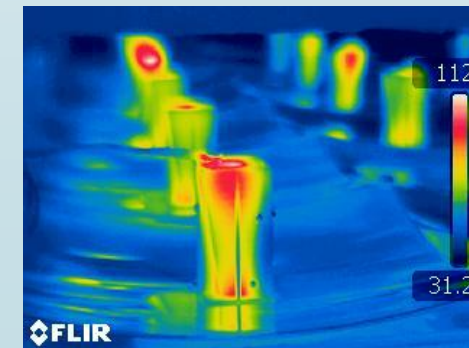
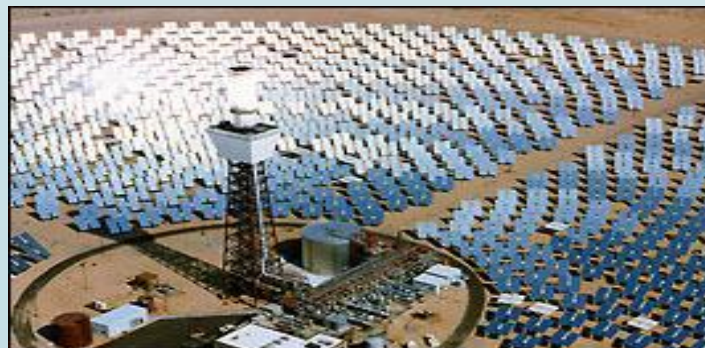
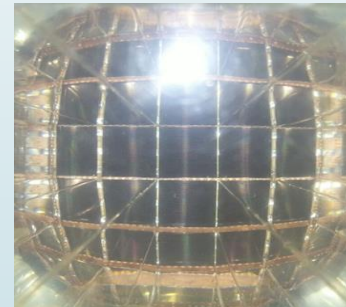
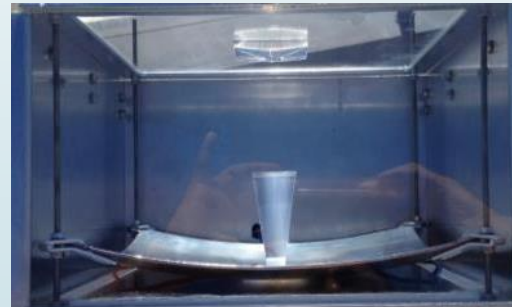
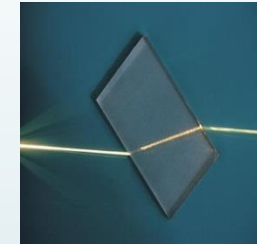


Opportunities for Metamaterials in Optics for Solar Energy

UK MMN 2023

Dr. Katie Shanks,

k.shanks2@exeter.ac.uk



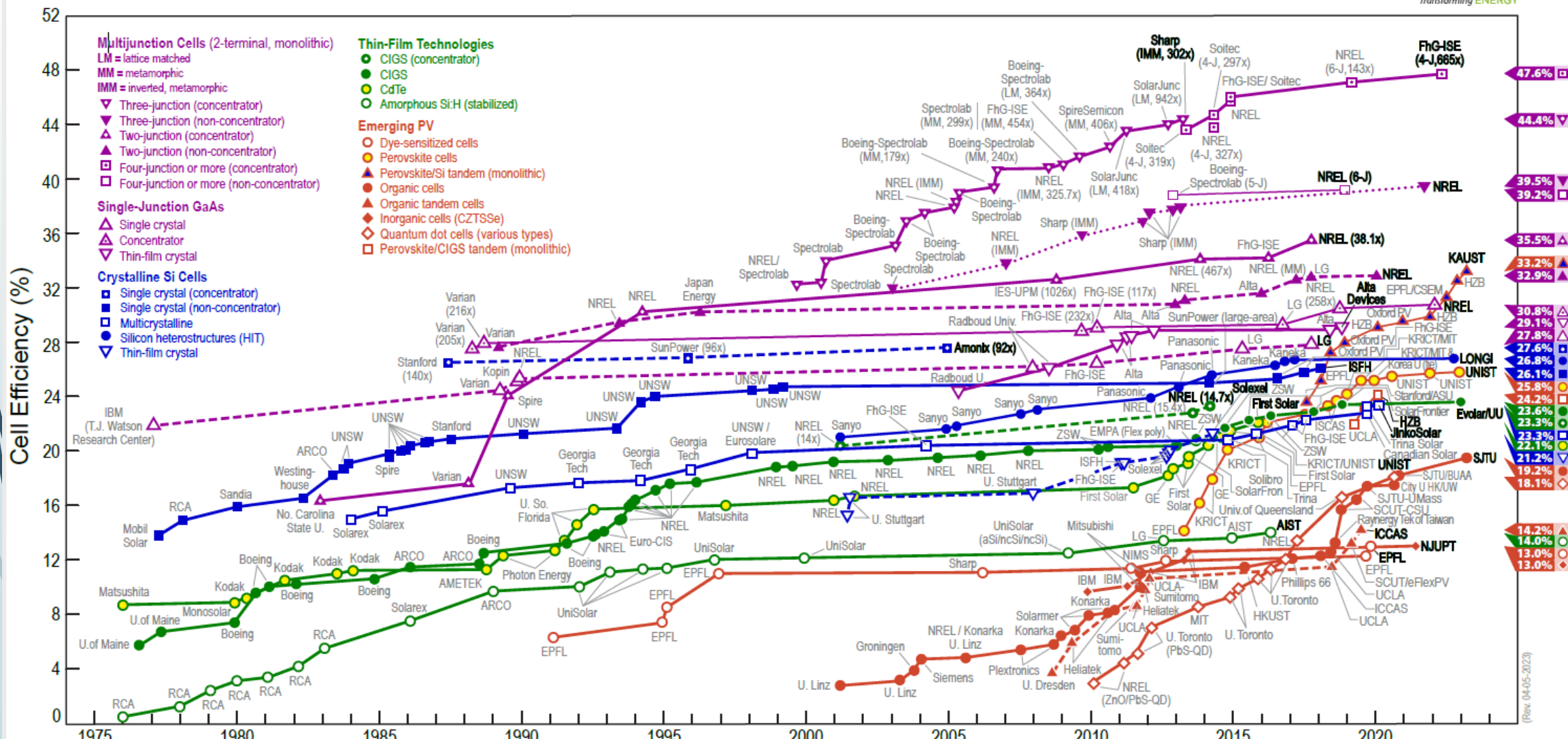
What are solar concentrators?



- Solar Concentrators **use optics** such as mirrors and lenses to **increase the sunlight** incident on solar photovoltaic or solar thermal devices.
- **Increase** the **power output** by increasing the power input.
- **Reduce** the photovoltaic **material required**.

