Chapter 1

Early Low-Light-Level and Electron-Beam Technologies, 1930–1945

Infrared and Electro-Optics Beginnings: Night-Vision Devices, the Electron Microscope, and the Electro-Optical Converter

About 200 years have passed since English astronomer and optician William Herschel (1738–1822) discovered infrared (IR) light—the event that originated such branches of science and engineering as night vision, optical ranging, communications, and others.

Soviet Academician Sergey Vavilov, the founder of the Soviet School of Physical Optics, regarded the great Russian scientist Mikhail Lomonosovas the inventor of the first night-vision device. In his 1936 paper "Mikhail Lomonosov's thoughts and works on optics," Vavilov writes, "Almost nobody knows that it is Mikhail Lomonosov who invented the night-vision 'observation tube.' " On June 30, 1757, Lomonosov offered the following question to the Russian Academy of Sciences as the theme for a research grant: "Is it possible to make an optical device that can enhance the light intensity to see things almost invisible in the dark?" Of course, modern methods of light intensifying were not available at that time, but Lomonosov brilliantly suggested and then proved that the night-vision tube should have a large, high-magnification objective and an exit pupil not greater than that of the human eye in the dark—ideas that underlie the design of many of today's night-vision devices.

M. V. Lomonosov (1711–1765).

It is also worth mentioning that our human desire to be able to see clearly at night had an early origin as well. The 1897 discovery of the first elementary particle—the electron—by British scientist J. J. Thomson became a milestone in physics, giving birth to many scientific and engineering disciplines. From 1892 to

1909, the basic principles of the electron theory were rapidly realized in research and many applications.

The study of electron and ion beams in the electric and magnetic fields was of great importance and resulted in K. F. Braun's invention of the cathode ray tube (CRT) in 1897. This invention gave birth to a new branch of engineering: vacuum electronics. By 1898, J. J. Thomson could deflect electron beams with a static electric field by putting two metallic plates in the CRT. Research into thermoelectric emission from 1882 to1901 led to J. A. Fleming's invention of the vacuum diode—an apparatus that works on electron principles.

In 1924, French physicist Louis de Broglie hypothesized that the electron had wavelike properties. When the hypothesis was proved, it launched the rapidly progressing scientific discipline of electro-optics. In 1926, H. Bush[1] studied rotationally symmetric electric and magnetic fields and showed that they can act as lenses. This research resulted in the design of a number of electro-optical devices.

In Europe and North America in the 1930s, progress in electro-optics led to the creation of two apparatuses: the electron microscope and the electro-optical converter of the near-IR to visible light, both being very important from engineering and military points of view.

The idea of the electro-optical converter, including the multistage one, was proposed by G. Holst and H. de Boer[2] of The Netherlands in 1928. Yet the first attempts to make the converter were not successful. A working device[3] was made by the authors (employees of Philips at the time) in 1934. The invention was given the name "Holst glass"; British firm EMI developed an industrial sample of the electro-optical converter and started to produce them for the Royal Armed Forces. Besides the United Kingdom and The Netherlands, Germany and the USA started intensive research in the field. The early theoretical works on electro-optics were written by V. K. Zworykin,[4] G. A. Morton,[5] E. Brüche,[6] and M. von Ardenne.[7]

Pioneering Efforts in the USSR

A new research institute, number 801, to conduct research in the field of electro-optics and IR engineering was established in the USSR in 1946. But many earlier efforts led up to the establishment of Institute 801. Russian pioneers in electron-beam microscopy research were S. I. Vavilov, A. A. Lebedev (who later became the head of Institute 801), V. A. Fabrikant, L. A. Artsimovich, G. A. Grinberg, V. N. Vertsner, L. M. Biberman, and G. V. Spivak. Before the advent of solid-state photoelectric devices, vacuum electro-optical converters had been the chief components for building many generations of IR devices.

By direction of the liaison department of the Red Army, the study of night vision was begun in 1935 by Professor P. V. Timofeev, V. I. Arkhangelsky, and E. S. Ratner in the vacuum engineering laboratory of the All-Union Electrotechnical Institute. The development of necessary objectives and eyepieces was organized by S. I. Vavilov and A. A. Lebedev in the State Optical Institute, Leningrad.

Pyotr Vasilyevich Timofeev (1902–1982) was a Soviet physicist, the corresponding member of the Academy of Sciences of the USSR, Hero of Socialist Labor, recipient of the USSR State Prizes, one of the founders of the national school of photoelectronics and IR engineering, and an honored member of the American Institute of Radio Engineering (1959). His scientific research included secondary electron emission, photoelectronics, night-vision devices, and optical range finding. He guided the development of the first national IR vidicon, IR lead sulfide photoresistors, electro-optical converters, and high-response kinescopes.

