OPTICA
Advancing Optics and Photonics Worldwide

Optics for Energy

Newsletter

CONTENT

Opening message
The trap of real-world deployment and the dangerous corner for basic science

Optics for Energy Article
The rising energy demand from data centers

Insight
Energy photonics

Career Focus Interview Series
Internet of power

Publication Review
Spectral in situ ellipsometer for thin layer measurements in thermonuclear fusion applications

Industry News
Europe's Solar Manufacturing Push Gains Momentum

Opportunities
Conferences, funding, training,...

Upcoming Event
Networking online coffee chat

JUNE., 2026_VOL9

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!

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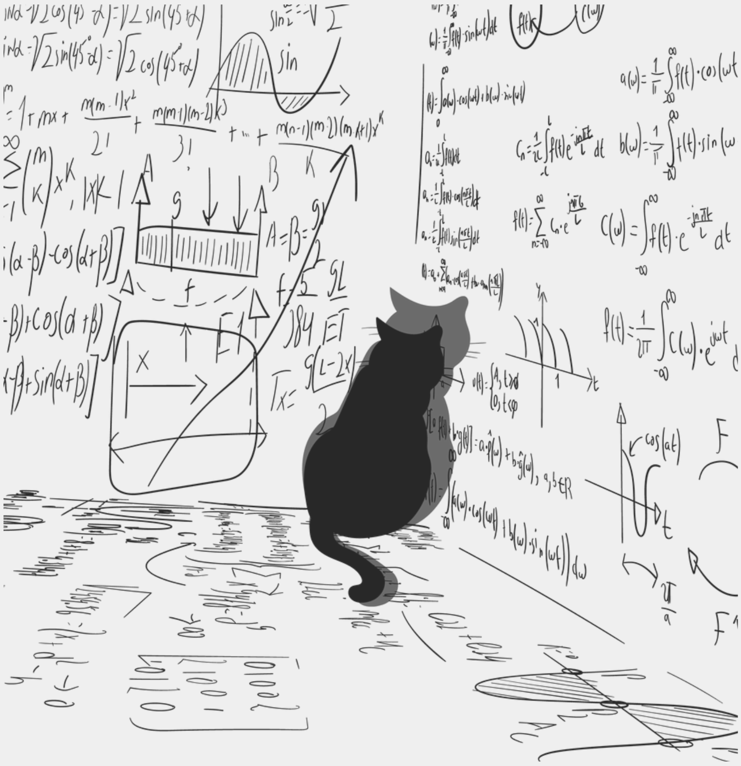
OPENING MESSAGE

By Banafshe Zakeri

The trap of real-world deployment and the dangerous corner for basic science



A lot is going on in the world; new and more complicated problems emerge, some of which, like climate change, seem to get out of our control faster than the pace with which we try to solve them. There are also other problems that are not urgent. In fact, our never-ending desire for an easier, more automated, and somewhat lazier life can find hidden problems that didn't even look like problems some years ago. It has become an entrepreneurial value to find problems customers didn't know they had, which is a funny way to look at problems, because if no one yet feels it as a problem, could it be a real one?!

In urgent or man-made problems, the burden on science to provide smart, applicable solutions is heavier than ever. Recently, I read a LinkedIn post saying that in countries like China, governments have policies to push university projects towards application, so that more connections will be made between research and society's actual problems. The trend is also appearing more frequently in funding policies.

Using verbs such as "to investigate" and "to understand" in proposals may be seen as negative because they could signal that there is no real problem behind the subject unless the aim is to deeply understand a topic. Could this mean that basic science and fundamental research are in danger of being pushed to the corner and becoming less important?

No-one can deny the importance of basic science. The fact that we can solve many problems today is due to an unprecedented amount of knowledge that basic science has been providing, the research topics that at the time might not have been categorized as application-oriented science. Knowing that no scientific discovery, even the most fundamental ones, has ever been or will be wasted might help us to stay at peace and stop worrying about what's going on in the heads of our scientists, or trying to orient their thinking towards the real problems in the world. Our world might be better off if we just trust the foundation of science, which is curiosity for knowing the unknown, to ponder, and to discover.

The Rising Energy Demand from Data Centers

Introduction

The rapid commercialization of artificial intelligence (chatbots, GenAI etc) and cloud computing has intensified global electricity demand, with data centers emerging as a major and fast-growing load sector. Meeting this demand requires not only increased generation capacity but also a transformation in how energy systems are monitored, controlled, and optimized. Optical technologies such as fiber-optic sensing, photonic communication, and distributed measurement systems are becoming central enablers of a more efficient and resilient energy ecosystem. Optical systems now form a continuous technological thread linking power generation, transmission infrastructure, and data center operation.

