OPTICA
Advancing Optics and Photonics Worldwide

Optics for Energy

NEWSLETTER

CONTENT

DEC, 2025_VOL7

WE NEED YOUR CONTRIBUTION

Make your research more visible

Send us your recent publication.
We promise
to make a comprehensive review
for a broad audience

Give us a shot from your camera

Submit any light-highlighting photo
whether from your lab,
or a sparkle of light that captured your eyes.

Share your story

Inspire others with your story

Click and drop

OPENING MESSAGE

BANAFSHE ZAKERI

Now that I'm writing this message, nearly the whole world are waiting for the end of 2025 while counting the days on their advent calendar. It's interesting to see that sometimes the end can be much more exciting than the begining. Perhaps because we all know that the later won't happen without the former; When something starts, there must be an end. This exciting time of waiting is a great opportunity to reflect back on the year we had behind and plan for the year to come. It might be disappointing to look at the list we wrote last year and the number of achievements we planned for but couldn't reach. "Does it even make sense to write a new plan also this year?!", we even might ask ourselves. When such doubts come, we should remember one physical fact; Potential energies are not always equal to work but they are necessary for every work to be done. Planning makes us aware of our potentialities and the things we can achieve. In a realistic scenario, our plans and outcome are seldomly the same and that's why it's important to reflect back and examine where that potentialities were consumed when not turning to the outcome we expected. It helps us to plan better this time not forgetting that as far as there are new beginnings, there shouldn't be any regret of making an end.

In OPTICA Optics for Energy technical group, the new executive committee took the responsibility of serving the group in 2025. We were very excited about our potentialities and the things we can do to achieve our main goal, to make meaningful and lasting connections in this community. Now, reflecting back on 2025, it's clear that we couldn't hit all of our milestones but we were able to start three new series that worth mentioning; "This is what I do ..." was the new webinar series with two main differences compared to the usual webinar series in optica technical groups; First, the speakers were from the group members giving them the platform to share their work with their fellow members. Second, they were managed to be more educational giving the audiences more background about the field of their research rather than just highlighting their recent results. We could arranged three of this series and it's a promising result that more members will be willing to share their research on OPTICA platform in future. The "career focus" interviews and "Industry webinars" were two other series which we could start in 2025. Of course nothing could be achieved without your contributions and we would like to thank you for showing up in 2025. We hope together can achieve more in 2026.

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

Chair
Dr. rer. Nat. Banafshe Zakeri
HySON Institute
zakeribanafsheh@yahoo.com

Vice Chair
A/Professor. Georgios Arnaoutakis
Hellenic Mediterranean University
arnaoutakis@hmu.gr

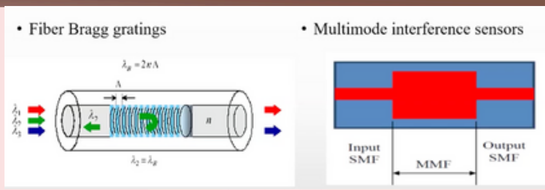
Event Officer
M.Sc. Idris Adeshina Sulaimon
Institut National de la Recherche Scientifique (INRS)
sulaimonidris61@gmail.com

Social media Officer
M.Sc. Rodgers Mutugi Gichuru
Multimedia University of Kenya (NIOL)
roycerodgers2@gmail.com

Webinar Officer
Prof. Ahmed Morshed
Ain Shams University
ahmed_morshed@eng.asu.edu.eg

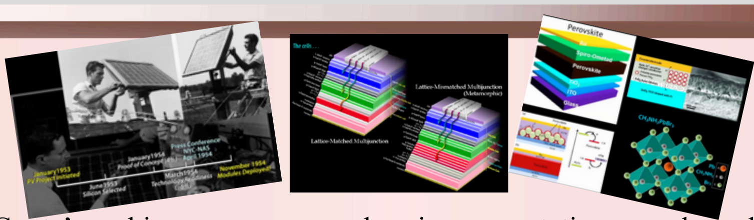
"This is What I do..."

Educational webinar series by group members



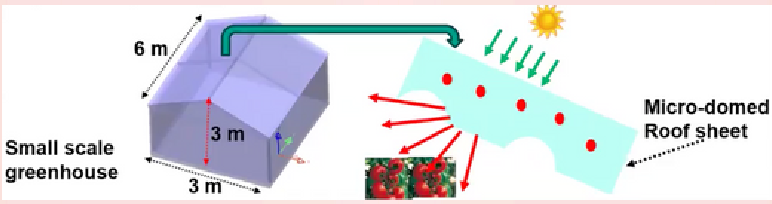
Prof. Ahmed Hisham Morshed was the first group member who shared his research on optical fiber sensors on monitoring pressurized pipes on OPTICA Optics for Energy online platform. In this educational webinar, he described the major advantages of sensing with optical fibers. Focusing on two types of sensors, fiber bragg gratings and multimode fiber sensors, he demonstrated the multiplexing of two sensors in different measurement scenarios while describing the experimental results.

