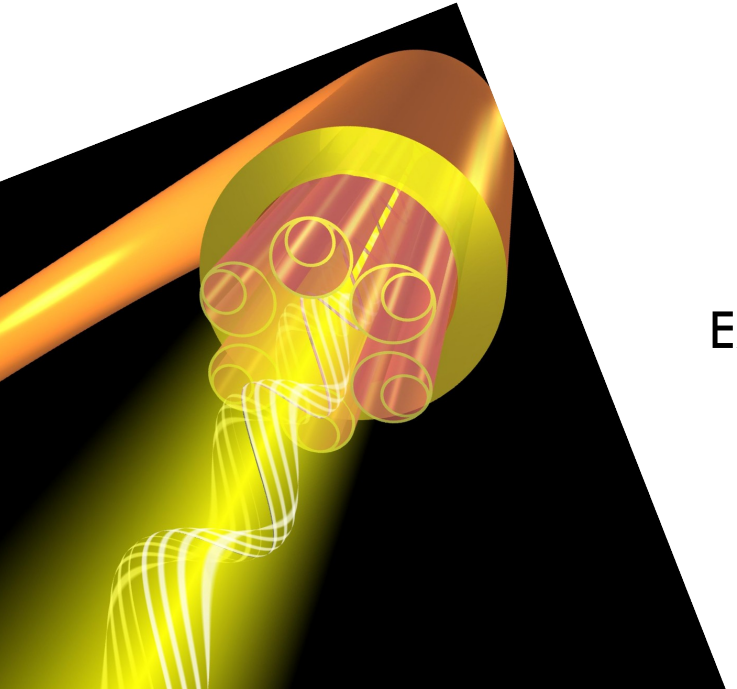
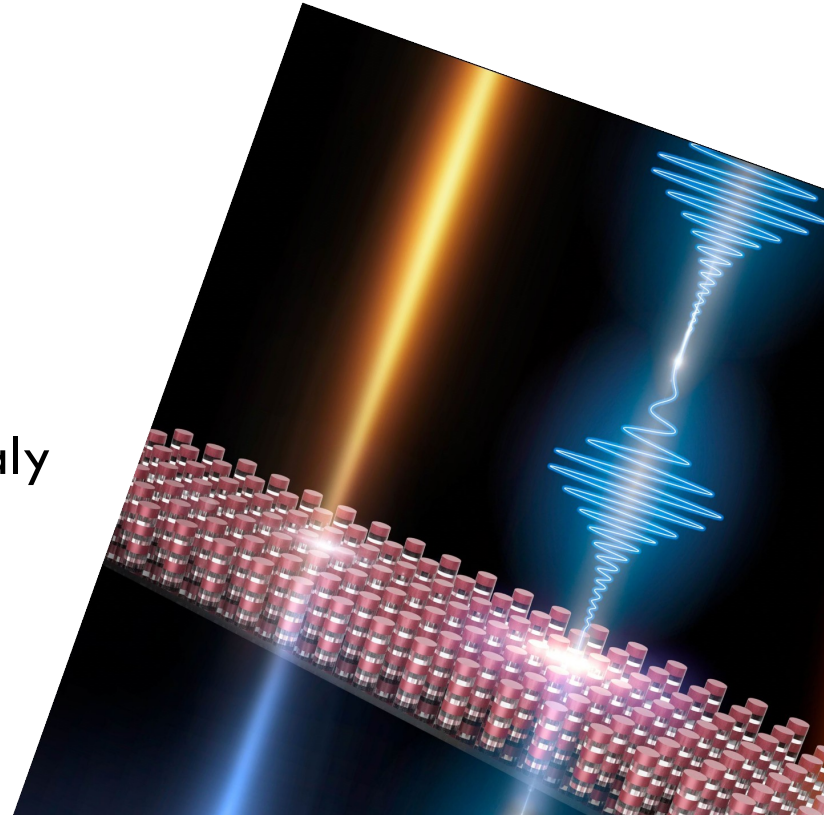
New materials, Dispersing Elements and Optical Devices: some thoughts





Andrea Bianco
INAF-OABr

Expanding Horizons in Italy
Roma, May 16, 2025

WST in mind

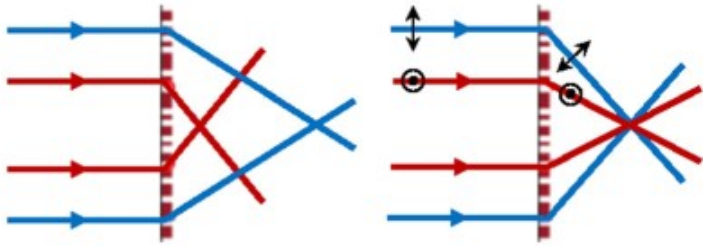
- Kilo MOS LR/HR + IFS;
- Large FoV + panoramic IFU;
- Km of optical fibers;
- Hundreds of spectrographs;
- Detectors&dispersers challenges;
- Operational challange.

