# The life and times of the LED — a 100-year history

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Many people believe that the LED was dicovered by US researchers working in the 1960s. In fact, Henry Round at Marconi Labs noted the emission of light from a semiconductor diode 100 years ago and, independently, a forgotten Russian genius — Oleg Losev — discovered the LED.

The semiconductor light-emitting diode, or LED, is a key component of today's technology. Modern households have numerous tiny glowing indicators — provided by LEDs — that are used for reading CD and DVD disks in computer and games-console drives, or for transmitting signals to electronic equipment from remote controls. Increasingly, cars are equipped with LED indicator and brake lights. Most crucially, however, the LED is a vital link between electronics and photonics: semiconductor lasers based on LEDs send modulated optical signals into telecom fibres, serving the ever-growing demand for broadband telecommunication and Internet. Over the next decade the value of the burgeoning LED market is predicted to exceed $15 billion per year.

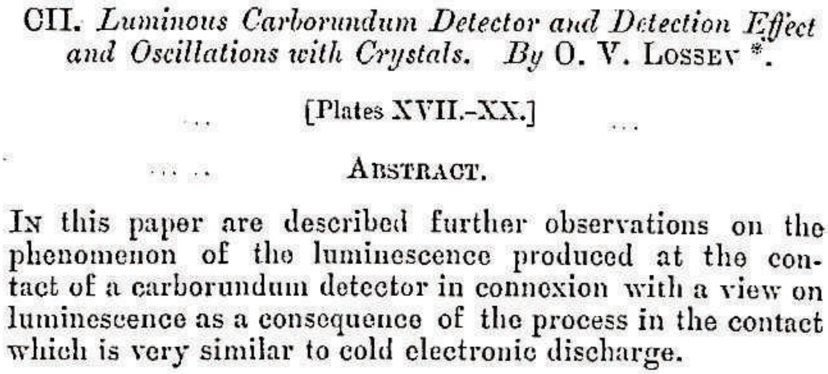
But do we actually know who invented the LED and when? We know very well that the semiconductor laser, which has an LED at its core, was revealed shortly after the demonstration of the first ruby laser. In 1962 four research groups in the USA simultaneously reported a functioning LED semiconductor laser based on gallium arsenide crystals[1–4]. Indeed, three of these papers were published in the same volume of *Applied Physics Letters*. Those involved were Robert Hall and Nick Holonyak from two different General Electric Company laboratories, Marshall Nathan of IBM and Robert Rediker of MIT, and their co-authors. These names now rightly belong in the optoelectronics hall of fame.

Modern LEDs are now available in a variety of colours and can be used in a wide range of applications.

## A FORGOTTEN FIGURE

Much less is known about the inventor of the LED itself. As it turns out, the story is a tragic one about a young and extremely talented scientist who spent his working life as a technician in several Soviet radio laboratories, eventually dying of hunger in 1942 during the blockade of Leningrad, at the age of 39. His name was Oleg Vladimirovich Losev. Losev received no formal education but during the span of his short research career he published 43 papers in leading Russian, British and German research journals and was granted 16 patents, of which he was the sole author. He made a number of major discoveries in solid-state electronics, including the first solid-state semiconductor amplifier and generator, the crystadine. In 1924 *The Wireless World and Radio Review* magazine wrote that "Mr. O. Losev of Russia has in a comparatively short space of time

Oleg Vladimirovich Losev, 1903–1942. Image courtesy of V. S. Letkhov.