Integrated power generation, transmission infrastructure, and data center operations (AI-generated image)

Toward adaptive and intelligent generation systems

Energy generation systems especially renewable sources such as wind, solar, and hydroelectric plants, require high-resolution monitoring to operate efficiently under highly variable environmental conditions. Optical fiber sensors provide a unique advantage in this domain due to their immunity to electromagnetic interference, long-distance capability, and distributed sensing capacity.

Distributed fiber-optic sensing technologies such as Raman, Brillouin, and Rayleigh-based systems enable real time monitoring of temperature, strain, and vibration across large infrastructure assets. In wind turbines, optical sensing can track blade vibration modes and structural fatigue, while in hydro systems, it can detect mechanical stress and flow-induced oscillations before failure occurs. These sensing capabilities allow predictive maintenance strategies that improve uptime and reduce operational costs.

A key advantage is that optical fibers can function as both communication channels and sensing elements, enabling dense integration of measurement systems directly into generation infrastructure without electromagnetic interference limitations typical of electrical sensors.

Grid infrastructure monitoring with optics

The electrical grid represents the critical intermediary between energy production and consumption, and its complexity is increasing due to decentralized renewable generation and fluctuating demand patterns. Optical technologies are now integral to transforming conventional grids into intelligent systems.

Fiber-optic sensing systems embedded in transmission lines and substations enable continuous monitoring of conductor temperature, mechanical strain, and acoustic disturbances. Techniques such as Distributed Acoustic Sensing (DAS) and Distributed Temperature Sensing (DTS) provide real-time insight into grid health, such as detection of faults, overload conditions, and environmental stressors such as ice loading and wind induced vibration.

These systems also support dynamic line rating, allowing operators to safely increase transmission capacity based on real-time environmental conditions rather than conservative static limits. This is particularly relevant for integrating renewable energy sources, where variability introduces new challenges for grid stability.

Fiber-optic networks form the backbone of smart grid communication systems, enabling low-latency data exchange and control operations. Their immunity to electromagnetic interference makes them uniquely suited for high-voltage environments, ensuring reliable data flow under harsh operational conditions.

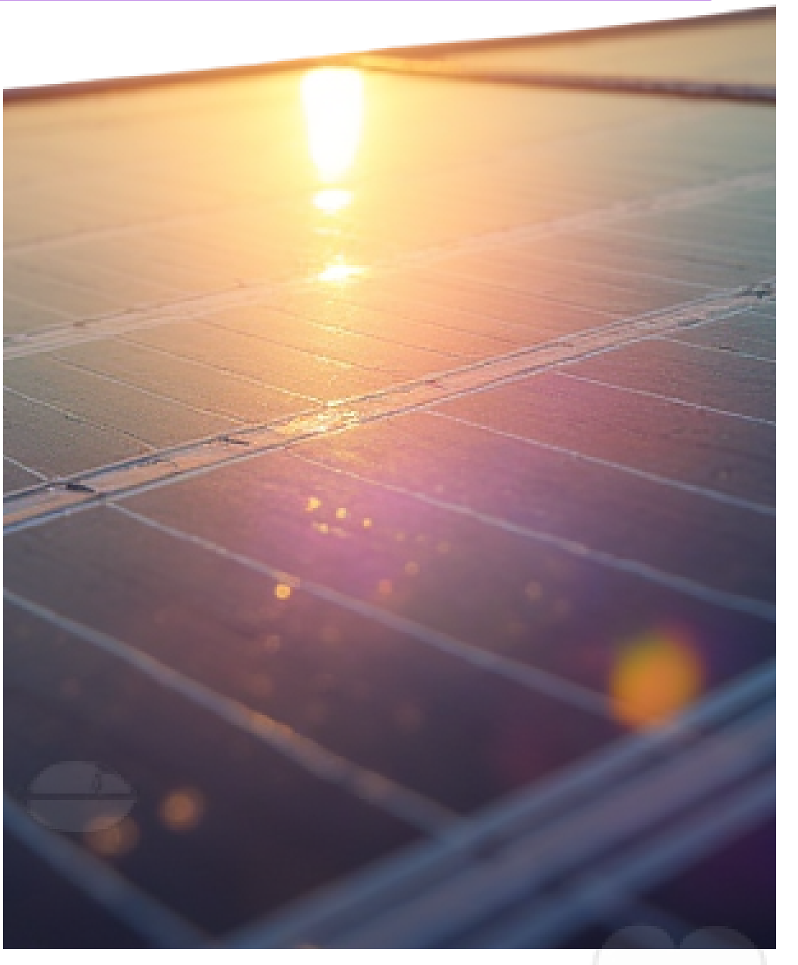
Conceptual rendering of fiber optic transmission line and a data center (AI-generated image).