What technologies? A selection…

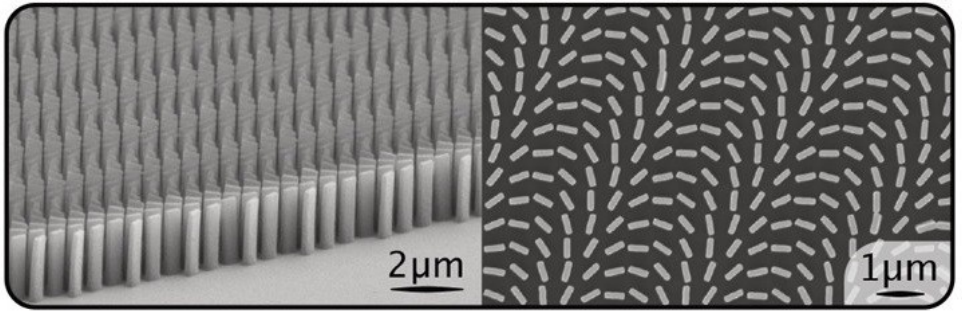
- Metasurfaces;
- Multifunctional holograms;
- Hollow core fibers;
- Plastic refractive elements.

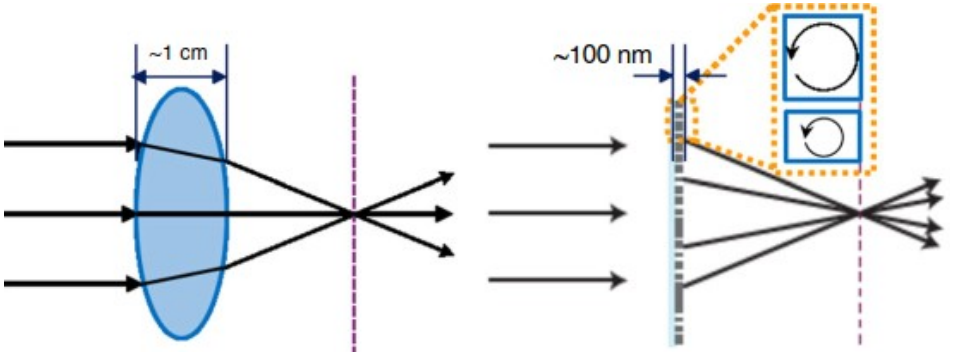
Flat optics: metasurfaces

- Optics can be flat!
- Very thin, but with high versatilty;
- Control of polarization, chromaticity,...