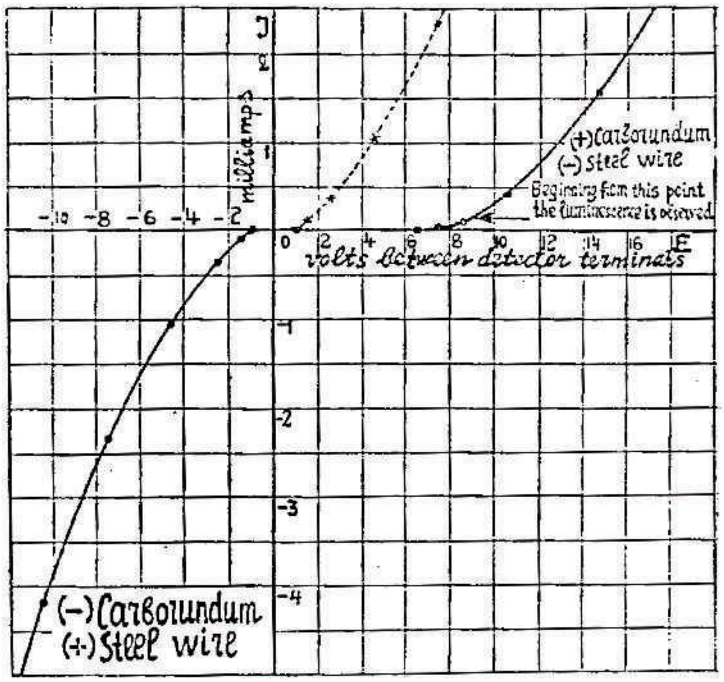
CII. *Luminous Carborundum Detector and Detection Effect and Oscillations with Crystals.* *By* O. V. Lossev *.

[Plates XVII.-XX.]

Abstract.

In this paper are described further observations on the phenomenon of the luminescence produced at the contact of a carborundum detector in connexion with a view on luminescence as a consequence of the process in the contact which is very similar to cold electronic discharge.

A facsimile of the abstract of Losev's paper published in the *Philosophical Magazine* in 1928 (ref. 7). This work describes detailed studies of LEDs.




A graph of the *I–V* characteristics of a carborundum detector indicating the onset of light emission, published by Losev in 1928 (ref. 7).

achieved worldwide fame in connection with his discoveries". However, Losev's contribution to science and engineering has now essentially been forgotten by the wider research community. This is despite a well-researched study of Losev's work by Egon Loebner, IEEE (Institute of Electrical and Electronic Engineers) senior member at the US Embassy in Moscow[5], and the efforts of a group of scientists in Losev's home town of Nizhniy Novgorod in Russia — most notably M. A. Novikov[6] and A. G. Ostroumov. Losev's remarkable life and scientific achievements could become the subject of a long and detailed study, but this commentary will only touch on his invention of the LED.

## THE GLOWING DIODE

In the mid 1920s Losev observed light emission from zinc oxide and silicon carbide crystal rectifier diodes used in radio receivers when a current was passed through them[6]. Losev's first paper on the emission of silicon carbide diodes, entitled "Luminous carborundum [silicon carbide] detector and detection with crystals", was published in 1927 by the journal *Telegrafiya i Telefoniya bez Provodov* (*Wireless Telegraphy and Telephony)* in Nizhniy Novgorod, Russia. Important publications in British and German journals soon followed[7–10]. They essentially constituted the discovery of what we now know as the LED. In his first paper on the LED[11], Losev established the current threshold for the onset of light emission from the point contact between a metal wire and a silicon carbide crystal, and recorded the spectrum of this light. In the 16 papers published between 1924 and 1930 he provided a comprehensive study of the LED and outlined its applications. Losev understood the 'cold' (non-thermal) nature of the emission, measured its current threshold, recognized that LED emission is related to diode action and measured the current–voltage characteristics of the device in detail. He also studied the temperature dependence of the emission down to the temperature of liquefied air (a predominantly nitrogen-based mixture of gases used at the time) and modulated the LED emission up to the frequency of 78.5 kHz by applying an a.c. current to the contact.

Most remarkably for a young technician with no academic qualifications, Losev was acutely aware of many contemporary developments

Класс 21 а, 27

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ПАТЕНТ НА ИЗОБРЕТЕНИЕ

ОПИСАНИЕ

светового реле.

К патенту О. В. Лосева, заявленному 28 февраля 1927 года (заяв. свид. № 14672).

О выдаче патента опубликовано 31 декабря 1929 года. Действие патента распространяется на 15 лет от 31 декабря 1929 года.

Предлагаемое изобретение использует общеизвестное явление свечения в карборундовом детекторе и состоит в том, что в световом реле для быстропишущего телеграфного или телефонного приема, передачи изображений на расстояние и других целей, в качестве модулируемого электрическим током источника света, применяется свечение в точке контакта карборундового детектора, включенного непосредственно в цепь модулирующего тока.

