

Optogenetics Market - Industry Size, Share, Trends, Opportunity, and Forecast, 2018-2028 Segmented by Light Equipment (Laser and Light-emitting Diode), By Actuator (Channelrhodopsin, Halorhodopsin, and Archaelhodopsin), By Sensor (Calcium (Aequorin, Cameleon, and Other Calcium Sensors), Chloride (Clomeleon), Membrane-gated (Mermaid), and Other Sensors), By Application (Neuroscience, Behavioral Tracking, Retinal, Disease Treatment, and Other Applications), and By Region, Competition

<https://marketpublishers.com/r/O6E18611EC67EN.html>

Date: October 2023

Pages: 181

Price: US\$ 4,900.00 (Single User License)

ID: O6E18611EC67EN

Abstracts

Global Optogenetics Market has valued at USD 545.60 million in 2022 and is anticipated to witness an impressive growth in the forecast period with a CAGR of 4.01% through 2028. Optogenetics is a cutting-edge biological technique that combines the principles of optics (light) and genetics to control and manipulate the activity of specific cells in living organisms, typically using light-sensitive proteins called opsins. It has revolutionized the field of neuroscience and has applications in various other fields, including biology, medicine, and biotechnology. At the core of optogenetics are opsins, which are light-sensitive proteins found in various organisms, including certain types of algae and bacteria. These proteins undergo structural changes in response to light, which in turn affect the electrical activity of cells expressing them. Opsins can be genetically engineered and introduced into target cells, allowing those cells to become responsive to light. The precise control offered by optogenetics has raised ethical considerations, particularly when applied to humans and animals. Researchers and institutions are guided by ethical standards when conducting optogenetic experiments.

Optogenetics has revolutionized neuroscience by enabling precise control of neural circuits. The continuous advancement of our understanding of the brain and the need for sophisticated tools to study it has driven the adoption of optogenetic techniques. Ongoing advancements in optogenetic tools, including the development of improved opsins (light-sensitive proteins) and more precise light-delivery systems, have made optogenetics more accessible and user-friendly for researchers. The potential for translating optogenetics from a research tool into clinical applications has attracted significant interest and investment. Researchers are exploring optogenetics' therapeutic potential for treating neurological and psychiatric disorders. Many research projects in optogenetics receive funding from government agencies and institutions interested in advancing neuroscience and medical research. This financial support has fueled research and development in the field.

Key Market Drivers

Technological Innovations

Opsins are light-sensitive proteins used in optogenetics to control cellular activity. Continuous research has led to the development of new and improved opsins with enhanced properties, such as increased sensitivity to light, faster response times, and altered spectral properties. These innovations have allowed for more precise control of neural circuits. Multiplexing in optogenetics involves the simultaneous activation or inhibition of multiple types of opsins in different neurons or neural populations. This technology allows researchers to study complex neural circuits and interactions. Innovations in multiplexing techniques have improved the scalability and versatility of optogenetic experiments. Advanced optical fiber systems and microscopy techniques have been developed to deliver light with high spatial and temporal precision. These innovations enable researchers to target specific brain regions or even individual neurons with greater accuracy. Researchers have developed wireless optogenetic systems that eliminate the need for tethered light sources and allow for more naturalistic experiments in freely moving animals. This technology enhances the study of behaviors and neural circuits in unrestrained conditions. Miniaturization of optogenetic devices and implants has allowed for less invasive experiments in small animals. These devices can be implanted directly into the brain, enabling long-term and chronic studies. Closed loop optogenetic systems incorporate real-time feedback from neural activity to adjust light stimulation. These systems enable dynamic experiments in response to specific neural patterns, enhancing the understanding of neural circuitry. Innovations in viral vectors and gene delivery techniques have improved the efficiency and specificity of introducing

optogenetic tools into target cells or tissues. This has facilitated the adoption of optogenetics in a wider range of organisms and cell types.

Two-photon microscopy combined with optogenetics allows for deeper penetration of light into brain tissue. This innovation has expanded the spatial reach of optogenetic experiments, making it possible to target neurons in deeper brain regions. The development of inhibitory optogenetic tools, such as Halorhodopsin (eNpHR) and Arch, has allowed for the precise inhibition of neural activity. Researchers can now manipulate neural circuits bidirectionally, activating, and inhibiting neurons as needed. In addition to opsins for control, optogenetic sensors have been developed to monitor neural activity and physiological parameters in real-time. These sensors provide valuable feedback for closed-loop experiments and enable the study of neural dynamics. Optogenetics has been integrated with electrophysiological techniques, allowing researchers to combine light stimulation with the recording of neural activity. This integration provides a comprehensive view of neural circuit function. Commercial suppliers have played a significant role in advancing optogenetics by providing researchers with well-characterized and validated optogenetic tools, making them more accessible to a broader scientific community. This factor will help in the development of Global Optogenetics Market.