F. Capasso, Harvard)
https://youtu.be/ETx_fjM5pms

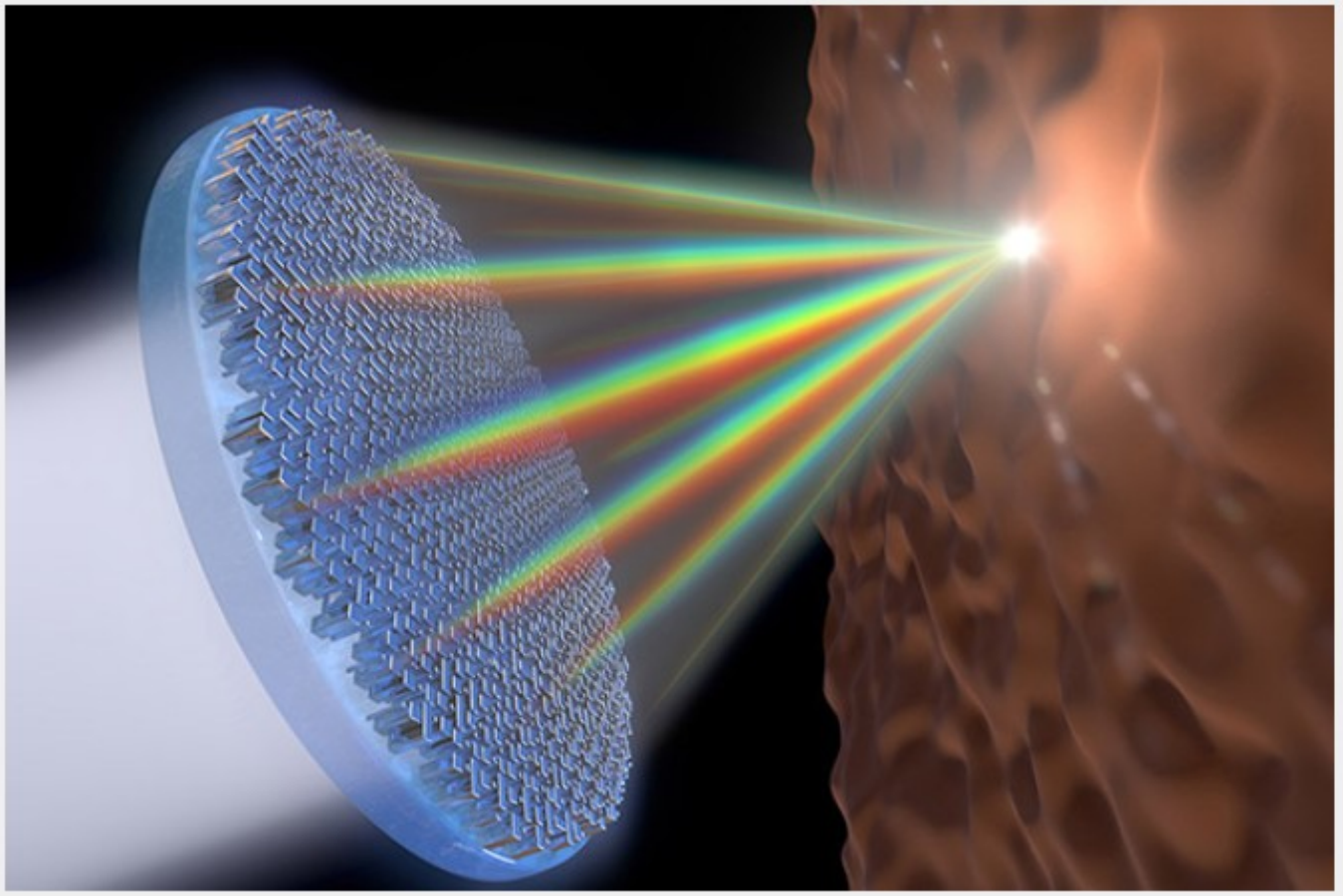




Visible metalenses with high focusing efficiency fabricated using nanoimprint lithography : arxiv.org/abs/2312.13851

Neshev and Aharonovich *Light: Science & Applications* (2018)7:58
DOI 10.1038/s41377-018-0058-1

Flat optics: metasurfaces

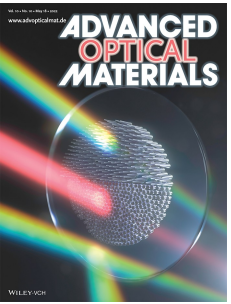


SINGLE METALENS FOCUSES THE ENTIRE VISIBLE SPECTRUM OF LIGHT TO ONE POINT

May 9, 2025

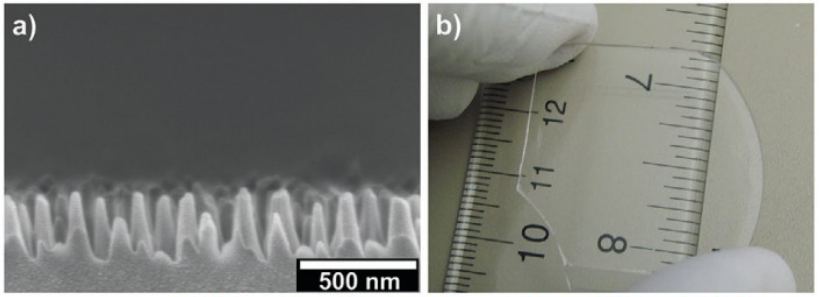
By

https://cns1.rc.fas.harvard.edu/single-metalens-focuses-entire-visible-spectrum-light-one-point/