На чертеже фиг. 1 изображает схему предлагаемого светового реле и фиг. 2— схему устройства для фотографической записи сигналов с применением светового реле.

К зажимам *A* источника тока сигналов, подлежащих записи, через потенциометр P включается светящийся карборундовый детектор *D*, в цепь которого включена батарея *B*, дающая дополнительное постоянное напряжение для наложения его на напряжение тока сигналов и усиления действия реле; путем регулировки этой батареи создаются наивыгоднейшие условия работы детектора *D*. Оптическая система *L* предназначена направлять световой поток, излучаемый карборундовым детектором, на движущуюся фотографическую пластинку *F*, на которой производится запись изменений этого потока. Детектор *D*, оптическая система *L* и пластина *F* заключены в светонепроницаемую камеру. Примерное включение светового реле показано на чертеже 2, где *E*— приемник-усилитель высокой частоты, *T*— автотрансформатор высокой частоты, а остальная часть схемы вполне аналогична только-что описанной.

Предмет патента

1. Световое реле для быстропишущего телеграфного или телефонного приема, передачи изображений на расстояние и для других целей, характеризующееся применением, в качестве модулируемого электрическим током источника света, свечения в точке контакта карборундового детектора общеизвестного устройства, каковой детектор включен непосредственно в цепь модулирующего тока.

2. Видоизменение охарактеризованного в п. 1 светового реле, отличающееся тем, что последовательно с указанным детектором *D* включен источник дополнительного напряжения постоянного тока *B* (фиг. 1 и 2) с целью усиления действия реле.

One for the history books. A facsimile of the first page of Losev's patent for a 'Light Relay' based on an LED (ref. 12). Losev was the first to recognize the potential of the LED for telecommunication applications.

in physics. He used Einstein's quantum theory to explain the action of the LED and called the emission process the "inverse photo-electric effect". In addition, he proposed a formula[8] relating the voltage drop on the diode contact, $V$, the electronic charge, $e$, and the light emission frequency, $v$, through Planck's constant, $h$, that is $v = eV/h$. The formula is still in use to this day. Despite the fact that semiconductor band theory had not yet been fully developed, Losev was able to relate the effect in silicon carbide to the diffraction of the electron de Broglie matter waves. According to the prominent Russian physicist Abram Ioffe, Losev wrote to Einstein asking him for help in further developing the theory, but received no reply[5].

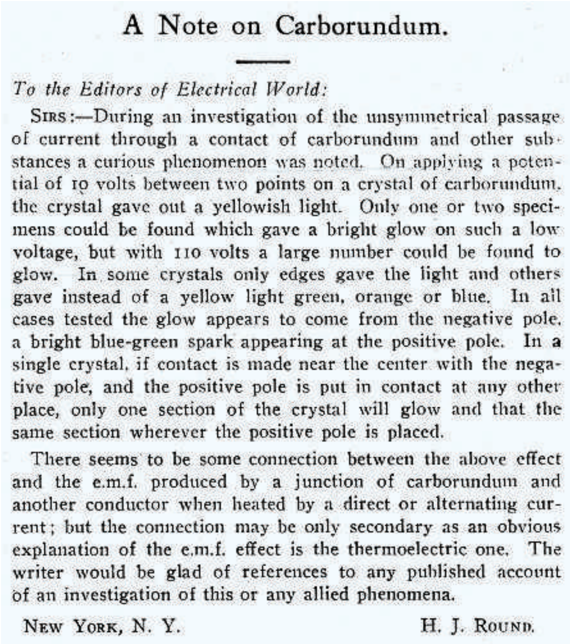
In 1929, Losev published detailed measurements of LED spectra and clearly observed their dependence on current[8]. It is incredibly interesting to see this data now, with the hindsight that the narrowing of the spectrum is evidence of laser action: the 1962 reports of laser action in gallium-arsenide-based diodes were underpinned by such spectral measurements. Did Losev see, without understanding its importance, coherent laser radiation from an LED in 1929? Perhaps not, but remarkably, the first significant blue LEDs reinvented at the start of the 1990s used silicon carbide.