Managing energy demands and consumption in data centers through photonics

As computational density increases, so does the demand for efficient power delivery, thermal management, and high-bandwidth interconnects such as GPU to GPU communications. Optical fiber interconnects significantly outperform copper-based systems in both bandwidth and energy efficiency due to resistive heating for high-capacity transmissions, reducing the need for repeated electrical signal amplification and thereby lowering total power usage.

Optical sensing technologies are increasingly being deployed within data centers for thermal mapping, airflow monitoring, and power distribution analysis. Distributed fiber-optical sensors can be integrated into racks, cooling systems, and power distribution units to provide real-time feedback on temperature gradients and electrical load distribution. This enables more precise thermal management strategies, reducing cooling overhead which is a major power consumption in data centers.

Energy Photonics



For years, energy photonics research has largely focused on maximizing power conversion efficiency. Silicon hit its practical ceiling, perovskite arrived as an alternative, and tandem architectures began routinely breaking what was once considered a hard theoretical limit. The best performing perovskite-silicon tandem cells have now reached 34.85% efficiency, certified by NRE. A team at the Ningbo Institute of Materials Technology and Engineering reported certified efficiencies of 30.3% in rigid tandem cells and 28.0% in flexible versions[1].

Today, the field is shifting toward a broader optimization space where optical design simultaneously addresses efficiency, manufacturability, sustainability, and cost. Recent developments suggest several converging trends;

Spectral engineering is becoming key
Advanced photonic structures are increasingly being used not simply to collect more photons, but to control where, when, and how photons interact with energy materials.

Energy systems are becoming optically intelligent
Modern energy systems increasingly integrate sensing, feedback, and adaptive optics. Optical monitoring is evolving from a characterization tool into an active component of energy infrastructure.

Photon management extends beyond solar cells
Research is expanding toward agrivoltaics, smart lighting, thermal management, and energy-aware photonic systems where controlling light distribution itself becomes an energy optimization problem.

The next challenge is scalability
Many high-performance laboratory designs and demonstrations now face a common question ,can advanced optical designs maintain performance when manufactured at scale?

Question for all of us
What optical innovation today has the highest probability of making measurable impact outside the laboratory within the next decade?

References:

1. https://doi.org/10.1038/s41565-026-02165-6

CONVERSATIONS

Fiber Optics: The Next-Generation Grid Solution for Energy Transmission

In an interview for Career Focus Interview series of OPTICA Optics for Energy Technical Group, the founder of Trine.Energy **Saroj Mishra** talked about his journey as an entrepreneur to use the established technologies of fiber optics and laser to solve one of the biggest problem of our century that is renewable energy transmission. Here are some highlights of this conversation.

Internet of power is the big vision behind Trine.Energy, the startup you are leading. Tell us more about this vision, why "Internet of power"?

So just to give you a bit of an idea what internet of power the vision is, we want to make electricity a global product. What we mean by that is we want to move electrical power at a global scale and at a real time just like much like what internet does for data and content. You know, today the electrical power is essentially very domest -ic, national type of infrastructure, and it does not connect the global producers and consumers. The downside of that is that if a country actually has surplus and the other country has a deficit, they cannot move that between themselves which is a big waste of electrical power. Currently, we're relying so much on fossil fuel and we want to get away from that. Many countries produce surplus. So, the solution could be to connect these surpluses and deficits at a global scale which will then make a global market. For that to happen, we need a global infrastructure, and there are not many technologies out there which are global in nature. One exception is the internet which is all laser and optical fiber. So, the inspiration came from there. Saying that what if we could take the same technologies of fiber optic and laser and use them to deliver power! That was the genesis of the idea “Internet of Power”.

Why optics? Have you tried also to find other solutions in other area of industry? what has driven you to the world of optics and photonics? Was it just your interest and fascination in optics or did you really find the potentiality of optics for solving this big problem?

It was a result of much discussion and debate. I think one of the ideas that have been explored was space- based power capture, the laser beaming that down to earth stations, for example. So many people actually have talked about this and I think there are some companies who actually working on that. But I actually have a problem with that idea because imagine beaming down high power laser from space down to earth, it is very risky from a national safety security perspective. Currently, 200 countries are trying to agree to a treaty which is beaming down a high power laser. It can be weaponized and the fact that we're living in a time where the world is very volatile, I think an idea like that actually will be a lot harder to execute. I'm not saying it is not scientifically possible. It is actually quite possible to do that but I think its implementation and execution will be a lot harder. Whereas fiber optic is already there, 1.4 million kilometers of fiber optic already exists connecting every country and countries have already agreed on. We can use similar infrastructure and that will be for the power.