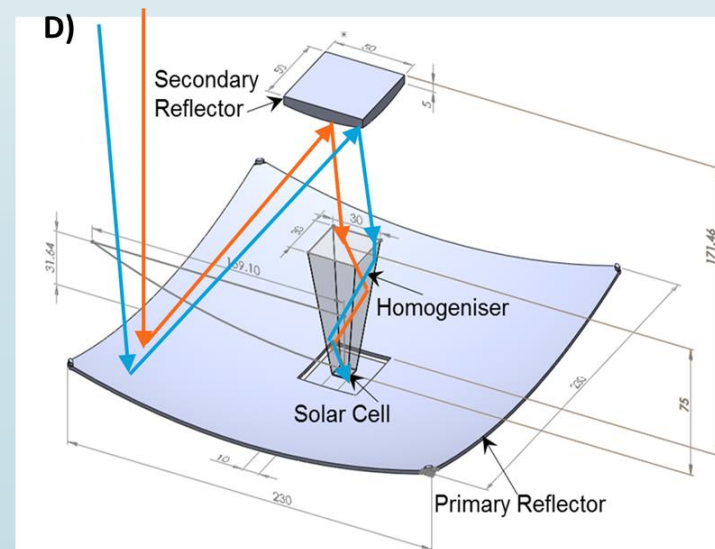
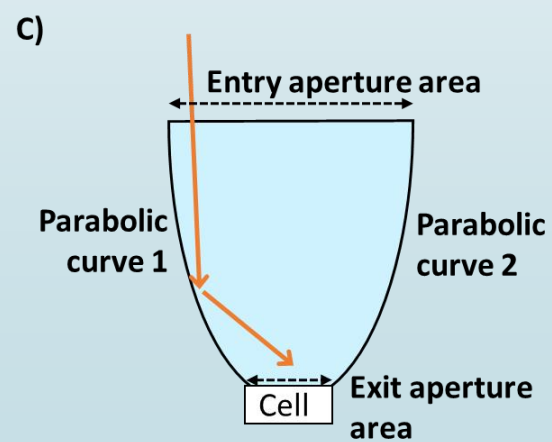
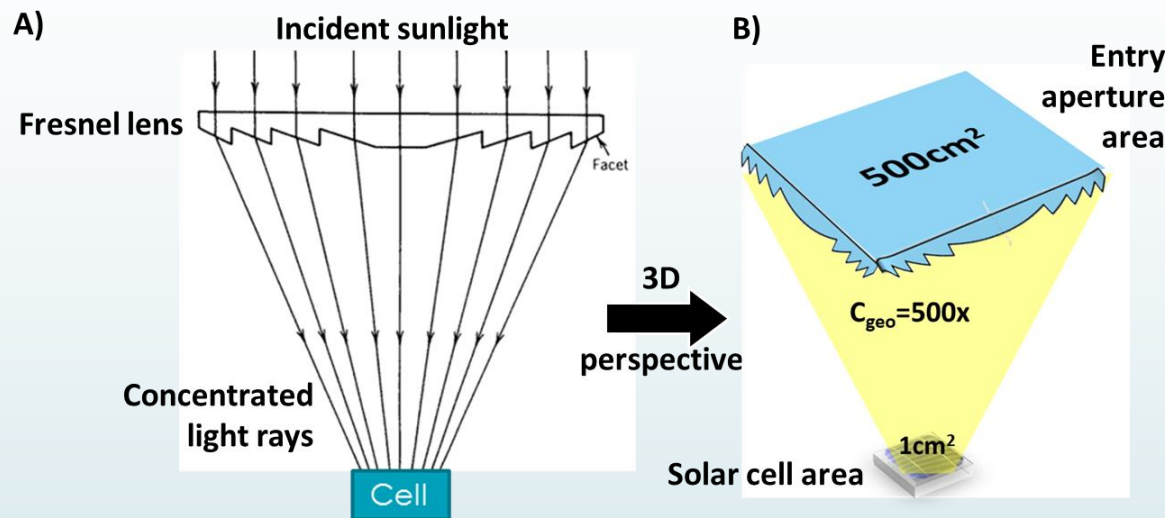
solar cells efficiency benefits

Best Research-Cell Efficiencies



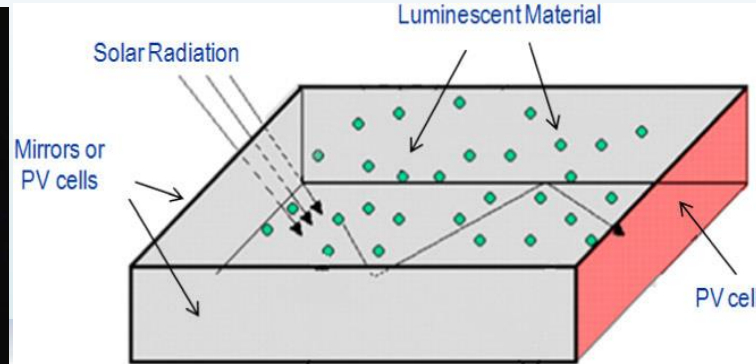
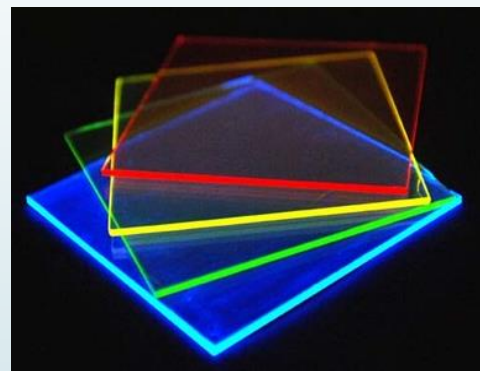
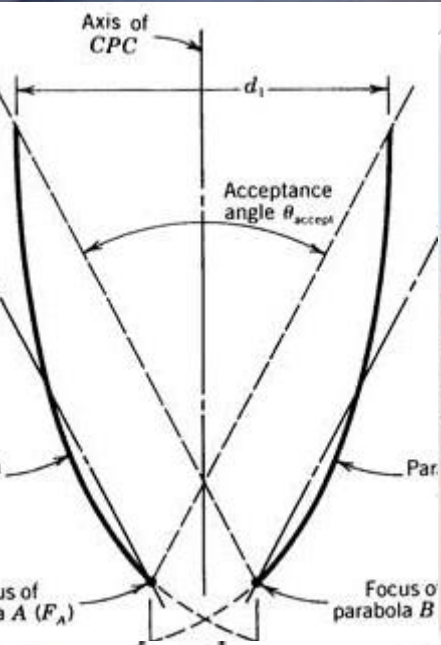
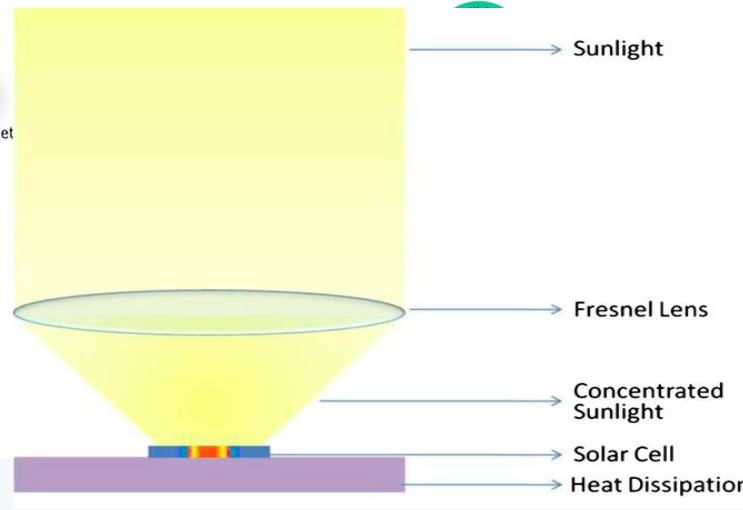
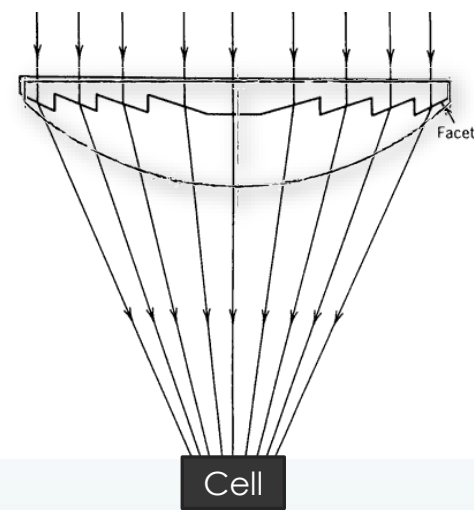
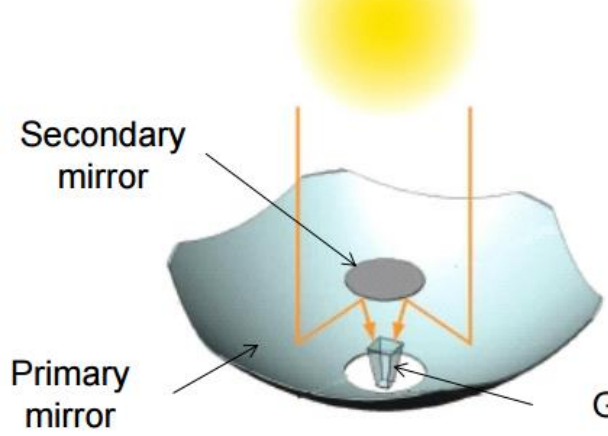
(Rev. 04-05-2023)