## THE REVOLUTION THAT NEVER HAPPENED

Losev was the first to understand the potential of the LED for telecommunications. In the introduction to his patent[12] entitled 'Light Relay', which was filed in 1927 and granted on 31 December 1929, he wrote: "The proposed invention uses the known phenomenon of luminescence of a carborundum detector and consists of the use of such a detector in an optical relay for the purpose of fast telegraphic and telephone communication, transmission of images and other applications when a light luminescence contact point is used as the light source connected directly to a circuit of modulated current." Unknown and uncelebrated, this should have been the beginning of the photonic telecommunications revolution.

## ALONE AND FORGOTTEN

Losev was a lonely scientist who left no disciples and never had a co-author. Being born into the noble family of a Russian Imperial Army officer was not exactly a good starting point in Bolshevik Russia, where people of such descent were banned from the career ladder. A self-made scientist who attended a few university courses but never formally completed his education, Losev was eventually awarded a PhD without a formal thesis by the Ioffe Institute in 1938. The happiest and most productive years of his research work were spent at the Nizhniy Novgorod Radio Laboratory before he moved to Leningrad where, after years of hardship, he eventually found himself a position as a humble technician at the Leningrad Medical Institute. According to Losev's recently discovered autobiography[6], he was nevertheless able to continue his research in Leningrad. He discovered that "using semiconductors, a tree-terminal system may be constructed analogous to a [vacuum] triode". However, in November 1941 he was unable to pass the finished paper (presumably on an important silicon device) from the besieged city of Leningrad to the evacuated editorial office of the *Soviet Physics JETP* (now *Journal of Experimental and Theoretical Physics*) in Kazan[5]. Was it a paper on what we now know as a transistor? We shall never know for certain unless his manuscript is found. Sadly, after he passed away in Leningrad during World War II, his name was simply forgotten. In the difficult years that followed nobody took the opportunity to propagate his knowledge or follow up the potential revealed by his discoveries. Thwarted by the turbulence of the times, is arguably well-deserved reputation as one of the titans of twentieth century physics and engineering was never established.



A Note on Carborundum.

*To the Editors of Electrical World:*

SIRS:—During an investigation of the unsymmetrical passage of current through a contact of carborundum and other substances a curious phenomenon was noted. On applying a potential of 10 volts between two points on a crystal of carborundum, the crystal gave out a yellowish light. Only one or two specimens could be found which gave a bright glow on such a low voltage, but with 110 volts a large number could be found to glow. In some crystals only edges gave the light and others gave instead of a yellow light green, orange or blue. In all cases tested the glow appears to come from the negative pole, a bright blue-green spark appearing at the positive pole. In a single crystal, if contact is made near the center with the negative pole, and the positive pole is put in contact at any other place, only one section of the crystal will glow and that the same section wherever the positive pole is placed.

There seems to be some connection between the above effect and the e.m.f. produced by a junction of carborundum and another conductor when heated by a direct or alternating current; but the connection may be only secondary as an obvious explanation of the e.m.f. effect is the thermoelectric one. The writer would be glad of references to any published account of an investigation of this or any allied phenomena.

NEW YORK, N. Y. H. J. ROUND.

A facsimile of Henry J. Round's note on the glow of carborundum — the first observation of electroluminescence, 100 years ago (ref. 13).

## SOLID-STATE OPTOELECTRONICS CENTENARY

The story would not be complete without mentioning one other remarkable person who has enjoyed better professional recognition — Henry J. Round, one of Marconi's assistants in England and later Chief of Marconi Research. In February 1907, Round published a 24-line note in *Electrical World* reporting a "bright glow" from a carborundum diode[13]. There was no follow-up publication, and apparently this small note was not known to Losev. As suggested by Egone Loebner[5], it is not appropriate to credit Round with the invention of the LED, but he should be recognized as the discoverer of the phenomenon of electroluminescence. In any case, the names of these two scientists, Losev and Round, should find well-deserved places in the front-line history of modern technology and the year 2007 should be celebrated as the centenary of solid-state optoelectronics.

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