Was it not frightening at the first place to go after such a big vision?

I think any new venture is risky. It is technology versus what you call the mission. I think these are two different things. The way to kind of break it down is the fact that sometimes the bigger vision actually does help because if you actually have a much larger vision, it’s more likely that you are attracting a much larger interest from people because you know there are more people interested in bigger visions than smaller visions. There's nothing wrong with small vision either, but if you take a much bigger problem to solve, the likelihood of you finding some real interesting people and investors is actually much higher. At one level, however, you also have to understand what problem are you solving! The size of the vision has to be big anyway but the quality of the problem that you're solving is also important. For me, solving a problem which is one of the existential issues of the century, if I can call it, was actually an interesting idea. Even though I don't come from this industry, the problem is something that I'm intimately related to.

What comes after vision? What is your playbook for the startup?

Start with a very fundamental question that what problem are you solving? That actually is a fundamental question that every founder has to answer. Because finding cool technologies is the easy part, the question is who wants! Because if you don't have customer, it’s just a fancy technology. You have to start with understanding the real pain point first and to quantify how big is it. When you talk about electricity the idea of building the next generation of the global grid, you know the demand side is huge. It is well established, plenty of research has been written, people are talking about it. So, I think you have to start there. The second is solution; How do you find the right solution to solve that problem? Third is to hire the right people, building the ecosystem, and taking the idea to the public. The real test starts afterwards, building the product and testing it, and finding the customer. So, in that sense this is the playbook

What is your suggestion for how to find the right business model and in which stage?

I think there is no silver bullet here. Maybe one or two ideas that I can suggest: first, you have to talk to a lot of people, within your friends, within your network, ideally the people who you believe will actually have the answers to your questions. That's one way. Secondly, you actually build a team, your co-founding can bring this complimentary kind of skill set, somebody from the business world who comes and joins your team to bring that insight. Most of the startups are actually multi-founders and they all bring different skill sets. If you have technical knowledge, maybe somebody else can bring the business knowledge or vice versa.

Scientists are trained with resiliency. They have perseverance in pursuing new ideas. Do you see it as a positive characteristic for the world of startup? Is the tradeoff between resiliency and knowing when to quit?

First of all, I have a huge respect for the scientific community, these kind of ideas that we can think of is because many people actually have contributed to understanding of the laser and the fiber optic. I think every scientist should be very proud that whatever work they do actually have some contribution for the world. I can definitely attest to that, because when we're doing our own analysis of the product development, dozens of research papers are already written, and their ideas actually are being used.So, their effort is not going waste, somebody somewhere will use it for the the mankind.

"I think many nations globally have actually become very powerful and advanced purely because they devoted much of time and funding to research. But if you have a mindset of commercializing what you are working on, I would say that you should have that kind of thinking all the time that whatever I'm doing right now what are the possible uses in industry later."

-Saroj Mishra, Trine.Energy

In the world of startup, however, you actually have to come out of your sort of research shell um and kind of look at the at the wider world. Keep yourself updated about what's going on in the world and where can your idea actually have a potential impact. This kind of thought process is actually helpful because it will give you direction, it gives you a bit of a steer of what could be the potential outcome of whatever you're doing.

Generally, I think research is a field where you have to keep investing on. Most of the nations globally have actually become very powerful and very advanced purely because they have devoted much of time and funding to research. But if you have a mindset of commercializing what you are working on, I would say that you should have that kind of thinking all the time that whatever I'm doing right now what are the possible uses in the industry later, and you keep yourself updated about what's going on in the world.

[Watch the full interview]

PUBLICATION REVIEW

Spectral in situ ellipsometer for thin layer measurements in thermonuclear fusion applications

Author: Maciej Krychowiak, https://doi.org/10.1063/5.0220315

Introduction

Ellipsometry is a technique widely used to characterize the thickness and optical parameters of thin films. It is based on the measurement of polarization change upon reflection off a material sample. While commercially available ellipsometers are designed for stationary applications and often rely on precise adjustment of the optical setup to maximize measurement precision, a simple portable device can allow for in-situ layer measurements and would be very useful in many situations.

A simplified spectral ellipsometer is presented in this article. It is proposed and tested with the aim of flexible implementation in space-limited applications in thermonuclear fusion research, e.g. as a hand-held device for large thickness scans of coatings deposited on first-wall components inside the vacuum vessel of fusion experiments, or for monitoring of plasma deposited coatings on diagnostic vacuum windows. Figure 1 illustrates the hardware setup of the in-situ ellipsometer. The simplicity of the hardware setup is compensated by complex Bayesian inference of the coating parameters, incorporating all uncertainties of the measurement and the model used. A neural network based analysis has further been implemented to reduce the required computational time, and promising test results were obtained.