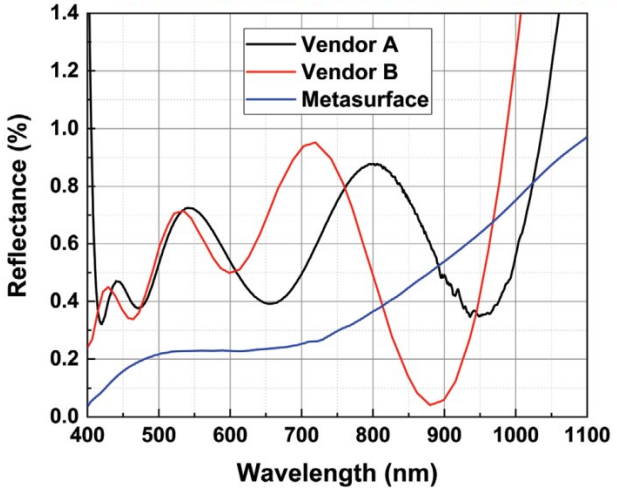


Metasurfaces: Coatings, splitters

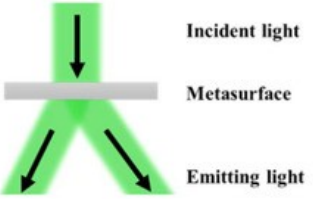
AR COATING

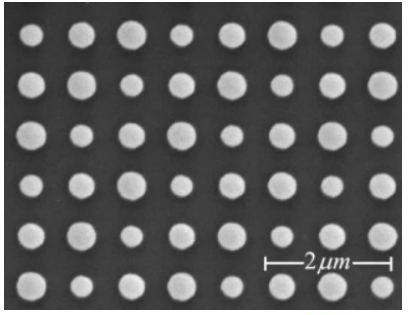


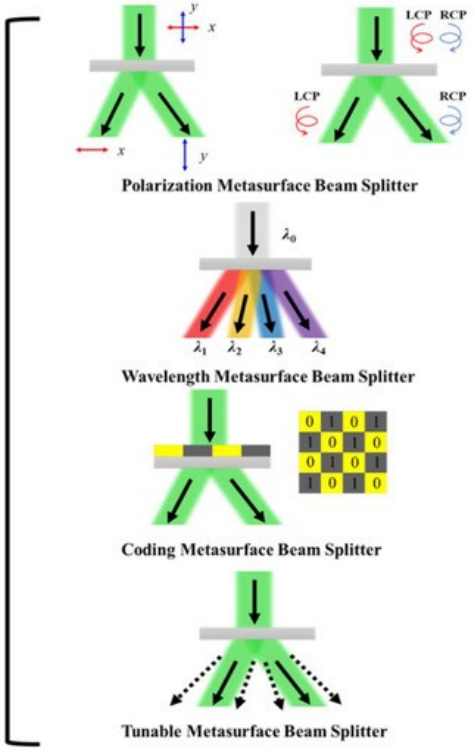
Adv. Optical Mater. **2022**, *10*, 2200151



BEAM SPLITTER



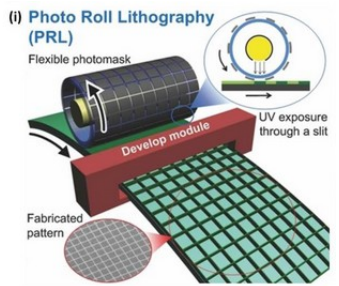


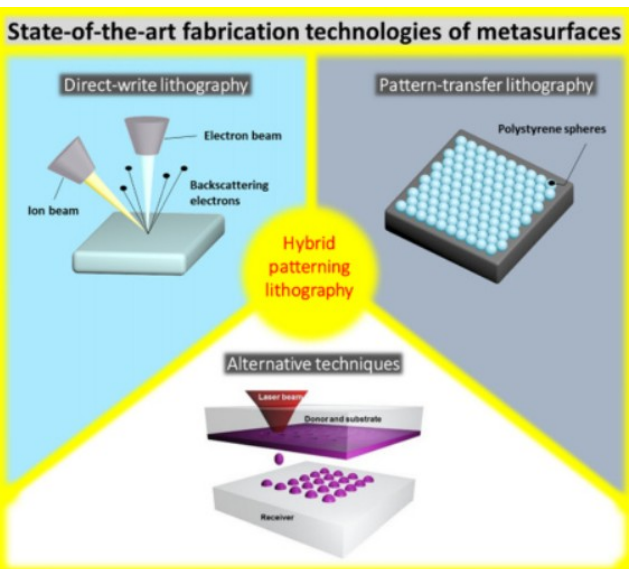


Nanomanufacturing **2022**, *2*, 194–228.

Meta-Challanges

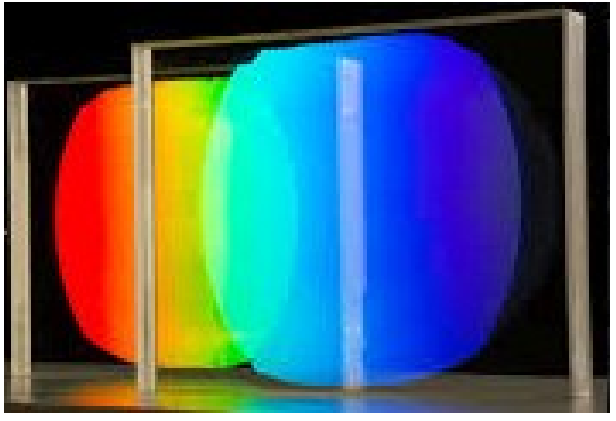
- Increase the size, force to work on large optics and not to small ones with large markets (smartphone cameras, wearable devices);
- Suitable industrial process;
- Suitable design tools (almost there).