Advancements in Neuroscience Research

Neuroscience research has seen significant advancements in recent years, driven by technological innovations, collaborative efforts, and increased funding. These advancements have deepened our understanding of the brain and its functions. Advances in connectomics have allowed researchers to map the intricate connectivity of the brain at the level of individual neurons and synapses. Techniques like electron microscopy and high-resolution imaging are helping create comprehensive brain connectivity maps. Functional Magnetic Resonance Imaging (fMRI) techniques have improved in spatial and temporal resolution, enabling more precise mapping of brain activity and connectivity. Resting-state fMRI has revealed functional networks in the brain, shedding light on its organization. Single-cell RNA sequencing has allowed researchers to study gene expression at the single-cell level, providing insights into cell diversity and gene regulation within the brain. This technology has been instrumental in classifying various cell types in the brain. Optogenetics and chemogenetics have become essential tools in neuroscience. Researchers can manipulate and study specific neural circuits with unprecedented precision, enabling a deeper understanding of brain function. The use of Crispr-Cas9 gene editing technology has enabled researchers to modify genes in animal models to study their effects on brain development and function.

This technology has revolutionized genetics research in neuroscience. Advanced neuroimaging techniques, such as diffusion tensor imaging (DTI) and positron emission tomography (PET), have provided insights into brain structure, connectivity, and metabolism, facilitating research on neurological disorders. Techniques like transcranial magnetic stimulation (TMS) and transcranial direct current stimulation (tDCS) have gained prominence for their potential therapeutic applications in neuropsychiatric disorders.

Machine learning and artificial intelligence have been applied to analyze large-scale neural data, making it possible to decode brain activity patterns, predict behavior, and diagnose neurological conditions. Brain-Computer Interfaces (BCIs) have advanced, allowing for more precise control of external devices using brain signals. These interfaces have potential applications in assistive technology and neurorehabilitation. The development of brain organoids, miniaturized 3D brain tissue models derived from stem cells, has enabled researchers to study early brain development, model diseases, and test drug responses in a more realistic environment. Growing understanding of neuroinflammation's role in neurological diseases, such as Alzheimer's and multiple sclerosis, has led to the development of novel therapeutic strategies targeting inflammation. Initiatives like the Human Connectome Project and the BRAIN Initiative (Brain Research through Advancing Innovative Neurotechnologies) have brought together researchers from various disciplines to accelerate our understanding of the brain's structure and function. The field has made strides in addressing ethical considerations related to brain research, including discussions about the responsible use of technologies like optogenetics and brain-computer interfaces. This factor will pace up the demand of Global Optogenetics Market.

Expanding Application Areas

Expanding application areas have indeed been a significant driver for the demand of optogenetics. Originally developed as a powerful research tool for neuroscience, optogenetics has found applications in various fields, expanding its reach and impact. Optogenetics' primary application has been in neuroscience, where it has enabled researchers to control and manipulate specific neurons and neural circuits with unprecedented precision. It has deepened our understanding of brain function, behavior, and the underlying mechanisms of neurological disorders. Optogenetics has been applied in cardiology to control cardiac tissue and study the heart's electrical activity. It has potential applications in arrhythmia research and the development of novel therapies for heart conditions. In optometry, optogenetics has been used to study the visual system and retinal function. Researchers have explored its potential for

restoring vision in conditions like retinal degeneration. Optogenetics plays a role in regenerative medicine by allowing researchers to control the differentiation and function of stem cells. It has potential applications in tissue engineering and the development of cell-based therapies. Optogenetics has been used to study pain perception and pathways in the nervous system. Researchers can manipulate pain-related neurons to better understand chronic pain conditions and develop potential interventions. The application of optogenetics in psychiatry research has shed light on the neural circuits involved in mood disorders, addiction, and anxiety. It offers insights into potential targets for therapeutic interventions.

Optogenetics has been used to study hormonal regulation and endocrine systems. Researchers can control the release of hormones and investigate their effects on various physiological processes. Optogenetics has found applications in cancer research, where it has been used to control cell behavior and study tumor growth and metastasis. It offers a tool for manipulating cancer cells and studying their responses. Researchers have applied optogenetics to investigate immune cell behavior and responses. It provides a means to control immune cell activation and study immune system dynamics. Optogenetics is used in bioengineering and synthetic biology to design and control cellular processes. It allows for the precise engineering of cells to perform desired functions. Pharmaceutical and biotechnology companies use optogenetics in drug discovery to screen and test potential drug candidates. It provides a valuable tool for studying cellular responses to drugs. As optogenetics expands into new application areas, discussions around the ethical implications of manipulating neural circuits and cellular functions have become more prominent. This factor will accelerate the demand of Global Optogenetics Market.