Fresnel Lens



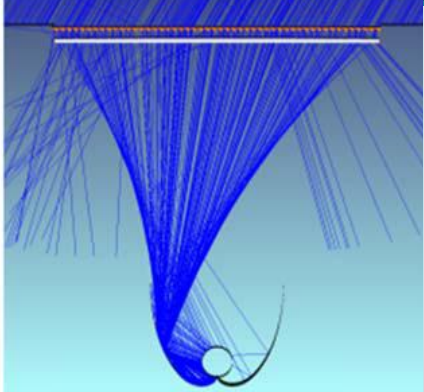
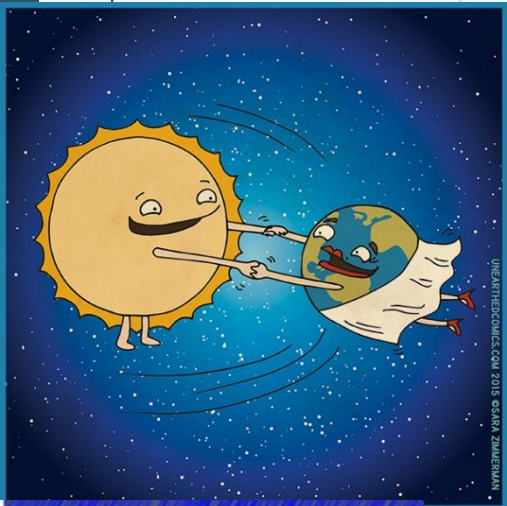
CPC Lens

Cassegrain reflector



Key factors for the Ideal Solar tech

- ▶ High efficiency (Optics + Cells)
 - ▶ Wide Wavelength Range (Silicon: 350nm-1100nm, MJ: 350nm-1800nm)
 - ▶ Metamaterials to extend this...?
 - ▶ Efficient resource use and space use
- ▶ Cost Effective
 - ▶ Weight? Transport, Material choice, demand and market?
- ▶ Reliability (Acceptance Angle)
 - ▶ All day, everyday... all year?
- ▶ Durability and life cycle
 - ▶ Materials lifetime? Maintenance? Recycling?
- ▶ Practicality and aesthetics
 - ▶ Matching application needs
 - ▶ Size/bulk?