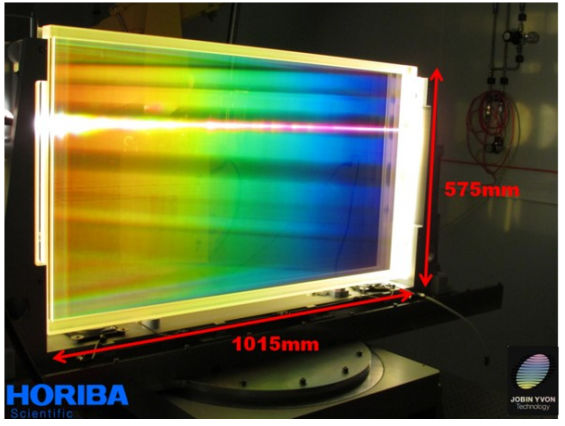




Dispersers

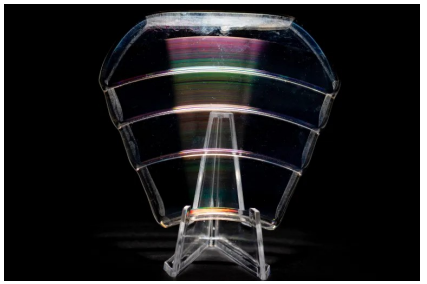
- Dispersers, i.e. diffraction gratings, must provide **high efficiency and be large**...necessary (energy detect);
- No size problem, already more than 1 meter;
- Serial production of identical copies in a reasonable time.

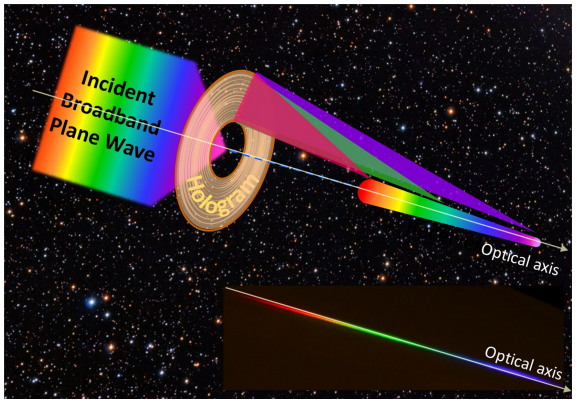




Disperser goes multifunctional

- Compact, simple and efficient devices.
- Embed in a single elements more optical functions:
  - Control of the wavefront;
  - Dispersion + focusing;
  - Beam splitting.

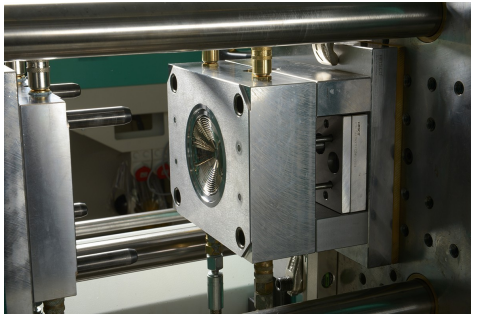


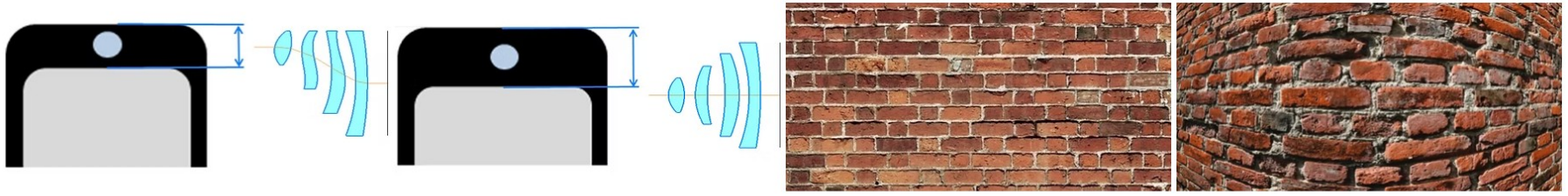


Hsieh, ML., Ditto, T.D., Lee, YW. *et al.* Experimental realization of a Fresnel hologram as a super spectral resolution optical element. *Sci Rep* **11**, 20764 (2021). https://doi.org/10.1038/s41598-021-99955-w

Plastic lenses and microlenses

- High quality **freeform lenses:**
- More compact and light devices with low WFE;
- AR coating possible;
- Precise injection molding is the key.

