

Optics for Energy

NEWSLEEER

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On the borders of imagination and grounding theories

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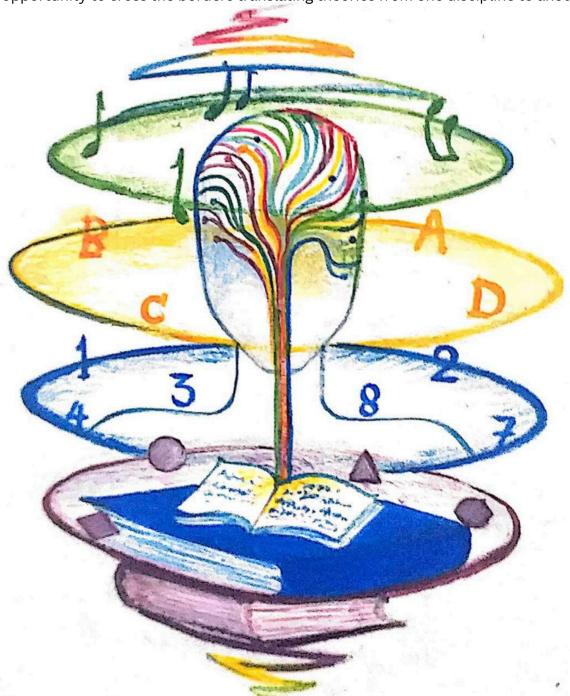


Click and drop



"Imagination is important than knowledge.", Albert Einstein

Surely what Einstein meant was not to simply fly our mind in any direction with no grounding in facts and scientific theories. Perhaps he wanted us to open our mind sometimes to seemingly childish and nonsense ideas. At one point, however, there must be a time to land our imagination in the ground of basic theories, logic, and facts, especially if we are eager to share our view with others. But even then, in examining our imagination, we should not hesitate to question the things that we have known as truth, not just to prove our mere imagination but to extend the domain of our knowledge. Fortunately, the borders between various areas of science is becoming narrower giving the scientists the opportunity to cross the borders translating theories from one discipline to another.



"The Internet of Power" (covered in our Technology Brief section), for instance, might not have been even dreamed centuries ago.

Yet, now possible with the interdisciplinary knowledge of optics for energy.

FOREWORD

Mission and Goals

The groups aims is to connect professionals and students in optics and energy through: Technical events ,Educational webinars, Networking activities, Social media engagement.

MUCH MORE would be possible with your contributions!

Meet the team



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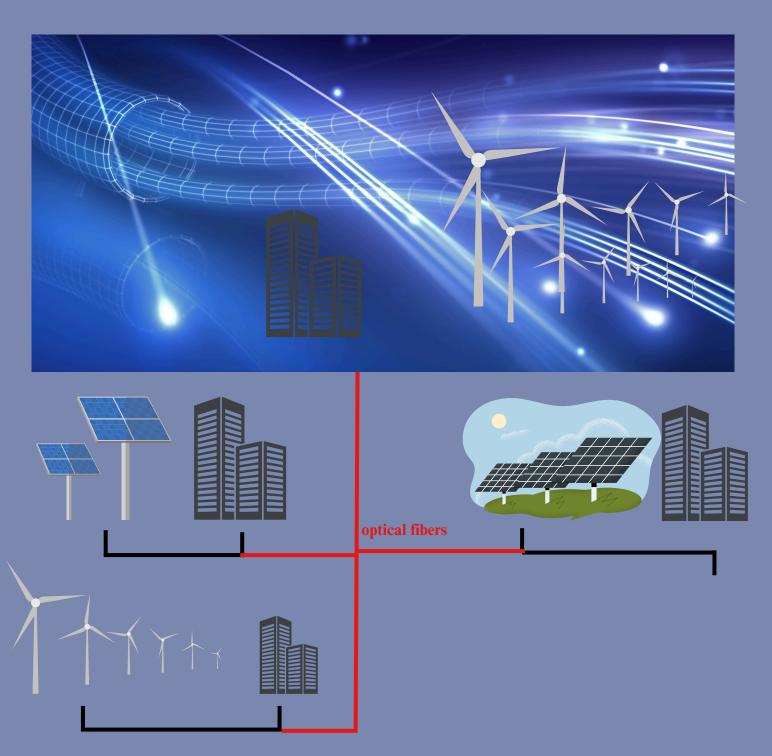
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OPTICS IN ENERGY TRANSMISSION

Provided by "Trine.Energy"

Fiber optic network carrying high power laser can become

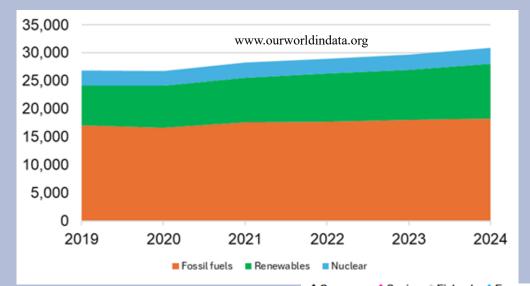
The Internet of Power



Zero marginal cost for electricity generation; A locked potential for future

Global electricity demand is expected to reach unprecedented levels in human history. Transformative technologies ranging from AI, electrification of mobility and industrial processes, crypto to quantum computing are driving this surge. Each requires substantial amount of reliable electricity to operate and to scale effectively. At the same time electricity generation from renewables is rapidly rising. They already account for more than a third of the global electricity generation. We will be

taxpayers. The combined forces of rising demand and intermittent supply are testing the limits of existing power infrastructure. Grids, the primary means of transportation of electricity, are ill-prepared to handle this test. While functional, they require immense effort to construct and are costly to maintain. They need significant upgrades after decades of underinvestment. According to various studies, achieving net zero emissions by 2050 requires an annual investment of 800 billions dollars by 2030. The governments currently do not have fiscal capacity to make this happen.