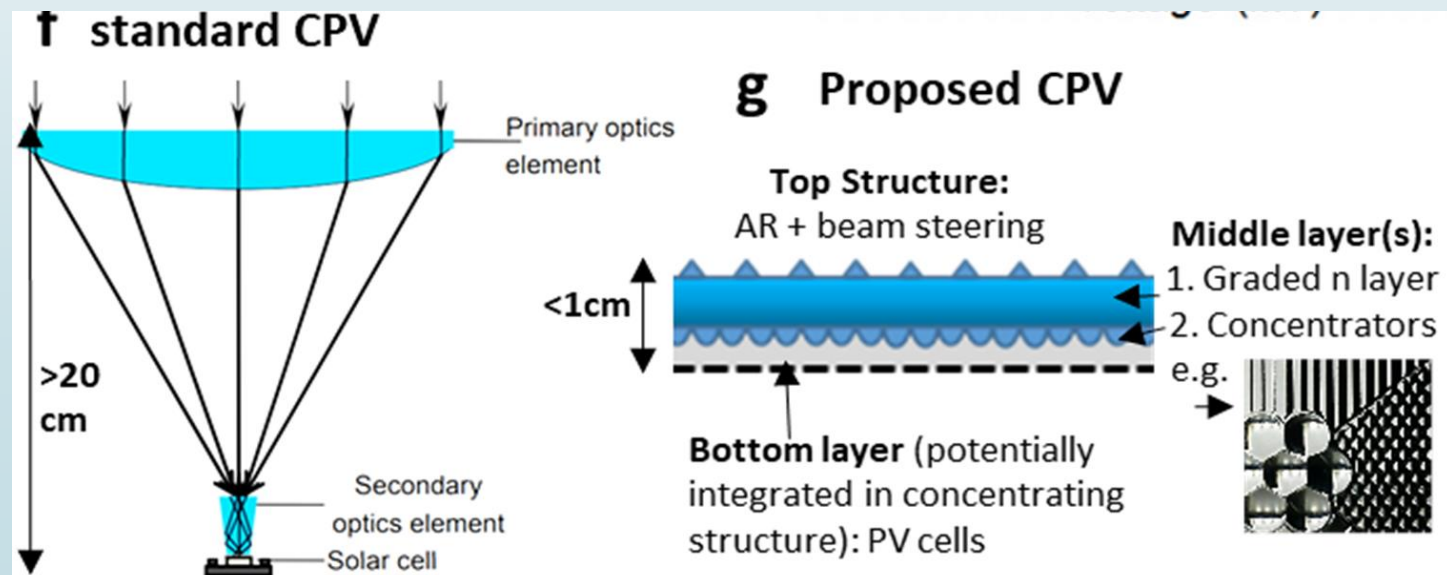


30°



Optical Metamaterial advantages

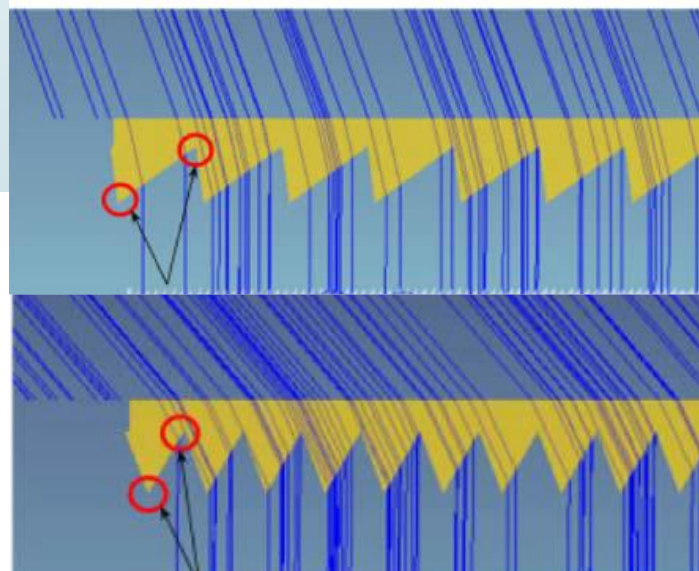
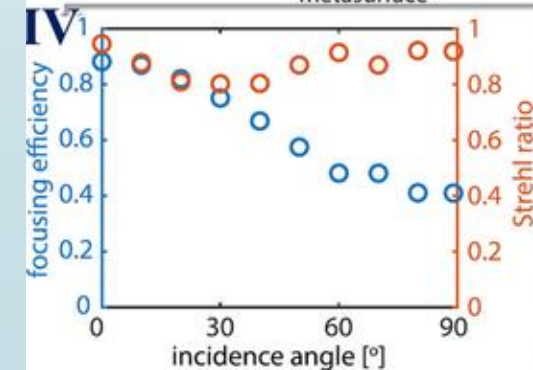
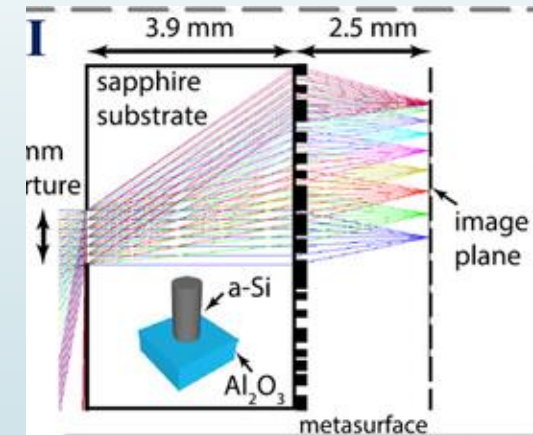
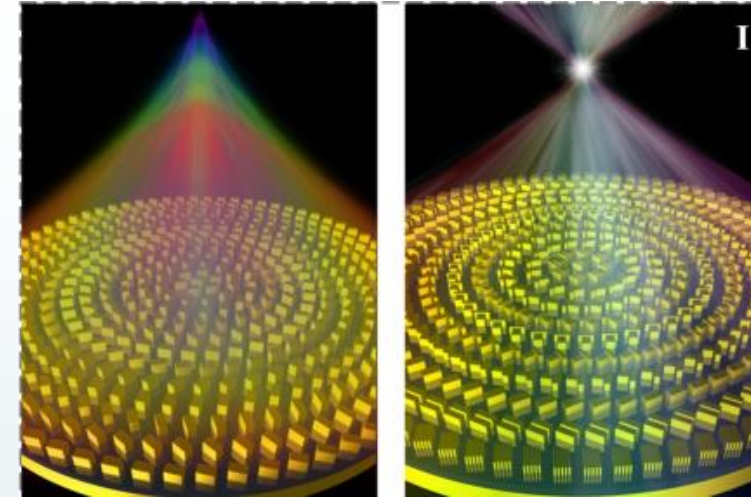
- Reduced size and weight (and cost)
- Reduced material usage (solar cells?)
- High Demand for Increasing Power density technology!
- 500Watts/kg
- >1500Watts/kg



Metamaterial advantages

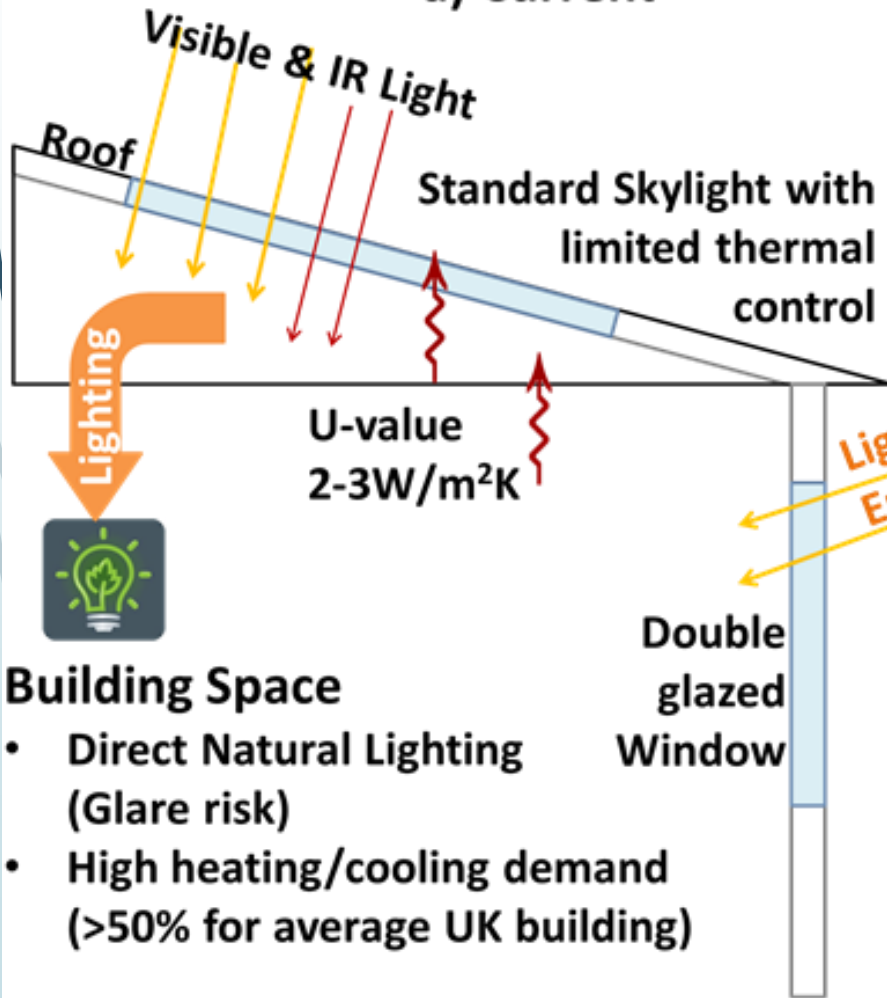
- ▶ Efficiency
 - ▶ Metalenses can minimise/suppress
 - ▶ spherical and chromatic aberrations
 - ▶ **However often reduced focusing efficiency!**

- ▶ Reliability (acceptance angle)
 - ▶ Beamsteering
 - ▶ Passive tracking mechanisms