Key Market Challenges

Limited Understanding of Neural Circuits

The human brain is incredibly complex, with billions of neurons and trillions of synapses. Our understanding of how all these elements work together to produce behaviors and cognitive functions is still incomplete. This complexity makes it challenging to design optogenetic experiments that target the right neurons and circuits. Although significant progress has been made in mapping neural circuits, especially in model organisms like mice, there are still gaps in our knowledge. Comprehensive maps of all the neural circuits in the brain are lacking, which can limit the precision of optogenetic experiments. Neural circuits can vary significantly from one individual to another. What works in one person's brain may not work the same way in another person's brain. This

variability can complicate the application of optogenetic techniques in clinical settings. Some deep brain regions are challenging to access and study, making it difficult to understand their circuitry. Optogenetic experiments in these regions may be limited by the ability to deliver light to the target neurons effectively. Linking specific neural circuits to complex behaviors and cognitive functions can be a formidable challenge. While optogenetics can manipulate neural activity, understanding the precise relationship between neural activity patterns and behavior is an ongoing endeavor.

Cost of Technology

Optogenetics experiments require specialized equipment, including light sources (e.g., lasers or LEDs), optical fibers, and imaging systems. These components can be expensive, especially for high-quality, research-grade systems. Researchers often need to customize their optogenetic setups to suit their specific experimental needs. Customization can add to the overall cost, as it may require engineering expertise and bespoke components. The purchase of optogenetic reagents, such as viral vectors carrying opsins, is an ongoing expense. These reagents need to be regularly replenished for experiments. In animal studies, maintaining transgenic animals or administering viral vectors can incur costs related to animal housing, care, and ethical oversight. Skilled personnel are needed to conduct optogenetics experiments, from designing protocols to carrying out experiments and data analysis. Employing trained researchers adds to the overall cost. Researchers require training and expertise in optogenetics techniques, which can involve additional costs for workshops, courses, or hiring experts. Consumables such as optical fibers, cannulas, and electrodes need to be regularly replaced, adding to ongoing operational costs. Regular maintenance and calibration of equipment like lasers and microscopes are necessary to ensure accurate and reliable results. Maintenance costs can add up over time.

Key Market Trends

Customization and Targeted Approaches

Researchers are customizing optogenetic tools to suit their experimental requirements. This customization includes the development of novel opsins, such as variants with altered kinetics, spectral properties, or tissue-specific expression patterns. These tailored tools enable more precise and effective control of neural circuits. Multiplexing in optogenetics involves the simultaneous use of multiple opsins with different properties in a single experiment. This approach allows researchers to target distinct neural populations within the same tissue or brain region. Customizing multiplexed optogenetic

systems enhances the flexibility of experiments. Customization extends to achieving cell-type specificity in optogenetic experiments. Researchers are designing opsins that selectively target specific cell types, such as excitatory or inhibitory neurons, or neurons expressing specific molecular markers. Optogenetics is increasingly being used for circuit-specific manipulation. Custom-designed opsins and targeting strategies allow researchers to activate or inhibit specific neural pathways or synapses, dissecting complex circuits to understand their function. In the context of potential clinical applications, researchers are developing customized optogenetic approaches to target specific neural circuits associated with neurological and psychiatric disorders. This targeted customization is crucial for the development of precise therapeutic interventions.

Segmental Insights

Light Equipment Insights

In 2022, the Global Optogenetics Market largest share was dominated by Light-emitting Diode (LED) segment in the forecast period and is predicted to continue expanding over the coming years. LEDs offer precise control over the timing, intensity, and wavelength of light, making them a popular choice for optogenetics experiments. Researchers can tailor the light stimulation to specific requirements, allowing for fine-tuned manipulation of neural circuits. LEDs are available in a wide range of wavelengths, which is crucial for activating various light-sensitive proteins used in optogenetics. This flexibility allows researchers to target specific neural populations or cellular processes. Researchers can customize LED setups to suit their specific experimental needs, allowing for the development of unique and tailored optogenetic systems. Over the years, LEDs have gained acceptance and validation in the scientific community for optogenetic applications. Researchers have published numerous studies using LED-based optogenetics, further establishing their credibility.

Actuator Insights

In 2022, the Global Optogenetics Market dominated by Channel rhodopsin segment and is predicted to continue expanding over the coming years. Channel Rhodopsin, particularly Channelrhodopsin-2 (ChR2), was one of the earliest and most widely used optogenetic tools. Its pioneering role in the field contributed to its widespread adoption and recognition by researchers. ChR2 and related Channel Rhodopsin proteins are highly effective at controlling neuronal activity. They enable precise and rapid control of neural firing with millisecond precision when exposed to light, making them invaluable

for neuroscience research. Channel Rhodopsin activation typically requires blue light, which is well-suited for LEDs. LEDs are a common light source in optogenetics, and their compatibility with Channel Rhodopsin makes it a practical choice for many researchers. Channel Rhodopsin allows for targeted activation of specific neurons or neural populations. This specificity is crucial for studying the function of brain regions or circuits. A significant body of research has been built around the use of Channel Rhodopsin, providing a strong foundation for its adoption in the scientific community. Numerous studies have demonstrated its effectiveness in various experimental contexts.