Vyacheslav Ivanovich Arkhangelsky (1898–1981) was a prominent Soviet radio engineer and recipient of the State (Stalin) Prize. He was one of the researchers who developed the first Soviet electro-optical converters, night-vision devices, television systems, etc. He was awarded the Order of the Red Star, the Order of the Red Banner of Labor, and other honors.

In the years prior to the Great Patriotic War (the 1941–1945 conflict between the USSR and Nazi Germany), the USSR had a few pilot devices that allowed the Red Army and naval forces to perform certain tactical tasks. In 1939 the research results were demonstrated to M. G. Pervukhin, People's Commissar of Electric Industry, and then, by his initiative, to the Council of People's Commissars: V. M. Malenkov, N. S. Khrushchov, and N. A. Voznesensky. The work was recognized as very important, and the electrotechnical institute was told to intensify its research efforts. The primary goal of this research was the development of devices for night reconnaissance and night driving. By this time, guided by Professor P. V. Timofeev—who is duly considered as the founder of night-vision engineering—V. I. Arkhangelsky, E. S. Ratner, M. M. Butslov, A. I. Pyatnitsky, and K. A. Yumatov had developed the first single-chamber cathodoluminescence image converters (C-1 and C-2). The production of these devices started in 1942 and played an important role in the development of the first generation of night-vision technology during the Great Patriotic War.

Research Institutes 8, 9, and 10, the All-Union Research Institute of Television (the location of V. I. Krasovsky's laboratory), and the Leningrad Electric-Lamp Plant "Svetlana" were also engaged in research on night-vision problems before

An experimental sample of the night-vision reconnaissance apparatus, fabricated at the All-Union Electrotechnical Institute in 1940, using the C-1 image converter and IR illuminator.

The first Soviet electro-optic converter C-1 developed at the All-Union Electrotechnical Institute, 1935–1942.

the war. In the spring of 1935, V. I. Krasovsky's laboratory could fabricate a system similar to Holst glass, and by 1936 semitransparent photocathodes with sensitivity higher than competitive samples were obtained. High-voltage power supplies were also designed and made there. A high-voltage alternating current was first generated with the help of an induction coil and interrupter powered from an accumulator. Then the current was detected with a cold-cathode kenotron, which also had been designed in V. I. Krasovsky's laboratory. In 1938 this kind of kenotron was greatly improved by P. V. Timofeev, who reduced its size to that of an acorn. The Research Institute 9 research team of A. M. Lebedev, A. N. Zaslavsky, I. V. Korobochkin, G. L. Shataev, K. S. Yasinovsky, G. A. Zubkov, V. N. Skorodumov, and others, under the guidance of S. V. Yudkevich, started developing IR devices using electro-optical converters in 1936. Experimental samples of IR direction finders called "Fire" used for night guidance of warships were made at Research Institute 9 by the beginning of the war. In 1938 the samples were sent to Sevastopol for a field trial. In 1941 K. S. Yasinovsky and N. V. Kurenkov were commissioned at Research Institute 9 to carry out another series of experiments, but they were stopped in the town of Orel with the news that Germany had started the war against the USSR.

Though researchers in other countries also conducted similar investigations, little was known in the USSR about their methods of making image converters. The technology had to be developed using internal resources. Beginning in the mid-1930s, the international scientific press stopped publishing materials on IR engineering. The competition among the great powers in the field of night vision had begun.

Wartime Technological Developments in the USSR

Infrared direction finder "Omega" mounted on a gyrocompass repeater.

At the beginning of the Great Patriotic War (autumn 1941), representatives of the air and naval forces came to the electrotechnical institute to work out an urgent plan for the development of IR devices for the Red Army. Their aim was to develop naval apparatuses that could guide warships as they entered or departed ports using IR beacons. IR instruments for aviation were intended to assist pilots in landing at night and under bad weather conditions. Though the electrotechnical institute had been evacuated to Sverdlovsk, the research and development works continued with even greater effort. The first samples of the IR direction finder "Omega" and nautical IR binoculars "Gamma" were developed in early 1942.

Nautical IR binoculars "Gamma" for spotting IR beacons.

V. I. Arkhangelsky later recollected that in March 1942, he and P. V. Timofeev (principal designers) and V. G. Biryukov (the assistant director for science) were summoned to the State Committee for Defense in Moscow. After demonstrating their IR devices to G. M. Malenkov, V. M. Molotov, L. P. Beriya, and high-ranking army officers, the committee passed the resolution of May 15, 1942, to introduce the apparatuses into the navy and start their production. Also, according to the resolution, a Special Design Bureau (SDB-1) was to be organized within the electrotechnical institute. The aim of the bureau was to develop devices that would allow humans to see in the IR range. Biryukov was appointed the head of SDB-1, P. V. Timofeev was appointed chief engineer and the head of laboratory no. 2, V. I. Arkhangelsky was appointed the head of laboratory no. 1, and V. I. Krasovsky was appointed the head of laboratory no. 3.