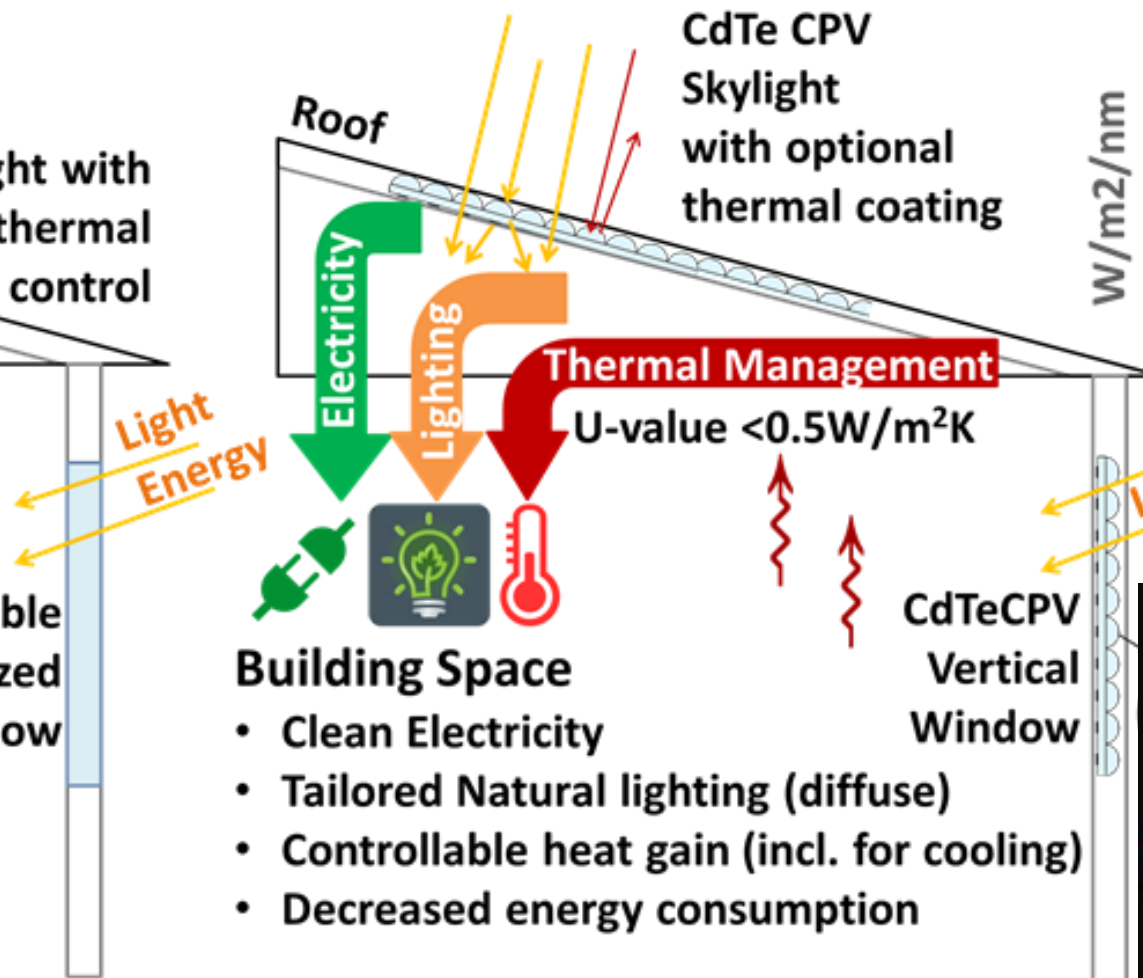
Spectrum Filtering and Splitting (Multiuse spaces!)

a) Current



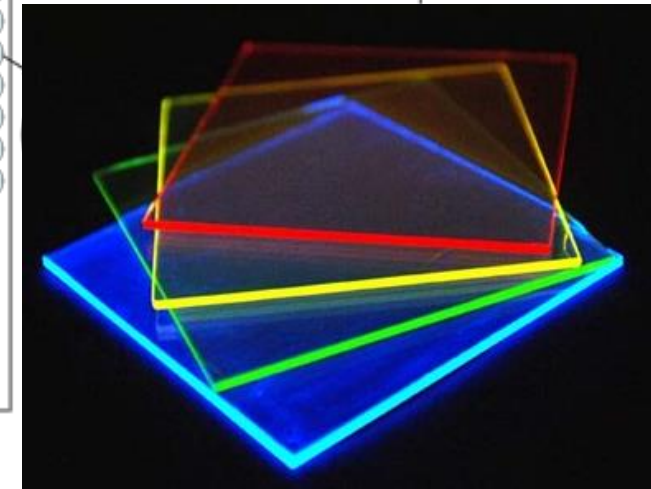
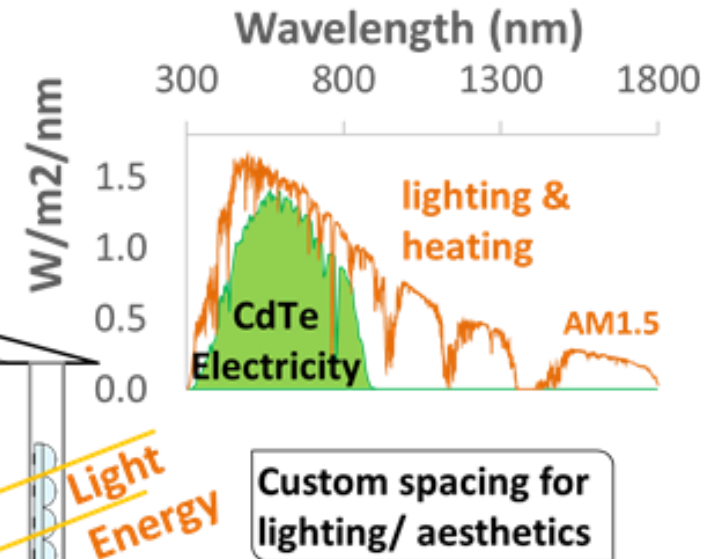
Unsustainable conditions