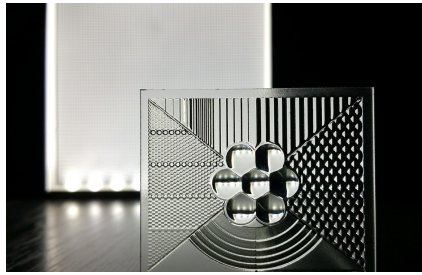




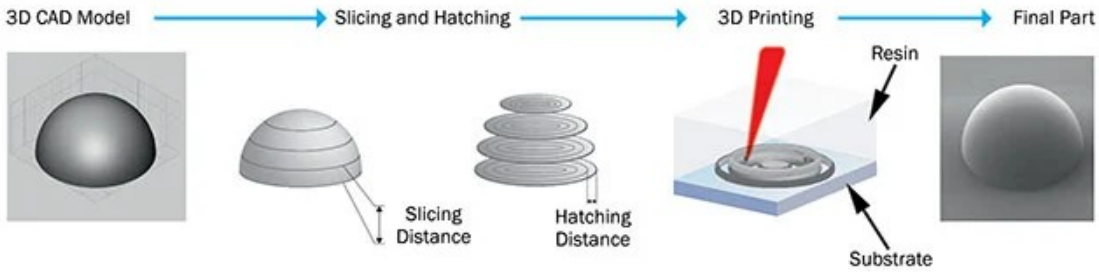
Small Bezel | Regular Bezel | Wide panoramic cameras | Wide panoramic cameras

https://www.dynaoptics.com/

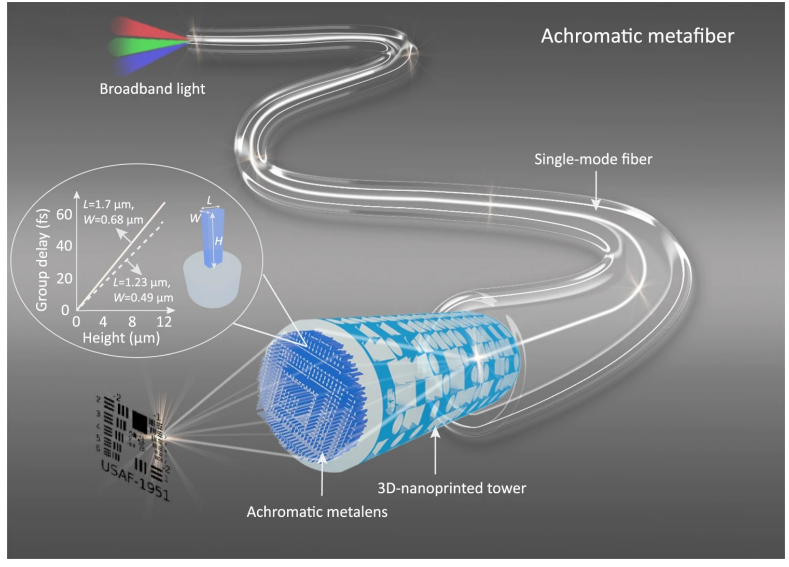
3D printed (micro)lenses



- Combination of 3D printing and plastic optics
- 3D printed micro-lenses where you want: patterning
- Optical fiber + microlens.

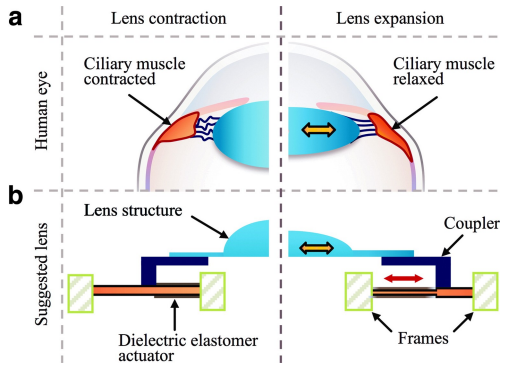


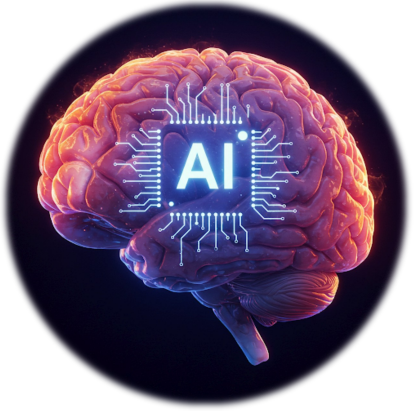
https://www.photonics.com/Articles/Ultraprecise_3D_Microprinting_for_Optical_and/a64047