[Watch the full webinar]



Dr. Nikhil Deep Gupta's webinar was a comprehensive presentation on solar cells, starting from their historical background and importance to their limitations leading to the recent developments. In his webinar, Nikhil introduced the concept of photonic nanostructures for solar cell harvesters. Several innovations and experimental approaches including his own research for pushing these devices to their current state-of-the-art were reviewed.

[Watch the full webinar]



Dr. Juvet Fru gave us a glimpse of his research on luminescent downshifting roofing sheets (LDS) for advancing agrivoltaic greenhouse design. Optimizing both spectral conversion and directional control of sunlight in LDS sheets, comprising high-efficiency phosphores in a PMMA matrix, results in high downward efficiency. His simulation result was the proof-of-concept for this interesting technology.

[Watch the full webinar]

Our guests in 2025

Shaping the world with David Giltner

Dr. David Giltner, physicist, entrepreneur, and founder of "Turning Science to things people need", was our guest for career focus interview series. With more than a decade of experience helping scientists to make a successful transition from academia to industry while authoring three books on this subject, David shared his insight and view on the differences between two environments and how understanding their different roles can help a scientist to not only be more employable in industry, but also shape the world by solving its real problems. We talked about the struggles of a scientist when moved to industry and how a mindset shift can help them overcoming those challenges. We had an interesting discussion about some of the strengths of the scientists such as learning skills, independency,... which might held them back in performing at a high level if not carefully harmonized with the fast pace and teamwork spirit in industry. *"It's great for us to be flexible learners, flexible thinkers, and learn by our own. But in industry we don't have the time to do that. We have to work in the team and we can move together faster, and they are a part of mindset shift."*

Watch the interview

Industry webinar with Edinburgh Instruments Ltd.

Dr. Stuart Thomson, head of products and applications at Edinburgh Instruments Ltd., joined us for an industry webinar and introduced advanced luminescence spectroscopy and microscopy of solar cell materials. Understanding materials in microscopic and molecular levels defines the race for developing efficient, stable, and cost-effective solar cells. This webinar was an exploration of how photoluminescence spectroscopy and microscopy can be applied to analyze and screen potential solar cell materials. Techniques including photoluminescence, quantum yield measurements, and fluorescence lifetime imaging microscopy (FLIM) were presented while showing interesting results of their applications in developing new solar cell materials.
This webinar is twofold, both educational and technical and we highly recommend watching the recording if you haven't been able to join the online session.

Watch the interview

Broadband Antireflective Metasurfaces for Silicon Solar Cells empowered by Machine Learning Algorithms

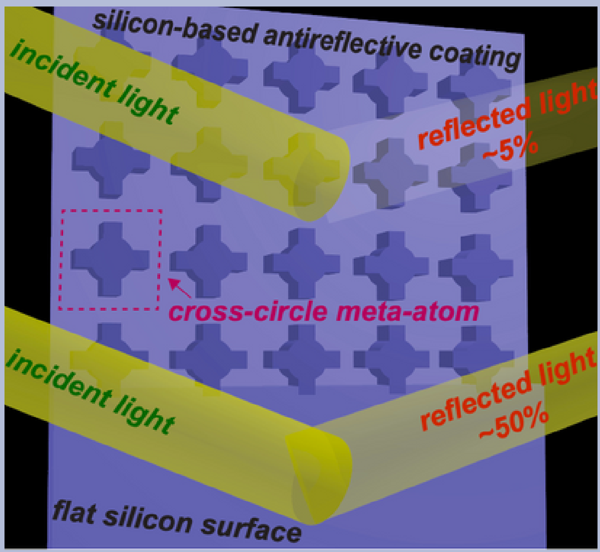
featuring the publication from Dr. Oleh Yermakov (Optics for Energy TG Member)

https://doi.org/10.1117/1.APN.4.3.036009

Overcoming reflection losses in silicon solar cells

Silicon solar cells lead the photovoltaic market because of their well-stablished production method. However, there is a long standing issue; A large amount of incident sunlight is reflected back at the silicon-air interface significantly lowering the amount of light absorbed and transformed into electricity. In silicon as a high-refractive index material, especially, the impedance mismatch causes considerable reflection. Traditional solutions involve multilayer dielectric and antireflective coatings (ARCs) which can reduce reflection to below 1% within narrow spectral ranges. Nevertheless these multilayer ARCs are costly and complex to produce. While inherently narrowband, they fail to effectively capture the broad solar spectrum.