b) Proposed

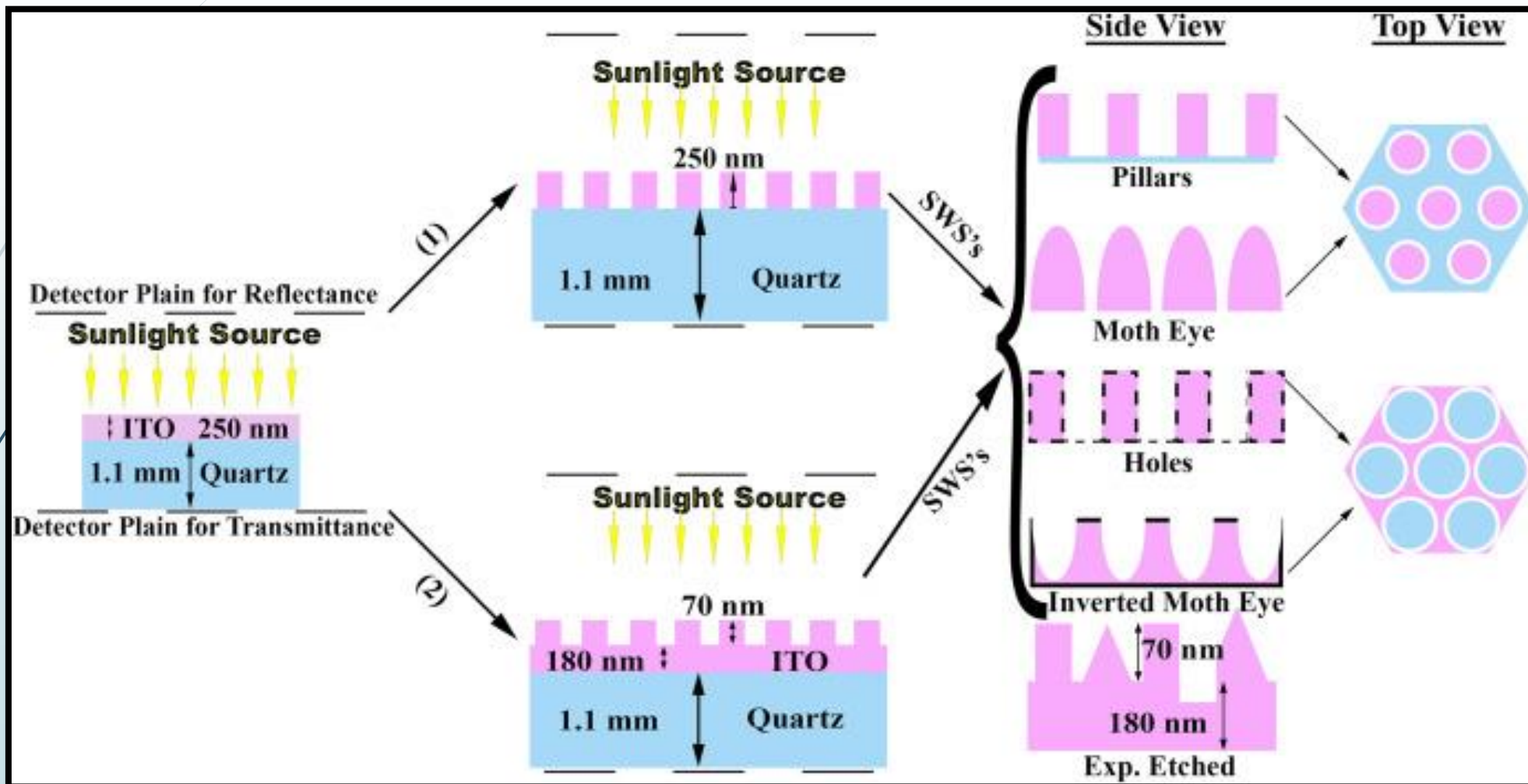


Sustainable and comfortable Conditions

c) Theory:

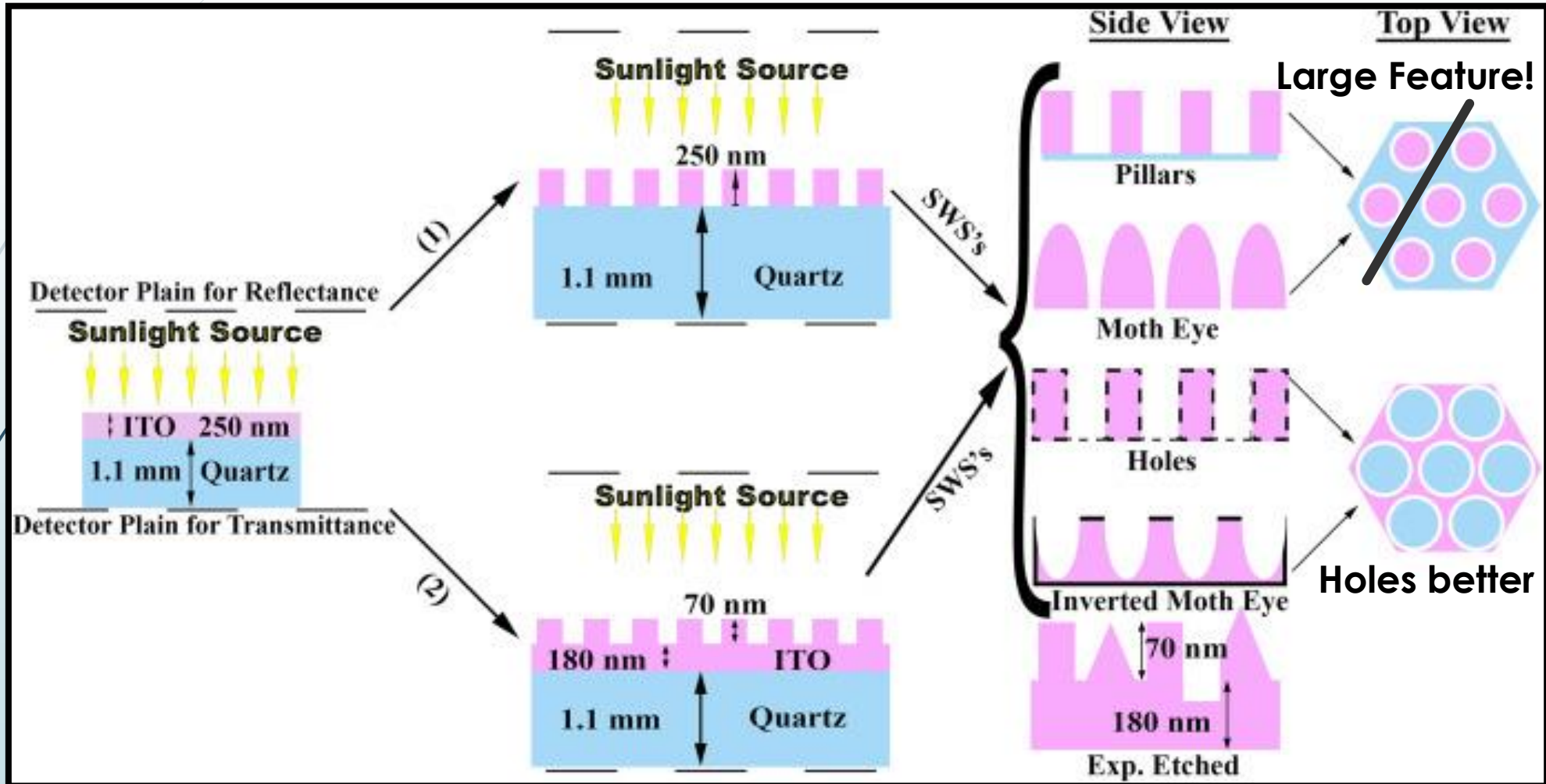


Spectrum Filtering and Splitting



Nanopatterned indium tin oxide as a selective coating for solar thermal applications - ScienceDirect

