capabilities, "spy satellites" have been orbiting by the hundreds (by several countries) to gather military intelligence or information about terrorist activities. Visible, Near-Infrared, Thermal Infrared (MWIR and LWIR), and Radar sensors are applied to gathering information about ground targets and activities of national security significance. Infrared imaging is also the main tool for the Missile Warning Satellites (MWS). The photodetectors and light emitting diodes (LED) operating in UV spectrum are of particular interest for wide range of space applications. Young stars and stellar remnants (white dwarfs) tend to emit substantial quantity of their radiation in the UV portion of the spectrum. Whereas, many of the important atomic resonance lines are in the UV or Doppler shifted into the UV. This makes UV astronomy ideal for studying the origins and elemental makeup of the universe. Furthermore, the atmospheric ozone layer absorbs nearly 100 percent of the energy in solar-blind spectrum. The UV photodetectors and UV LEDs operating in this spectral window would allow space communication, which would be secure from earth.

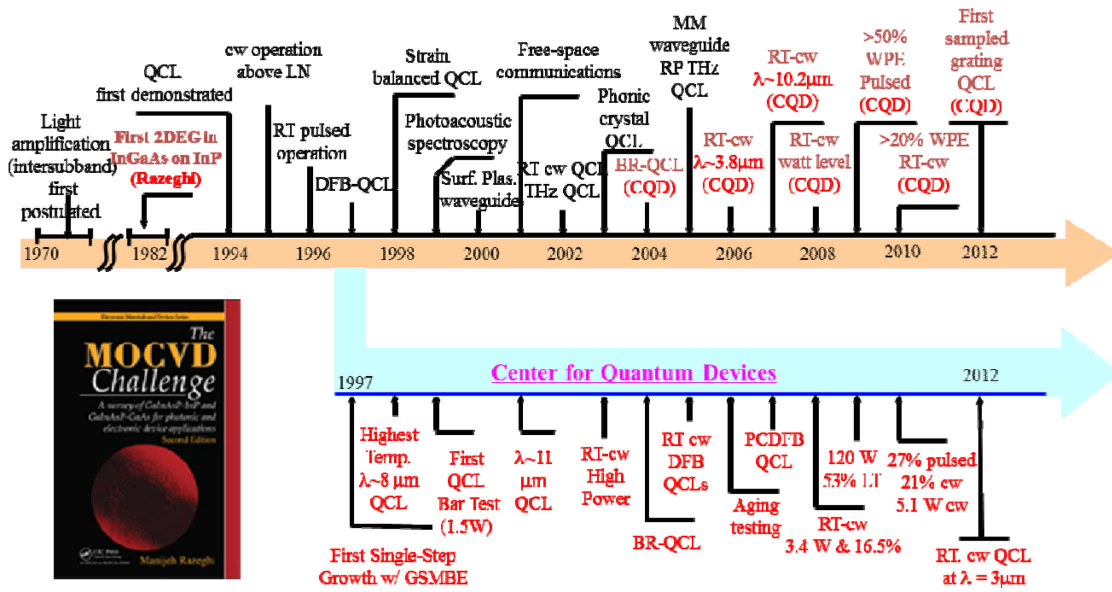

Figure 2. Historical development of quantum cascade lasers.

Human eye, as the first electromagnetic wave receiver, helped us to discover the universe. But its detection spectrum is extremely limited compare to the whole electromagnetic spectrum. Therefore, the search for alternative ways of detecting electromagnetic waves has been going on from a long time ago. Starting from second half of 20th century, semiconductors became the main platform to realize compact, low-power light detectors and emitters in different regimes from terahertz to deep UV. After years of considerable effort to bring these technologies to maturity, we now see the results of this formidable new science in almost every electronic and photonic device that we encounter. Among the most successful triumphs are the type-II superlattice photodetectors (Figure 1) and quantum cascade lasers (Figure 2) for detection and emission from terahertz to short infrared as well as III-Nitride-based materials (Figure 3) for UV detection and emission—these technologies have demonstrated the beauty of turning fundamental concepts into practical devices, thanks to advanced growth technologies. This enables us to design and realize compact devices capable for fulfilling the space applications. Here, we present our research results about these three technologies and their potential applications for space exploration.

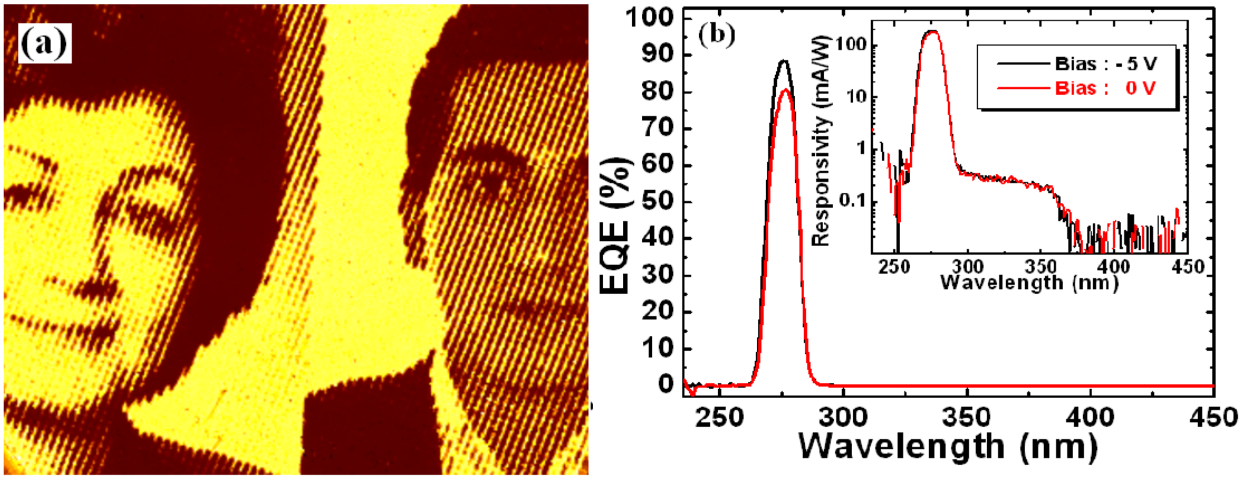

Figure 3. (a) 320 × 256 UV image. (b) Photodetector (PD) showed unbiased peak responsivity of ~176 mA/W, increasing to ~192 mA/W under 5 volts of reverse bias.