Metasurfaces, on the other hand, offer ultra thin, nanostructured layers that can manipulate light beyond the capabilities of conventional coatings. Metasurfaces consist of periodic arrangements of subwavelength nanostructures and Meta-atoms that can induce tailored electromagnetic responses. These structures manipulate incident light by imposing spatially varying phase shifts or resonance effects, enabling a variety of functionalities such as beam steering, polarization control, and critically antireflection. Unlike multilayer coatings, metasurfaces are ultrathin, potentially simplifying fabrication and reducing costs. Further, silicon-based metasurfaces exhibit minimal parasitic absorption compared to plasmonic (metal-based) counterparts, aligning well with the requirements of photovoltaic applications. Developing advanced metasurfaces especially with more complex desired functionalities, however, requires new design stra-



https://doi.org/10.1117/1.APN.4.3.036009

-tegies. Dr. Yermakov and his collaborators are among the researchers who explore innovative designs of single layer silicon metasurfaces to serve as broadband ARCs. Their research includes using advanced computational design methods combined with machine learning to optimize the optical performance of their designed metasurfaces.

Forward and inverse design approaches

Traditional or forward design creates metasurfaces based on physical intuition and parametric exploration. For example, initial designs may use simple shapes like cylinder or crosses to induce desirable phase shifts. Simulations assess how changing parameters such as size, shape, or height affect reflective properties, guiding incremental improvements.

Forward design, however, is limited by the vast parameter space and the complexity of electromagnetic interactions, often resulting in suboptimal solutions.

To overcome these limitations, inverse design technique powered by machine learning algorithms was adapted by the authors. Specifically, they use a graph learning operator network (GLOnet) capable of exploring extensive parameter spaces more efficiently than traditional methods. This approach involves training a neural network to generate geometrical parameters - e.g., the radius, width, height, and period of nanostructures - that optimize a target function: minimal reflection over a broad spectral range. The network iteratively improve its predictions by considering electromagnetic simulations's feedback, enabling the discovery of complex geometries with superior broadband performance.

Practical meta-atom geometries

The optimized designs include structures like cross-shaped nano-antennas and circular or combined geometries that produce desired resonance effects across 500 to 1200 nm. These geometries are chosen based on their manufacturability and robustness under different incident angles.

Achieving near-perfect broadband antireflection

The key achievements presented in this study include broadband reflection suppression, comparison with standard layers, enhancement of power capture, and optimization of design and materials.

Regarding broadband reflection suppression, the metasurface coatings significantly reduce reflectance to below approximately 2% across the entire spectral range of 500–1200 nm, as illustrated in Figure 5. This marks a remarkable improvement over traditional antireflective coatings, which typically operate effectively only within a narrow bandwidth. Additionally, the designs demonstrate robust angular performance, with only a modest increase in average reflection of about 4.4% for incident angles up to 60°, highlighting their angular insensitivity.

In comparison with standard multilayer dielectric ARCs, such as single- and double-layer coatings, the metasurface designs exhibit superior broadband capabilities. While multilayer ARCs require precise thickness control and are limited to narrow spectral bands, the metasurfaces maintain low reflection over a broad spectral window using a single-layer configuration.

The suppression of reflection directly enhances the transmission of solar energy into the silicon substrate. The enhancement factors for both reflected and transmitted powers indicate multiplefold improvements in reflection suppression, leading to increased absorption of solar radiation. This improvement is more uniform across the solar spectrum, aligning well with the spectral distribution of sunlight. Optimal performance is achieved when the spectral minima of the metasurface-based ARC coincide with the peaks of solar emission, thereby maximizing energy harvesting efficiency.

Furthermore, the study employs machine learning algorithms to accelerate the exploration of design parameters, generating geometries that optimize the balance between complexity, manufacturability, and performance. The proposed structures are compatible with advanced fabrication techniques such as electron-beam lithography, nanoimprint, or laser-assisted methods, thus facilitating their potential application in real-world devices.

Toward a solar future powered by Nanophotonics

This paper underscores how combining advanced computational design, machine learning, and nanofabrication can push the boundaries of photovoltaic technology. Single-layer silicon metasurfaces capable of broadband, angle-tolerant reflection suppression offer a promising alternative to conventional ARCs, unlocking the potential for more efficient, cost-effective solar energy harvesting.