The rapid growth of renewables, together with the renaissance of nuclear energy and advances in fusion suggest that there will be no shortage of electrical power to meet future demands. The primary challenge will be in distributing it in both national and global scales.

soon living in a world where marginal cost of energy generation will be zero. Solar and wind growth is unstoppable. Nuclear is making a comeback. Fusion is finally looking like a real deal. The real problem to solve would be the global transportation of electricity. While renewables provide cleaner energy, their output is inherently intermittent. They can't be moved or stored with the same ease as fossil fuels, which made them the most successful global product ever. Today's power grid infrastructure was invented a century ago and hasn't seen any real innovation ever since. Failure of governments to increase grid capacity is forcing renewable producers to sell at a loss (negative pricing), or curtail production, costing billions of dollars to

Image credit- Bloomberg (Link to article)

5

2019

2020

2021

2022

2023

2024

Internet of Power; Towards a global electricity network;

Power-over-Fiber (PoF) technology has the potential to serve as the foundation for the electricity grid of the future. Laser and fiber-optics systems are highly flexible and scalable. Moreover, they can be produced in significantly higher volumes than traditional transmission cables. They are also easier to deploy and less expensive to maintain and their performance and cost efficiency are rapidly improving. Laser is highly global successful product; The global backbone of internet, which is in the form of under-sea fiber optics network runs on laser. Unit cost of laser has been dropped exponentially which is a huge advantage for technologies that use laser. In addition, laser is highly versatile and easy to handle compared to electricity.

Fiber Optics is the backbone of the modern internet - a network spanning 1.4 million kilometers now connects virtually every corner of the planet. By analogy, an "Internet of Power" could enable instantaneous and seamless electricity transaction between producers and consumers worldwide, eliminating regional silos and balancing supply and demand in real time. Such a network would create a globally integrated energy system of unprecedented utility.

A commercially viable approach involves integrating existing technologies to develop products that can be deployed in the near term and meet a clear market demand. For example, providing power redundancy infrastructure such as defense installation and data centers, can be achieved by scaling PoF systems to deliver 1-5 MW over the distances of 1-5 km. Both power and distance can be further scaled through modular designs. By leveraging technologies that are already invented and commercialized, and by pushing the boundaries of engineering and finance, PoF could address one of the most significant bottlenecks in the global energy transition.

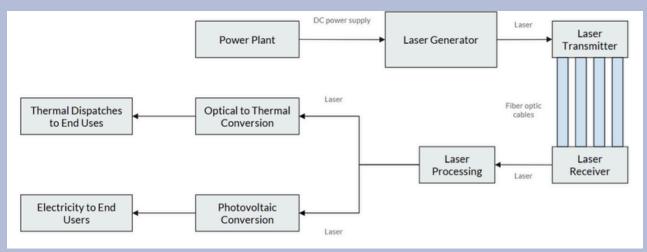
On addressing the issue of the global energy transmission, *Trine Energy*, a startup based in UK, plans to combine technologies from different fields of science and engineering, especially laser and fiber optics, and create a complete product that customers can use. They believe that creating a product that solves one of the biggest challenges of this century is a mission worth pursuing. While working on the design of their energy transmission system, these are some of the key challenges they need to solve in the process:

- Minimizing optical losses over long distance transmission.
- Managing high level of heat generated during transmission.
- Achieving high optical-electrical conversion efficiencies.
- Meeting the maintenance and safety standards comparable to existing grid/transfer infrastructure.

Sources & References:

- BloombergNEF, "Reading the global power grid for net zero, October 31, 2024
- Eric Pradana, et al., "Technology update on patent and development trend of power over fiber, a critical review and future prospects", *Journal of Photonic for Energy*, 2023
- Zhang, L., et al., "High Power Optical Fiber Energy Transmission, Advances and Applications" MDPI Photonics, 2022.
- Trine.Energy https://trine.energy/

Concept system



Publications Review

Silicon nanohole based enhanced light absorbers for thin film solar cell applications by Das et al. (2024)

Introduction

Thin-film silicon(Si) solar cells continue to attract interest due to their material abundance, matured fabrication technique, reliability, low cost and compatibility with large scale fabrication. However, reduced optical absorption in ultrathin Si layers remains a fundamental challenge, mainly due to low absorption coefficients particulary beyond the visible spectrum. Nanophotonic light trapping geometries have emerged as promising solutions, offering strong field confinement and extended photon path lengths through subwavelength structuring.