Sensor Insights

In 2022, the Global Optogenetics Market dominated by Chloride segment and is predicted to continue expanding over the coming years. Chloride channels can be used for optogenetic inhibition, allowing researchers to silence or inhibit neural activity when exposed to light. This complements the excitatory optogenetic tools (e.g., Channelrhodopsin) and provides a more comprehensive toolkit for controlling neural circuits. The combination of excitatory (e.g., Channelrhodopsin) and inhibitory (e.g., Halorhodopsin) optogenetic tools can enable researchers to study neural circuits more comprehensively by both activating and silencing specific neurons or populations. The availability of commercial products and reagents for chloride channel-based optogenetics can facilitate their adoption among researchers. Commercially available tools are often well-characterized and validated. Advancements in the development of chloride channel-based optogenetic tools, including improved variants with enhanced properties, may have contributed to their popularity.

Application Insights

In 2022, the Global Optogenetics Market largest share was dominated by Neuroscience segment in the forecast period and is predicted to continue expanding over the coming years. Optogenetics was originally developed as a powerful tool for studying the brain and neural circuits. Its primary application has been in neuroscience research, allowing researchers to precisely control and manipulate the activity of neurons in vivo. As a result, the majority of optogenetics applications and studies have been focused on neuroscience. The complexity of the brain and the need for precise control over neural circuits have made optogenetics an indispensable tool for neuroscientists. It enables researchers to investigate fundamental questions about brain function, behaviour, and neurological disorders. A significant number of research publications and studies in the field of optogenetics have been related to neuroscience. This extensive body of

research has further fuelled interest in using optogenetics to advance our understanding of the brain.

Regional Insights

The North America region dominates the Global Optogenetics Market in 2022. Due to the rising prevalence of chronic diseases in the area, the increasing use of optogenetic devices, particularly in university and research labs, and the partnerships and new product launches by important market participants. The main drivers of growth in the neurological field are rising government initiatives. With more investment, more businesses can enter the market and offer creative solutions to meet patient requirements. More care is needed for the growing patient population, which raises the need for optogenetics and accelerates the market's expansion. Additionally, it is projected that partnerships and agreements will propel the industry.

Key Market Players

Hubner Group (Cobolt Inc.)

Coherent Inc.

Gensight Biologics S.A.

Laserglow Technologies

Noldus Information Technology Inc.

Judges' Scientific PLC (Scientifica)

Shanghai Laser & Optics Century Co. Ltd

Bruker Corporation

Thorlabs Inc

Report Scope:

In this report, the Global Optogenetics Market has been segmented into the following categories, in addition to the industry trends which have also been detailed below:

Optogenetics Market, By Light Equipment:

Laser

Light-emitting Diode

Optogenetics Market, By Actuator:

Channel rhodopsin

Halorhodopsin

Archaerhodopsin

Optogenetics Market, By Sensor:

Calcium (Aequorin, Cameleon, and Other Calcium Sensors)

Chloride (Clomeleon)

Membrane-gated (Mermaid)

Other Sensors

Optogenetics Market, By Application:

Neuroscience

Behavioral Tracking

Retinal Disease Treatment

Other Applications

Global Optogenetics Market, By region:

North America

United States

Canada

Mexico

Asia-Pacific

China

India

South Korea

Australia

Japan

Europe

Germany

France

United Kingdom

Spain

Italy

South America

Brazil

Argentina

Colombia

Middle East & Africa

South Africa

Saudi Arabia

UAE

Competitive Landscape

Company Profiles: Detailed analysis of the major companies present in the Global Optogenetics Market.

Available Customizations:

Global Optogenetics Market report with the given market data, Tech Sci Research offers customizations according to a company's specific needs. The following customization options are available for the report:

Company Information

Detailed analysis and profiling of additional market players (up to five).

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- 17.5. Recent Developments
- 17.6. SWOT Analysis
 - 17.6.1. Hubner Group (Cobolt Inc.)
 - 17.6.2. Coherent Inc.
 - 17.6.3. Gensight Biologics S.A.
 - 17.6.4. Laserglow Technologies
 - 17.6.5. Noldus Information Technology Inc.
 - 17.6.6. Judges' Scientific PLC (Scientifica)
 - 17.6.7. Shanghai Laser & Optics Century Co. Ltd
 - 17.6.8. Bruker Corporation
 - 17.6.9. Thorlabs Inc.

18. STRATEGIC RECOMMENDATIONS

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