Photon-assisted tunnel rectenna for solar energy harvesting

Authors: Y. ZHOU, B. ZHANG, Z. LUO AND Q. CHENG.

Introduction

While solar cells generate electricity by utilizing the particle nature of light, which is currently the most practical way to harness sunlight, a promising and efficient approach for solar energy harvesting and power generation involves designing a rectifying antenna (rectenna) that harnesses the wave nature of light. On the theoretical side, studies have shown that a rectenna for optical and IR radiation can achieve conversion efficiencies exceeding that of solar cells. This work introduces a solar rectenna that is composed of a periodic subwavelength spiral antenna and a metal-oxide-semiconductor photon-assisted tunnelling diode. The spectral absorption and electromagnetic field distributions are obtained by numerical simulations and the tunnelling current densities generated by the solar rectenna are calculated. The study is expected to advance the development of ultra-high frequency rectennas and pave the way for efficient solar energy harvesting.

The Structure Proposed

Three critical factors need to be considered when designing an efficient solar rectenna structure: The first is to ensure that the nano-antenna has high broadband absorption, particularly in the visible and IR ranges. Secondly, the rectenna should focus the incident light field in the tunnelling barrier of the rectifier diode for good matching. Finally, suitable diodes are to be utilized for maximizing the conversion of the enhanced light field to a DC output.

The proposed solar rectenna with a magnified $Ag/SiO_2/n^+Si$ (MOS) unit cell is shown in Figure 1(a) below. The rectenna structure consists of a periodic array of MOS cells placed directly on the surface of a uniformly doped silicon substrate. A composite unit cell composed of MOS structures with three different radii is shown in the bottom left inset. The Ag spiral antennas have a radius R of 100 nm and a unit cell period P of 220 nm. The spiral antenna is an Archimedean spiral, with an initial radius r_0 of 10 nm and a pitch d of 30 nm. Thicknesses of the $Ag/SiO_2/\ n^+Si$ layers from top to bottom are h_2 = 50 nm, h_3 = 3 nm and h_4 = 50 nm, respectively. A thick SiO_2 layer with h_1= 50 nm covers the Ag to prevent oxidation. The material of the metallic antenna can be replaced with Au, Al, or Cu without significantly affecting the absorption characteristics. This is because, in the visible and near-infrared wavelength bands, the dielectric functions of metals such as Au, Ag, and Al are very similar. A promising approach for making the proposed solar rectenna is compatible with mature micro-nano fabrication processes, such as advanced complementary MOS technology.

Numerical Simulation

To reveal the physical mechanism of the proposed solar rectenna, electric and magnetic field distributions ($|E|^2$ and $\log(|H|)$) of the TM-polarized light with a normal incidence at various resonant wavelengths (i.e. 0.63 μm, 0.95 μm and 1.79 μm) are simulated in the x-z plane.