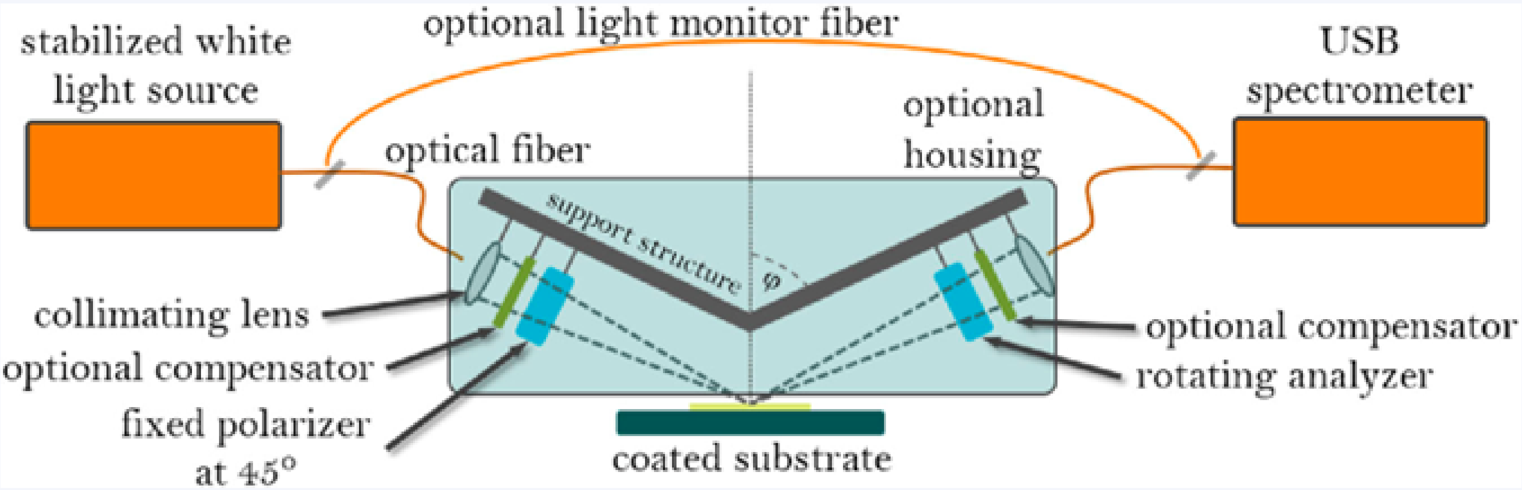


Fig. 1. Basic hardware setup of the ellipsometer.

The structure proposed

For the in-situ monitoring of thin layers deposited by plasma on the vacuum side of diagnostic observation windows, which lead to gradual increases in window transmission losses, a suitable arrangement of the components is shown in Fig. 2. In the usual case of smooth coatings on vacuum windows, the use of compensators is not necessary. All other components, including piezo-crystal based rotatory stages, are nowadays available with a compatibility with ultrahigh vacuum and relatively high magnetic fields and could, in principle, be installed inside the vacuum vessel of a fusion device. The lens with the polarizer of the illuminating and detecting arms of the ellipsometer can be fixed on either side of the optical head of the primary spectroscopic diagnostic. Special attention needs to be paid to avoid collecting light from the reflection at the front (uncoated) side of the window, which would effectively lead to partial depolarization of the detected light.