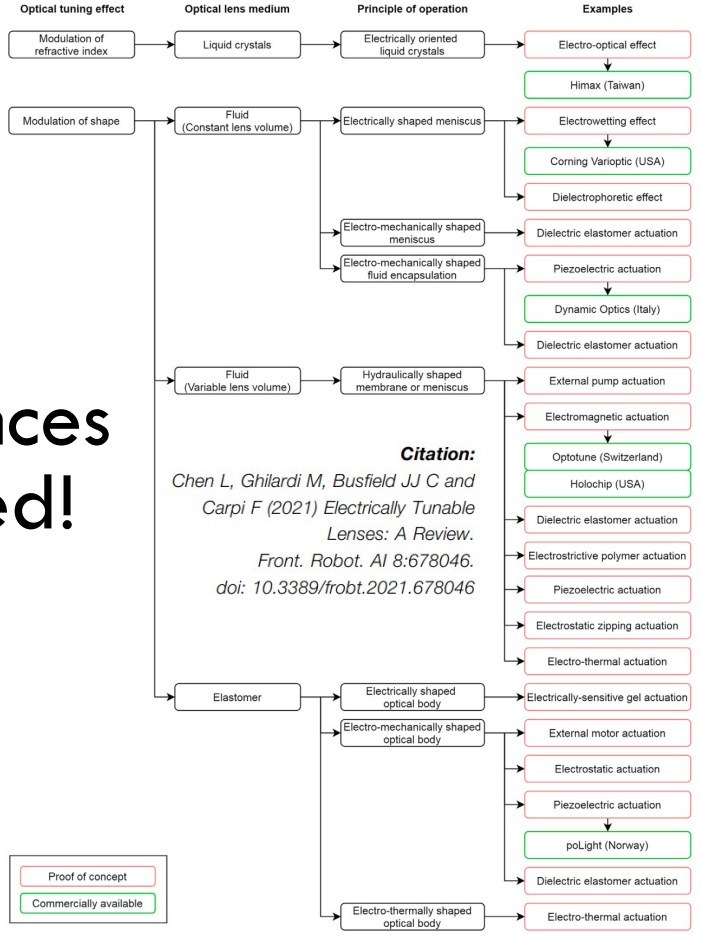


Plastic lenses: more dynamic, less static

- Plastics are intrinsically softer than glasses. Bad and good;
- Plastic OEs easier to be deformed…
- Actively control the optical performances of the assembled system. Brain needed!

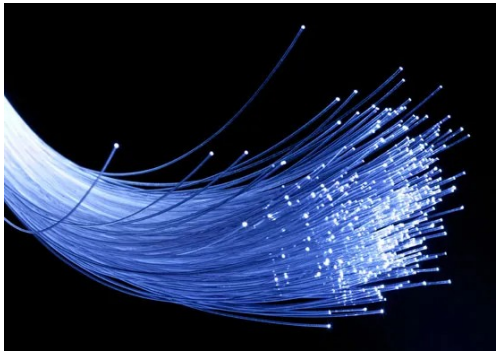


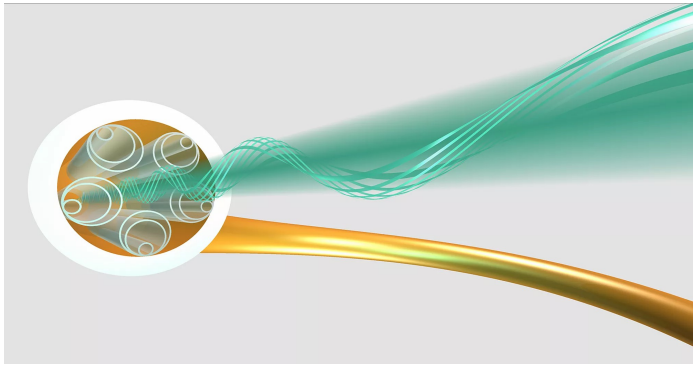


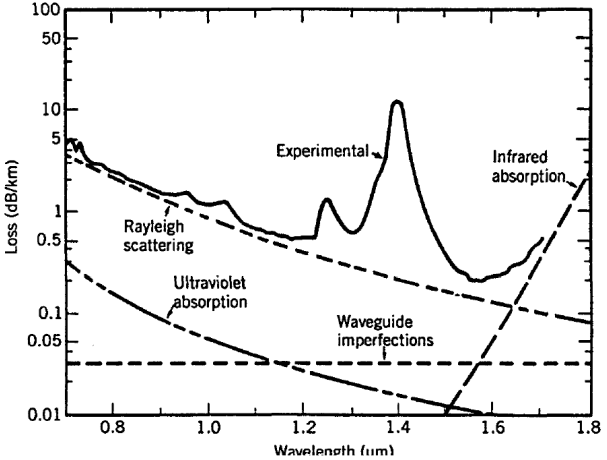


Optical fibers: Hollow core fibers

- Optical fibers are the base of MOS@WHT and of many instruments: decouple the telescope and the instrument;
- Losses become important reducing the wavelength and the control of the modes is important;
- A revolution is almost here with HCF?

