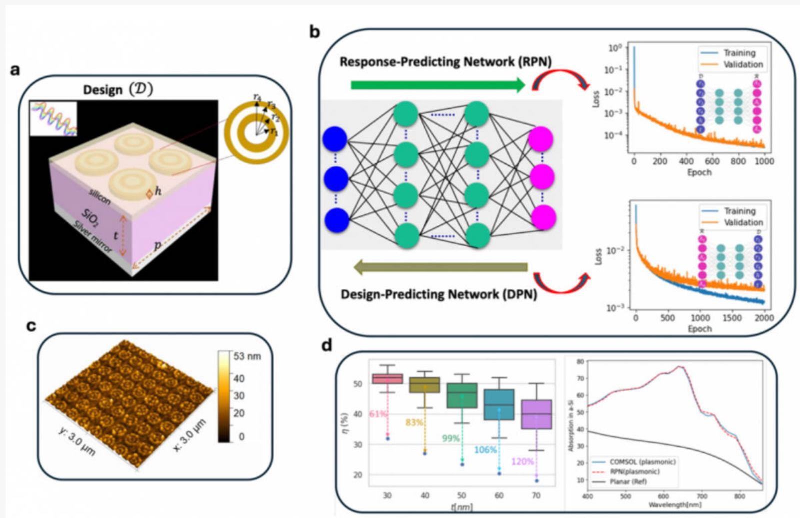
Enhancing Plasmonic Absorbers with Machine Learning

GA, UNITED STATES, January 14, 2025 /EINPresswire.com/ -- Scientists at KAUST and collaborators have developed an ultra-thin silicon film embedded with silver nanorings to enhance light absorption. By optimizing interactions between the cavity and plasmonic modes and leveraging deep learning, they achieved over 100% photocurrent improvement. This contribution holds great promise for creating highly efficient and customizable devices, including solar cells, photodetectors, and optical filters.



Schematics of the machine learning aided meta-absorber.

Light absorption is a cornerstone for several applications such as solar cells, photodetectors, and optical sensors, to name a few. Yet, the trade-off between the thickness of the absorber and its efficiency has long limited the performance of such devices. The goal in this investigation is to get the best of both worlds—ultra-thin materials with maximized absorption.

In a recent paper published in Light Science & Applications, a group of researchers from King Abdullah University of Science and Technology (KAUST), led by Prof. Ying Wu and Prof. Xiangliang Zhang (now at University of Notre Dame), successfully put forward an efficient broadband light absorber within an ultrathin amorphous silicon layer embedded with silver nanorings. By combining tailored plasmonic design with deep learning techniques, the researchers achieved an unprecedented photonic enhancement of over 100%.

The team’s innovative approach involves combining concentric silver nanorings within an ultrathin silicon layer. These nanorings generate localized surface plasmons (which are intriguing collective oscillations of light that have led over the course of the last two decades to the vibrant field of plasmonics) that couple with the cavity modes of the structure to efficiently trap light. This interplay allows the thin silicon layer to absorb much more light without increasing its physical thickness.

One key contribution of this study consists of leveraging deep learning techniques to further optimize the design. To this end, the scientists developed two tailored neural networks: a response predicting network (RPN) to predict the absorption spectra for a given meta-absorber parameters, and a design predicting network (DPN) to solve the inverse problem, i.e., finding the best design for a desired absorption spectrum. The proposed study is shown to significantly reduce the time and computational resources needed for the metamaterial design.

“Our machine learning framework allows us to explore vast design spaces and suggest the optimal parameters with incredible precision,” notes Prof. Wu. This approach yielded a remarkable photonic enhancement of over 100% in comparison to previous state-of-the-art light absorbers. The study also stands out for its combination of theoretical and numerical predictions as well as optical experimental validation. The absorption spectrum of the fabricated metascreen absorber agrees with the simulated results, confirming the practicality of the design. The potential applications of this research are far-reaching: Enhanced light absorption opens-up possibilities for more efficient solar panels, advanced photodetectors, and tailored precise optical filters. Beyond energy and sensing, the ability to precisely control the optical properties of materials could also lead to breakthroughs in telecommunications, healthcare, and imaging technologies.

“This work not only advances our understanding of plasmonic meta-absorbers but also showcases how physics-informed deep learning can redefine the design and optimization process,” adds Prof. Wu.

Looking forward, the team plans to explore other geometries and configurations to push the boundaries of what is possible with different types of metasurfaces. Also, investigating the deployment of these absorbers in real-world settings, such as photovoltaic devices is the natural next step for the group. The combination of advanced physical modeling and AI-driven design is set to unlock new possibilities in optics and photonics, paving the way for highly efficient and customizable devices.

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