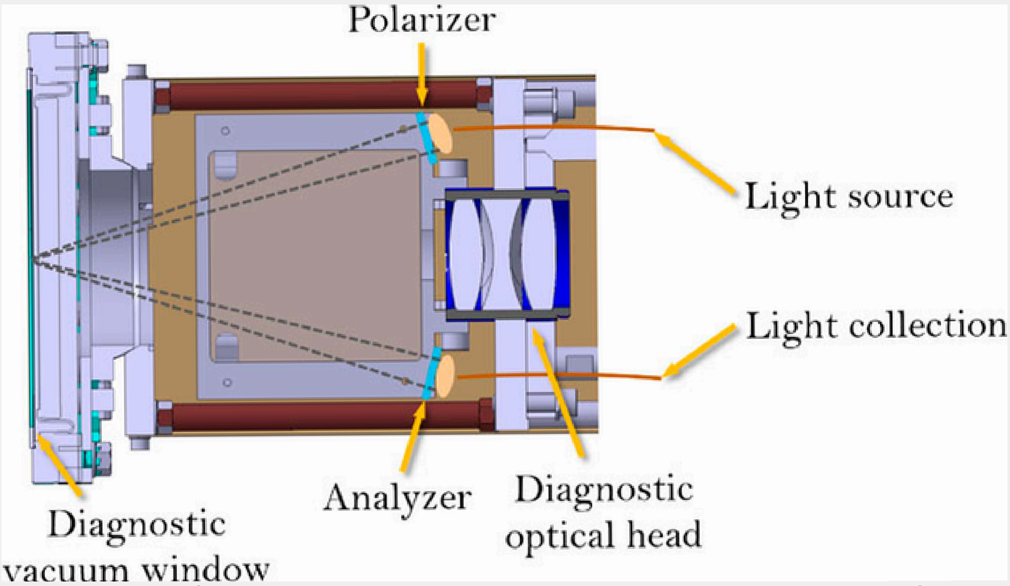


Fig. 2. Arrangement of the ellipsometer components in a diagnostic port for monitoring thin layers deposited on vacuum windows in fusion devices.

Bayesian modeling and diagnostic design

The Bayesian modeling framework Minerva was employed for data analysis in this work. The measurement parameters were modeled using a non-parametric Gaussian process with a squared exponential covariance function. However, only transparent layers have been analyzed, and hence, k(λ) was set to zero for all wavelengths. The model accounts for the imperfection of positioning in the space of the rotatory stage with the analyzer and the imprecision of each analyzer angle used in the measurements. It accounts for the change in the spectral shape, for example, induced by filament temperature drifts of the light source and the detector non-linearity. In order to validate the hardware setup as well as the Bayesian analysis model and inference, test measurements were done using standard layers of SiO2 with known thickness on a silicon wafer, which featured also a reference surface without any coating. At each setting of the analyzer angle, two spectra (background subtracted) were recorded: with the incident light reflected at the coated and the reference area to ensure exactly the same setting of the analyzer angle. The refractive index n(λ) of SiO2 was assumed to be known. A sample of spectra recorded at an analyzer angle of 80^0 is shown in Fig. 3. The mean value of the layer thickness obtained was within the confidence interval provided by the manufacturer of the thickness standard, confirming that the ellipsometer setup and the analysis model work properly.

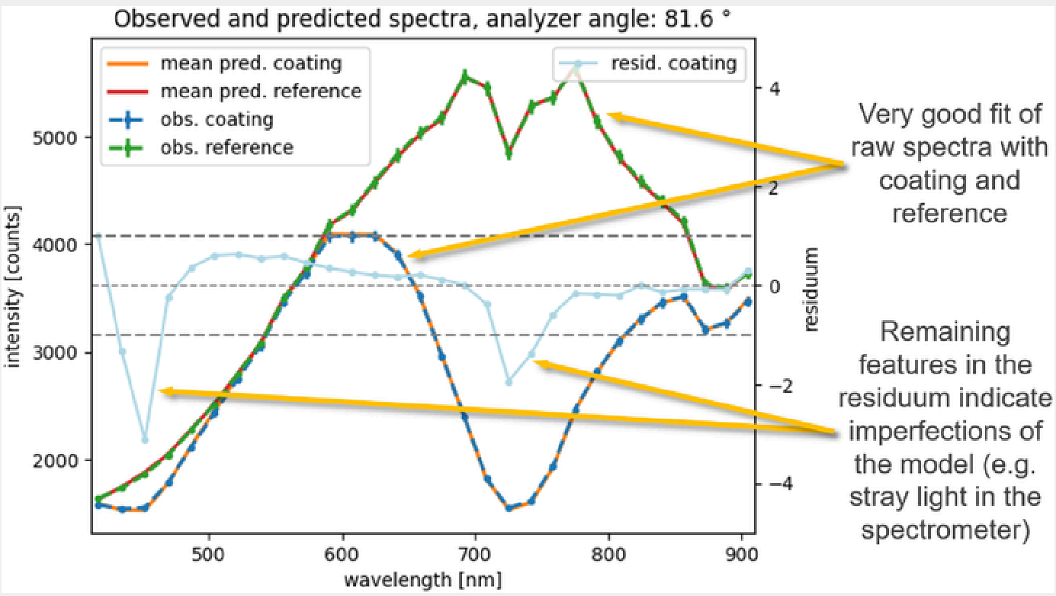


Fig. 3. Measured and fitted spectra recorded at the analyzer angle of 81.6^0 for the case of illuminating the coated and the reference silicon wafer areas.