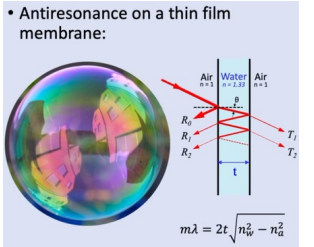




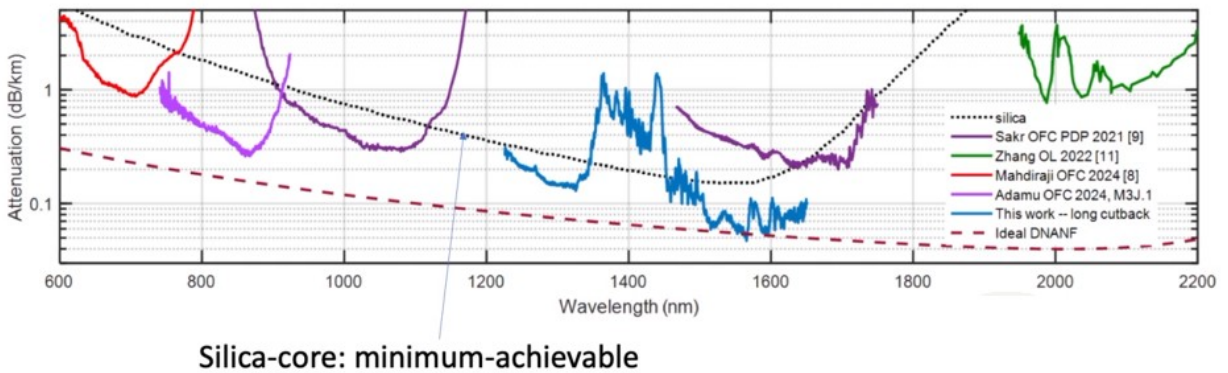


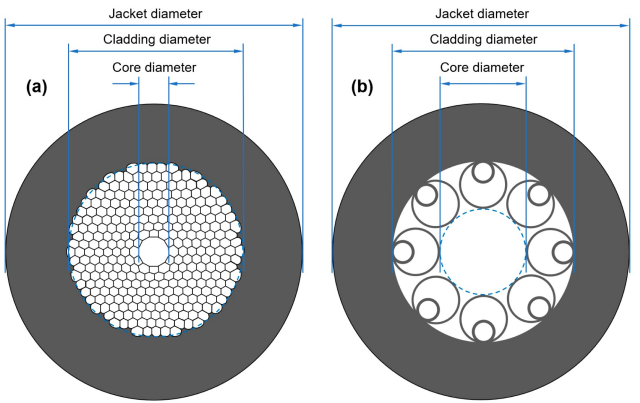
Loss spectrum of a single-mode fiber produced in 1979. Wavelength dependence of several fundamental loss mechanisms is also shown.

Hollow core fibers



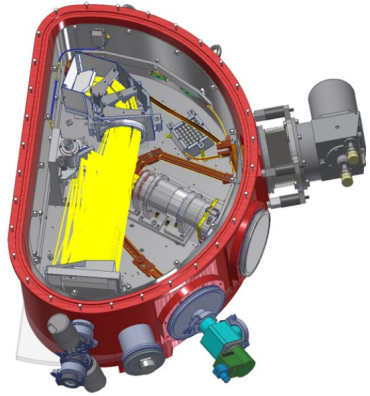
The light is guided into air/vacuum; the light is guided through a hollow core primarily by **photonic bandgap effects or anti-resonant reflecting mechanisms.** The light travels mostly through air or vacuum, which significantly reduces attenuation because air has lower absorption and scattering losses compared to solid materials. Suitable for UV!





Tesla/Renault and gigapress

- Renault 5 electric built in 10 hours!
- Could we build a similar size spectrograph in a half day?
- Different design approaches with serial production in mind.



Conclusions

- Optical technologies are changing in a large extent: meta, plastic, dynamic, holo…this is good for WST and others;

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Conclusions

- Optical technologies are changing in a large extent: meta, plastic, dynamic, holo…this is good for WST and others;
- But we cannot wait at the window…
- Select the key techs, find valuble collaborations do develop them in our, astronomical, direction.

Conclusions