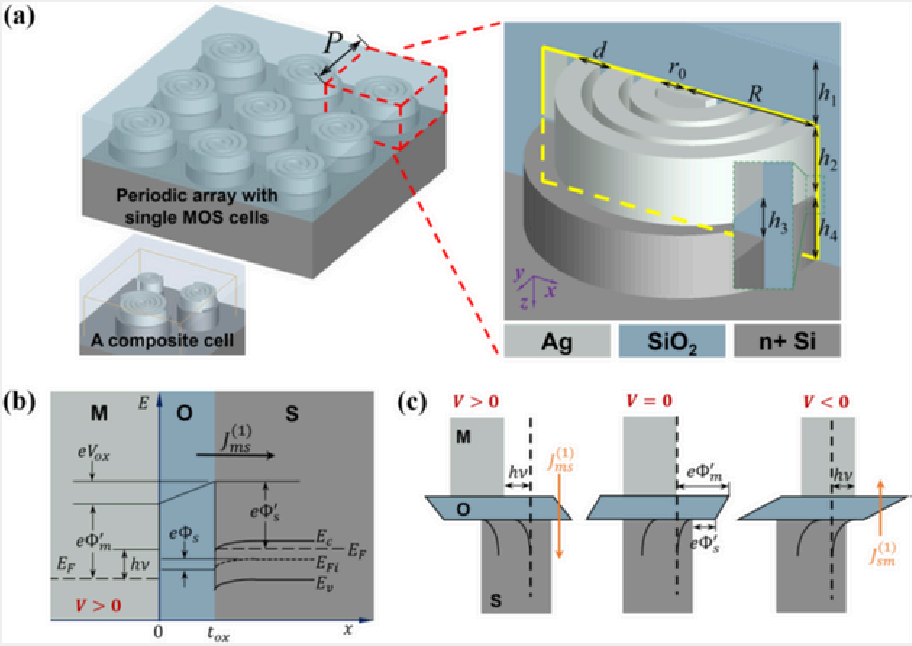


Fig. 1. (a) Schematic diagram of the proposed solar rectenna and magnified unit cell of the rectenna. Here, a periodic array of subwavelength MOS structures is placed directly on the surface of a uniform doped silicon substrate. The inset on the left shows a composite unit cell composed of MOS structures with three different radii. (b) The energy-level diagram shows the single-photon tunnelling process, where the photon energy hn acts as a positive bias. (c) Band-diagram cross-section of the MOS tunnel diode under various bias conditions. The electron barriers are $\Phi'_m = 3.63$ eV and $\Phi'_s = 3.3$ eV. The tunnelling currents are shown schematically. J(1), single-photon tunnelling current density; sm, semiconductor (Si) to metal; ms, metal to semiconductor.

The cross-section used to map the contour of the electromagnetic field is positioned along the diameter of the spiral antenna, as indicated by the yellow box in the structural diagram of Fig. 1(a). The length of this region along the x-axis is equal to the period, and along the z-axis, it includes a portion of the air, the cover layer, and the MOS structure. It is found from the electric field distributions that localized surface plasmon resonance (LSPR) and surface plasmon polaritons (SPPs) are excited in the solar rectenna, enabling light to be coupled into the metal antenna and localized in the oxide tunnel gap above the semiconductor support column. This process creates a light absorption induced by the coupling of LSPR and SPPs. However, the mechanism of magnetic field distribution is different. The field distribution indicates that two magnetic polaritons are excited in one unit cell, one is within the semiconductor support column, and the other is between adjacent metal antennas. At the short wavelength of 0.63 μm, the resonance is considered to be the magnetic polaritons (MP) above the metal and inside the semiconductor support column, where the magnetic field is strongly confined. While at the long wavelength of 1.79 μm, coupled magnetic polariton (CMP) dominates the absorption. In this case, the magnetic field is mainly localized at the edge of the metal antenna. The primary distinction between MP and CMP is that the MP resonance generates a local magnetic field at the center of the cell, while the CMP resonance produces a local magnetic field shifted toward the cell boundary (the center of the adjacent cell) due to the influence of neighbouring cells.

The magnetic distributions of the resonances at the wavelength of 0.95 μm indicates a combination of the MP and CMP resonances.

Conclusion and Outlook

This study proposes a periodic subwavelength metamaterial solar rectenna that can efficiently collect and effectively utilize solar energy. The solar rectenna utilizes a MOS structure to convert incoming sunlight into a DC output through photon assisted tunnelling, through the combination of LSPR, SPPs, MP, and CMP. The spectral absorption is polarization insensitive due to the use of an Archimedean spiral in the metal antenna. The results indicate that the composite cell possesses a near-perfect absorption between 0.9 and 2.0 μm, peaking above 0.99. After calculation, the solar rectenna can achieve a maximum tunnel current density of 13.93mA/cm^2 without bias voltage, which is comparable to that of multi-junction solar cells.

For actual device fabrication, using ITO or graphene instead of SiO_2 as a cover layer is a promising option. These materials can serve as electrodes to draw current while having minimal impact on the resonances due to their transparency. Tunnelling diodes can be further optimized, particularly in terms of barrier shape. This work enhances the matching between the antenna and the diode, while broadening and improving the absorption band, thereby paving the way for efficient solar energy collection.

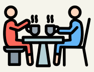
https://doi.org/10.1364/OE.531545

Looking forward

Be the next speaker for "This is what I do..." series

Drop your abstract **here**

We aim for some new series in 2026;



Coffee chat

Right communications facilitate making efficient connection. Join for these coffee chats to find your future partners, mentor, ...

This would be no official event, but a friendly chat between professionals and students.

Welcome to my lab...

A recording series to show you what's happening inside research labs.

We will find research group with relevant research area and visit them to record a glimpse of what they are working on for you..

Please make a short time and respond to this survey. It will help us in orienting the activities and topics based on your needs and interests.

We wish you a happy new year

سال نو مبارك

Καλά Χριστούγεννα, όμορφες γιορτές και καλή Πρωτοχρονιά!

Likizo njema, na muwe na mwaka mpya wenye mafanikio

Ẹ kú ọdún tuntun!

na m

تمنياتنا بعام جديد سعيد

Communication 💬 and Engagement

DISCUSSION

Click here to join

INFORMATION SHARING

Click here to join

Click here to join

EVENT UPDATES

email (TGactivities@optica.org)