Fast neural network analysis of layer thickness

The complex Bayesian analysis comes however at a cost of long computational time: one full based inference takes a few hours on a modern desktop PC. In the envisaged application of the ellipsometer as a hand-held device for multiple thickness measurements of large surface areas of first-wall components in a fusion experiment, a fast analysis will be helpful for a quick judgment of spatial gradients of the thicknesses. For this purpose, a neural network based on the Tensor Flow keras library was trained and the first optimization was done, providing promising results. Between one half and one million samples of synthetic spectra for measurement with and without a coating have been used to train the network. Realistic signal noise was applied, 30 data points in the wavelength range of 400–900 nm were created for each spectrum, and the incident angle of 70^0 was assumed as well as 45^0 for the polarizer angle and nine settings of the analyzer angle (in 20^0 steps). The optical parameters n(λ) and k(λ) of SiO_2 and Si in the reference substrate were used and assumed as known. The layer thicknesses were predicted with relatively high precision for almost the entire input thickness range used.

Conclusion and Outlook

Spectral ellipsometers can be used to derive thicknesses and optical parameters of thin layers deposited in thermonuclear fusion experiments. The in-situ characterization of such layers supports the understanding of material migration with the plasma inside the vacuum vessel and can be used to monitor transmission losses of vacuum windows used to diagnose the plasma by optical spectroscopy. In this work, a simplified setup of an in situ spectral ellipsometer was investigated with the aim to provide an as simple as possible setup, which is flexible enough to be easily adapted in fusion applications with strongly limited space. The measurement is based on the detection of the change in relative phase delay and relative intensities of the s and p polarized light reflected at a coated substrate. A stabilized white light source and a USB type single-channel spectrometer are used enabling measurement in the full visible and potentially in the near UV and near IR spectral range. In the simplest configuration for monitoring smooth coatings on vacuum windows, only two polarizers (one of them on a rotatory stage) constitute the core of the setup. For measurements on rough surfaces of first-wall components (with a hand-held diagnostic head), an additional compensator is needed to detect the depolarization degree of the reflected light. The reflected spectra are recorded for multiple (10–20) settings of the analyzer angle.

The simplicity of the setup is partially compensated by application of a complex Bayesian inference with a full propagation of all measurement and model uncertainties. A probabilistic Bayesian inference model was implemented. Test measurements on a coating standard (SiO2 film on Si substrate) with known parameters and analysis of the test datasets validated the hardware setup and the Bayesian model.

For the application as a hand-held device for multiple measurements of layer thickness on large surfaces of first-wall components in fusion devices, a neural network has been trained and partially optimized to provide real-time thickness estimates of layers with known optical parameters. Further research is necessary to achieve a final design of the two proposed applications of the ellipsometer: The reflection model used in the Bayesian inference needs an extension to account for multiple layers and tests with not fully transparent coatings. Both proposed applications of the ellipsometer were primarily meant to be used in fusion devices with a moderate level of radioactivity, allowing, for example, man access to the plasma vessel between experimental campaigns for layer measurements with the hand-held device inside the vacuum vessel. Hardening the ellipsometer design for work at higher radiation levels is conceivable but would need a significant amount of additional development. For example, the hand-held design would need a mechanical adaptation to a remote handling arm, and the darkening of optical components caused by neutron fluxes would need to be considered.

Industry News

Solar and battery manufacturing(AI-generated image).

Europe's Solar Manufacturing Push Gains Momentum

Europes solar sector is entering a new phase as policy shifts and supply chain economics begin reshaping manufacturing strategies. China's removal of export VAT rebates for solar PV products and the reduction of battery export rebates from 9% to 6% through December 2026, combined with rising raw material costs, are increasing pressure on module and battery pricing.

This comes at a time when EU solar deployment continues to accelerate, with total installed solar generation capacity reaching 406 GW. While deployment growth remains strong, the changing cost dynamics may alter the balance between imported components and domestic production.

The reduction in Chinese export incentives is unlikely to be the sole driver behind Europe's manufacturing ambitions. Much of the EU's push toward local manufacturing was already underway due to supply-chain resilience concerns, industrial policy objectives, and efforts to reduce strategic dependence on overseas production. However, the VAT rebate changes increase the economic attractiveness of local production by narrowing price advantages previously enjoyed by Chinese exports.

Looking ahead, solar capacity growth in Europe is expected to continue, although the growth trajectory may shift from purely installation-driven expansion toward increased investment in domestic manufacturing capacity. If higher import costs persist and supportive industrial policies remain in place, the current market environment could accelerate the localisation of both solar PV and battery value chains rather than significantly slowing deployment itself.