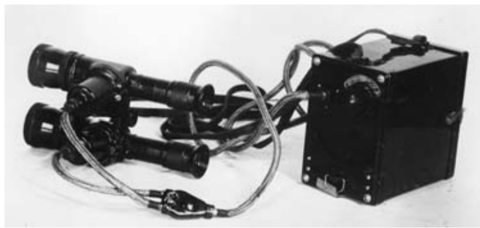
Because of the blockade of Leningrad, some engineers from Research Institute 9 and plant Svetlana (S. V. Yudkevich, P. Kh. Likhtman, K. S. Yasinovsky, N. V. Kurenkov, V. I. Krasovsky, V. T. Lukashenya, P. S. Ivanov, V. F. Olbek, and others) were relocated to SDB-1. Academician S. I. Vavilov was put in charge of the whole scientific program. At the same time, a special unit was organized at the Moscow Electric Lamp Plant 632 to produce the main constituent part of night-vision devices: electro-optical converters. The necessary optics were to be produced at the works of the People's Commissariat for Arms, light filters were made at the Red May and Misheron Plants, and the production of power supplies and assembly of devices were done at the pilot plant of the electrotechnical institute. The night-vision devices found the most use in the Black Sea Fleet. By the order of the chief of staff of the Black Sea Fleet in mid-1943, all ships were obligated to use Omega devices when entering or leaving the ports of Poti, Tuapse, Gelendgik, and Batumi. Earlier the Omega direction finder had been used successfully to guide ships at the port of Sevastopol during the defense of the town. As other navy bases were freed and restored, the IR navigation systems were put to compulsory use by the entire Black Sea Fleet. Altogether, 1,969 Omega direction finders and 1,232 Gamma binoculars were supplied to the navy forces through January 1, 1945. Practical application of the night-vision devices in the navy was achieved by P. Kh. Likhtman and S. V. Yudkevich, both of whom became leading specialists at Research Institute 801 after the war.

The SDB-1 developed IR equipment for the air forces to facilitate airplane landing, designation of the air-drop zone, etc. The first trial was carried out west of Smolensk in December 1943. The equipment allowed pilots to detect an IR beacon at distances of up to 40 km and to identify the aerodrome at a distance of 3 to 4 km. The detection of portable IR beacons was also possible within a 3-km range. After several field tests the equipment was supplied to the 1st Aircraft Army for further testing in combat conditions. However, at the time Soviet airplanes were dominant and it was unnecessary to mask aerodromes, so air force officers refused to adopt the new equipment.

An IR navigation beacon.

During summer 1943, the USSR government set the task of developing devices that could not only detect IR beacons, but could also provide IR target identification and illumination. Successfully developed in 1943–1944, the equipment went mostly to combat engineering corps. A special motorized engineering regiment was formed by the State Committee for Defense. Equipped with night-vision devices "Alfa," "Gamma," and "Kometa," and IR illuminators OSA-1 and OSA-2, the regiment was directed to master the technique and test it. The IR binocular Alfa, in combination with the illumination station OSA-2, could detect a target in the dark at a distance of 250 m;

Infrared illuminating station OSA-1.



An airborne IR binocular.

Infrared binocular "Alfa" used by the combat engineering corps.

Gamma had a detection range of 150 m. Device Kometa was designed to find a passageway through a mine field at night. Long-range target detection could be done by the experimental night-vision device "Slon." Given IR target illumination, Slon allowed the operator to see a human figure as far as 450 m away. The regiment was supplied with 7 illumination stations, 100 Alfa binoculars, 78 Gamma devices, and 363 Kometa devices. From 1943 to 1945 the regiment organized more than 300 trainings, which proved the usefulness of these devices.

Infrared long-range telescope "Slon" used by the combat engineering corps.

In 1944 the first Russian IR gunsight "Iskra" was developed for the combat engineering corps. The sight was handled by two operators. The first operator (the viewer) had to find the target with the help of an IR binocular and light it with a 30-W IR illuminator. The second operator took sight and fired. The gunsight allowed night shooting at targets located 60 to 100 m away. The electro-optical devices were not used in battle conditions.

The use of electro-optical devices during wartime showed that IR technology available at the time could provide reliable enough detection, but only of sources that emitted strong IR radiation, e.g., IR beacons. The available electro-optical converters were large and used much electric power, and they were not sensitive enough to detect targets that produced weak IR signals.

Night gunsight "Iskra" mounted onto a sniper rifle.

A target-designation device, an addition to the gunsight "Iskra."