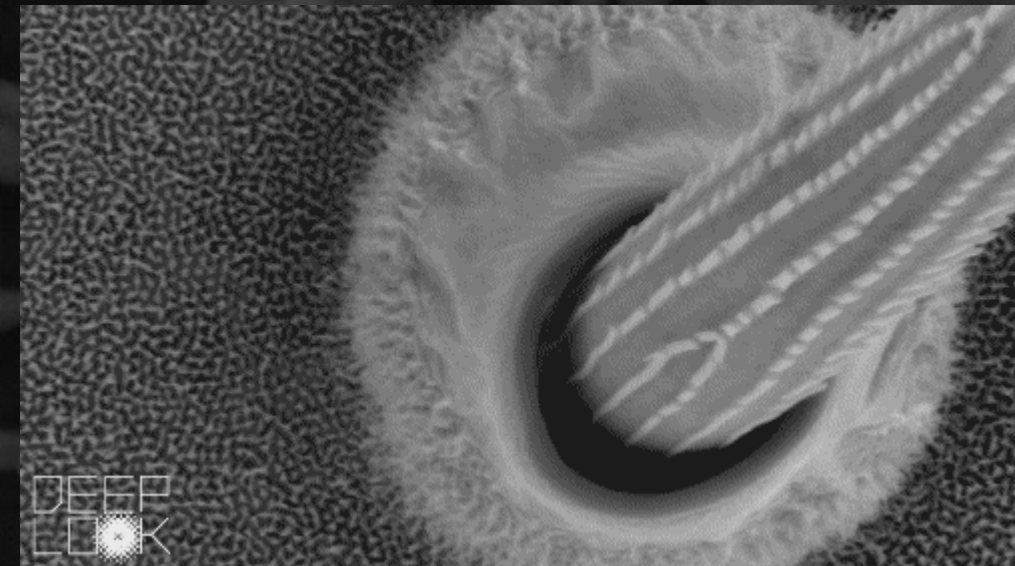
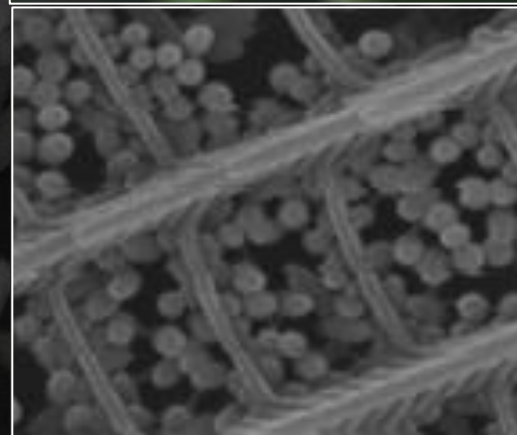
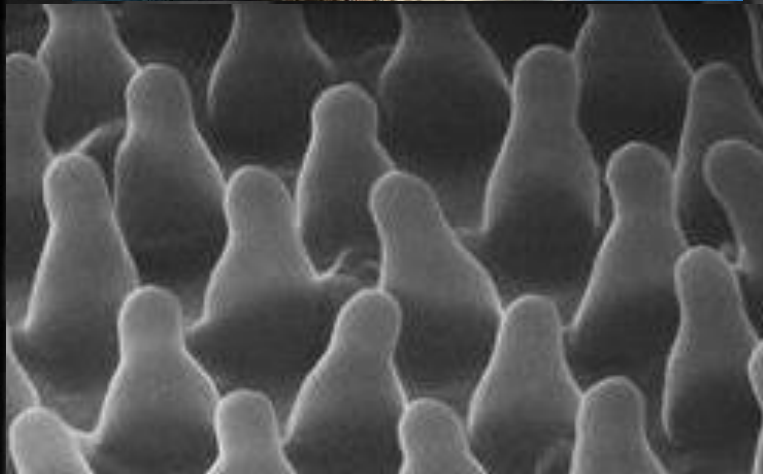
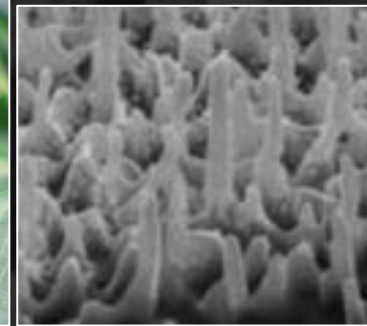
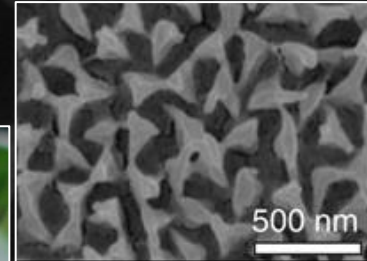
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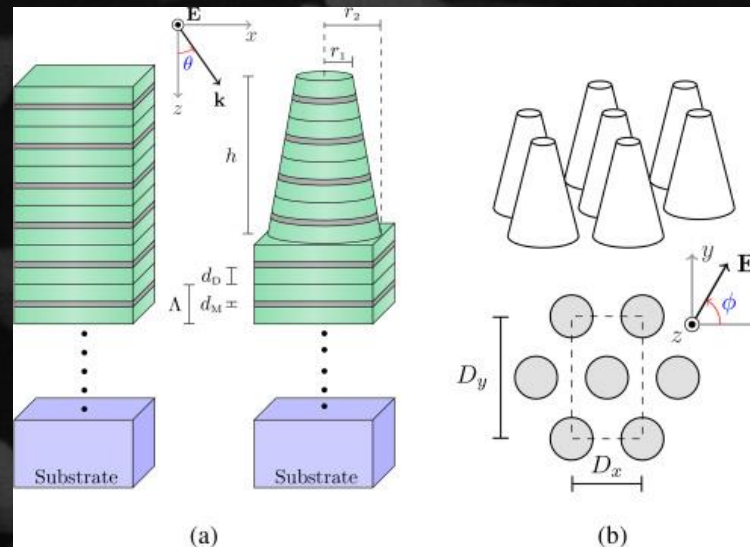
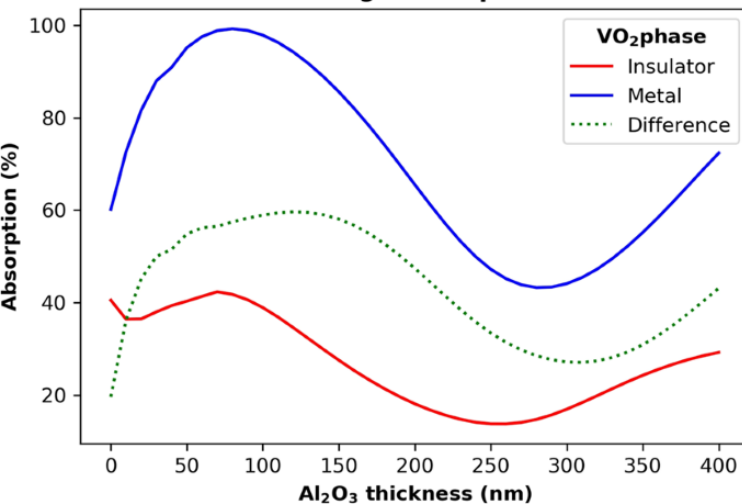
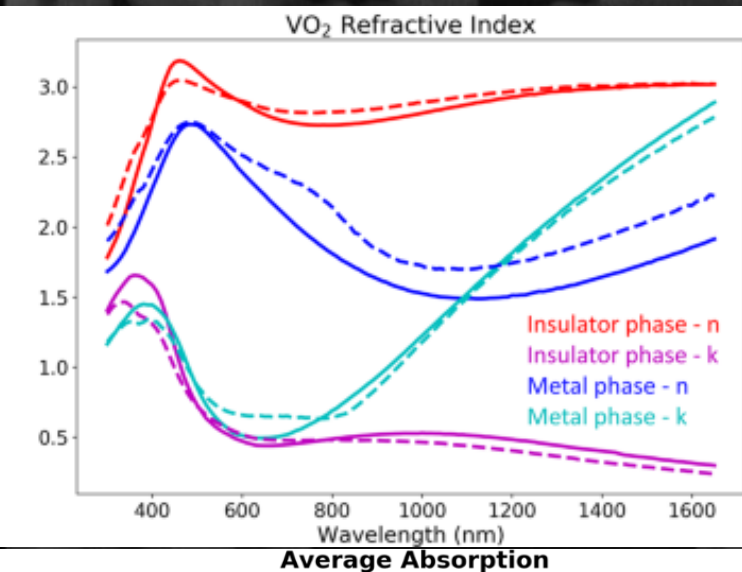
Interdisciplinary research into biomimicry

Inspiration from Nature for optical nanostructure.