This work addresses absorption and efficiency enhancement by integrating periodic nanohole arrays in a 3 µm Si-slab, operating across wavelengths of 300nm to 1100 nm and comparing square and circular hole geometries. The researchers target simultaneous optical, electrical, and thermal optimization, aiming to establish a high performance platform for next-generation ultrathin Si photovoltaics.

Method

The optical absorption behavior was modeled using a 3D finite difference time domain (FDTD) framework with periodic boundary conditions. A 75 nm $\mathrm{Si_3N_4}$ antireflection coating and 300 nm Ag back reflector were included to minimize reflection and transmission losses, respectively. Electrical performance metrics were evaluated through Lumerical charge transport solvers using carrier generation maps imported from the optical simulations.

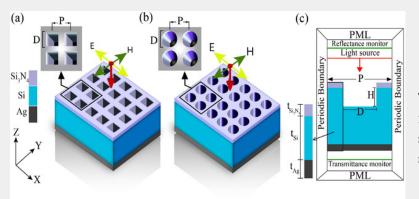


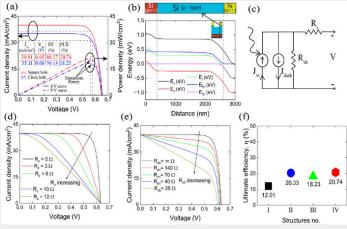
Illustration of the: square, circular nanohole and crosssection view of the simulation setup

Doping profiles were varied to form p-i-n device structures and recombination mechanisms, including surface and Auger pathways, were considered. Thermal response was examined under steady state and transient illumination to assess operational reliability.

Results

The nanohole structures significantly improved broadband absorption compared to bare Si. The optimized square hole design achieved an average absorption of 72.6% between 300 and 1100 nm, with peak absorption of ~99.8% near 501 nm. Polarization insensitive response was verified due to symmetry, ensuring robustness under real solar illumination.

Electrical evaluation indicated a short-circuit current density of 39.91 mA/cm² and power conversion efficiency of 20.74% for the square-hole architecture, exceeding many state of the art thin Si reports. Fill factor performance remained high at approximately 80%. Parametric sweeps revealed optimal performance for 800 nm hole depth and 295 nm diameter.



J-V and P-V characteristics comparing square and circular nanohole Si absorbers

Thermal simulations confirmed only ~10 K temperature rise under operating conditions, maintaining device stability across varied ambient temperatures, thus supporting practical operational feasibility.

https://doi.org/10.1007/s11468-024-02603-y

Inspiring story:

By Ahmed

A calculator, how amazing such a device is! It can perform complicated calculations in the blink of an eye, I wondered as a high school kid.

What is there inside, how does it work? I once got a chance to discover therein are a keypad with on/off buttons, and wires to connect their choices to a small "black box with many legs". They told me that this black box with many legs encapsulates a "chip" that is the performing core of the device, a piece made of "electronic material" with many connected little sub-devices that only "developed countries" are able to make! Later then, I knew of electronic computers and other "electronic" devices, which all facilitate a better human life. All are imported to my home country, as they are made somewhere else!

Why wouldn't a country with huge resources, like many "developing countries", be able to make these electronics? Don't we have their "Know How"? We should then arrange to know, to be able to make them when

an investment in their fabrication is called for.

With curiosity and purpose in mind, I got the passion to learn Electronics Engineering and later to join a university faculty to educate my fellow citizens on electronics and their various "High Tech" applications; to foster a knowledge and human resources pool promoting the establishment of local high tech industries and waiting for the courageous capital to investment in them.

Then came the revolution of computer communications - the Internet, and its facilitating "Optical Fiber Communications". It's another high tech challenge to comprehend, benefit from and foster a community to reap its fruits. Again, curiosity and purpose drove me to delve into the technology, travelling overseas and earning higher degrees in Optoelectronics. Returning back home, working as a university faculty member, I now see many of my fellow students holding leading jobs in local high tech establishments, doing Electronics, Optics, Optoelectronics and Communications.

What about your story? Share it with us with a Click & drop

Next Event

"This is what I do"

Webinar on

Enhanced Photon Extraction Using Micro-Structured Luminescent Downshifting

Layers for Smart Greenhouses

Optimizing spectral conversion and directional control of sunlight is key to next generation agrivoltaic design. Dr. Juvet Fru will share his work on comparative Monte Carlo ray-tracing study of large area luminescent downshifting (LDS) roofing sheets engineered with inward facing microstructures to direct photons efficientrly towards crops. The LDS sheets fabricated from high efficiency phosphors in PMMA matrix are benchmarked against luminescent solar concentrators(LSCs) of identical dimensions. Results show that thick LDS layers achieve markedly higher downward extraction (DE) efficiency than LSCs, with performance advantages increasing at larger scales. Among the tested geometries, micro-cuboids deliver the highest DE efficiency (57%), outperforming domes, pyramids, and cones due to their larger facet area and reduced angular selectivity. These findings highlight the scalability and commercial potential of micro-structured LDS roofing to enhance crop illumination, spectral management, and agrivoltaic greenhouse productivity.



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