Dates	Solar	Batteries
Before 31 March 2026	9% VAT rebate	9% VAT rebate
April 1st 2026 – December 31 2026	9% VAT rebate	6% VAT rebate
January 2027 onwards	0% VAT rebate	0% VAT rebate

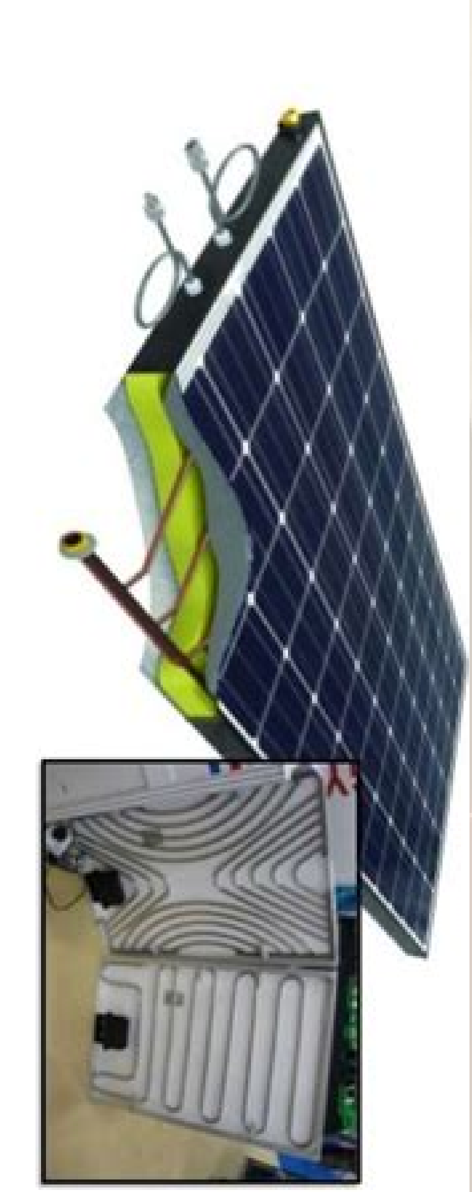
Advances in Solar Thermal Technologies To Drive a New Energy Era

Innovations in solar thermal technologies are accelerating the transition toward efficient, large scale renewable energy systems. One promising development is the use of *graphene nanofluids in solar collectors*, where suspended graphene nanoparticles enable direct volumetric absorption of sunlight within the heat transfer fluid itself. This approach improves thermal conversion efficiency by reducing surface losses and enhancing heat extraction compared to conventional collector designs.

At the industrial scale solar thermochemical technologies are also reaching important milestones. *Synhelion* a pioneer in concentrated solar thermochemical systems have demonstrated significant progress toward producing synthetic aviation fuels at costs approaching fossil-fuel competitiveness. Using concentrated solar energy from mirror fields, high-temperature reactors split water and CO_2 into syngas, which can subsequently be converted into sustainable fuels. By directly using solar heat rather than electricity, this process bypasses grid dependence and enables efficient large scale fuel production.

These technological advances are occurring alongside strong market growth for concentrated solar power (CSP). The global CSP sector is projected to reach approximately $10.46 billion by the end of 2026, growing at a CAGR of 15.54%. Much of this expansion is driven by increasing demand for long-duration thermal energy storage, particularly molten salt systems, which complement intermittent photovoltaic generation and improve grid stability.

Growing concerns over energy security, alongside energy crises arising from geopolitical tensions and conflicts in major oil-producing regions is further accelerating investment in alternative energy infrastructure. These developments highlight the expanding role of solar thermal technologies not only in electricity generation but also in industrial heat, energy storage, and sustainable fuel production.



PV thermal absorber
Image reference

Conceptual rendering of a solar thermochemical synthetic fuel plant (AI-generated image).

Opportunities

Training

Training and Research in Italian Laboratories (TRIL)

Italy

Scientists from developing countries

Up to 1 year

Closes Dec 31, 2026

Apply now

Awards

Optica Ambassador Program 2027

Worldwide

Emerging leaders

Closes 9 Aug 2026

Apply now

Funding

EU Horizon call

Europe

Up to €2M

Closes Jul 15, 2026

Scholarship

Boris P. Stoicheff Memorial Scholarship

Global

Up to $ 3,000

Closes Jul 15, 2026

Conference

Optica Advanced Photonics Congress

LongBeach, USA

Worldwide

26 - 30 July 2026

Apply now

Conference

Optica ImageSense Congress

Maastricht, NL

Worldwide

12 - 17 July 2026

Apply now

Upcoming Event

NETWORKING ONLINE COFFEE CHAT

Communication 💬 and Engagement

DISCUSSION

[Click here to join]

INFORMATION SHARING

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EVENT UPDATES

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