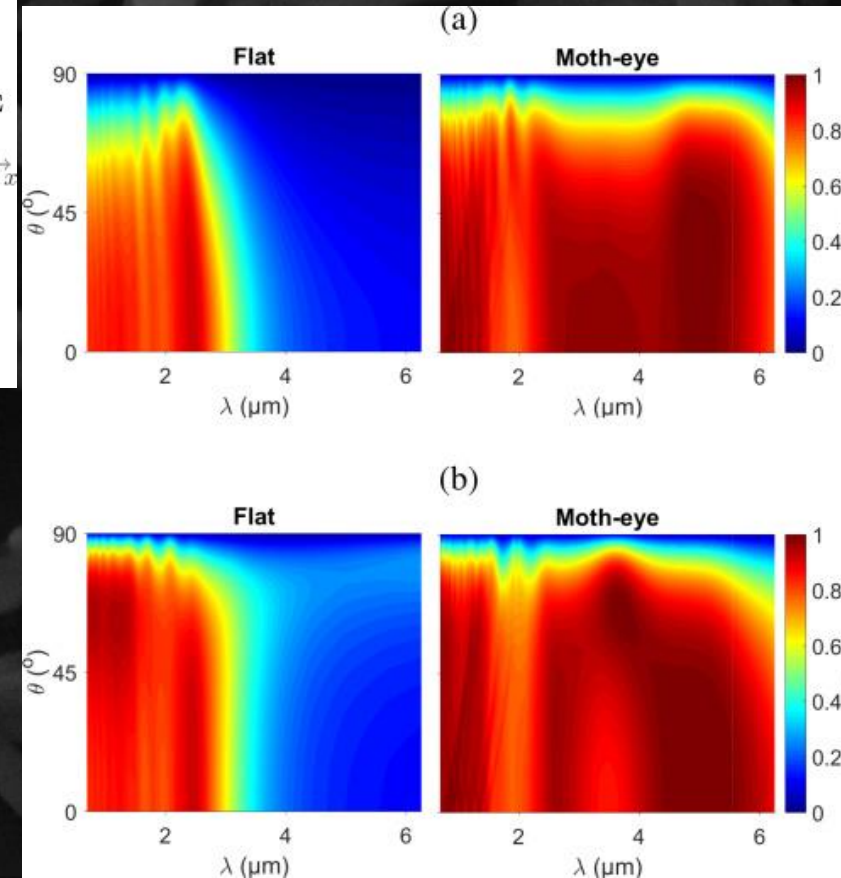


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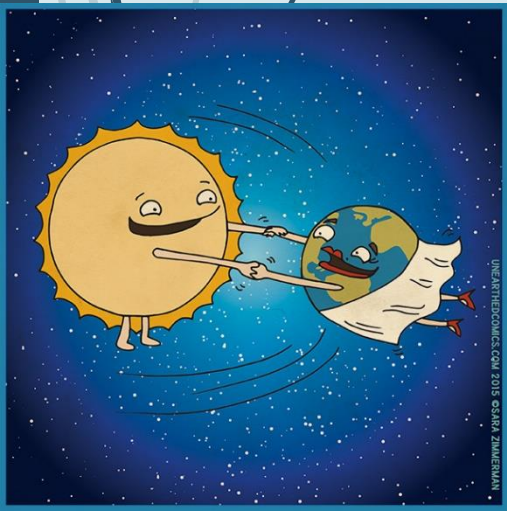
Rushin Contractor et. al. "Ultra-broadband, polarization-independent, wide-angle absorption in impedance-matched metamaterials with anti-reflective moth-eye surfaces," *Opt. Express* 26, 24031-24043 (2018)



Badloe, T., Kim, I. & Rho, J. Moth-eye shaped on-demand broadband and switchable perfect absorbers based on vanadium dioxide. *Sci Rep* 10, 4522 (2020).
<https://doi.org/10.1038/s41598-020-59729-2>

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 - ▶ **Matching application needs**
 - ▶ **Size/bulk?**



Collaboration offerings:

Design, assemble and testing solar prototypes

- ▶ **Optical + weather Modelling software**
 - ▶ Comsol, Lumerical, ASAP, APEX, PVSyst, Tsol.
- ▶ **Outdoor testing facilities**
 - ▶ Global, Direct and diffuse Irradiance detectors
 - ▶ Weather station + Solar trackers
- ▶ **Cell efficiency and performance**
 - ▶ Constant and flash solar simulators
 - ▶ External and internal quantum efficiency measurements
- ▶ **Optical measurements**
 - ▶ 200-2500nm Transmittance, Absorbance, Reflectance
 - ▶ Includes integrating sphere for specular vs scattering.
- ▶ **System manufacturing and assembly**
 - ▶ Solar cells, (silicon, CdTe, some emerging types)
 - ▶ Optical moulds, reflective film, manufacturing contacts
- ▶ **Need!: People who can make customised visible Metalenses!**

Powering the future



Optimising solar technology

Build Solar: integrating energy production into glass and buildings

Solar driven hydrogen production



Using biomimicry for innovation in energy production



Supporting energy independent farming



Met4Tech: optimising responsible extraction and use of technology metals

Minviro: understanding and reducing the impact of raw materials with life cycle assessment



Lithium for Future Technologies (LIFT)

Thank you for your time!

- Q and A welcome or via email:
- k.shanks2@exeter.ac.uk

Understanding environmental and ecological change



The environmental dimensions of Antimicrobial Resistance (AMR)

Host-parasite interactions in bacterial systems



Species co-evolution, interaction and immunity



Animal ecology and conservation management



Personalised ecology



Modelling climate change, crops and pests



Remotely sensed data for ecosystem monitoring



The ecological impact of Artificial Light at Night (ALAN)



Measuring human impacts with Life Cycle Analysis (LCA)

Conserving and regenerating nature



Award winning BEEHAVE modelling project

BEE-STEWARD software tool to support pollinator friendly farming



Using AI to respond to the threat of Asian hornets on pollinators



Renewing biodiversity through a people-in-nature approach (RENEW)

Cornwall and Isles of Scilly Environmental Growth strategy

Cornwall State of Nature report

Improving urban biodiversity in Cornish towns



Managing domestic cat predation of wildlife



Marine ecosystems and fisheries management



Upstream thinking: catchment management applying nature-based solutions



Using microbes for bioremediation

Informing sustainability policy and practice



Designing a Sensibility for Sustainable Clothing

Circular food systems



Arca: supporting businesses to transition to the circular economy

Tevi: helping Cornish SMEs to grow the environment

Lagas: natural capital information management hub



Sustainable Development and Resilience of Coastal Communities (ROCC)



Local goal-based governance



Co-producing tools for adaptive heritage management



Informing global policy on AMR

Developing phage therapies



Managing bovine TB



Smartline: using domestic technology to improve health and wellbeing

Powering the future



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