Glass, daylighting and lighting

(COMBINING ENERGY EFFICIENCY WITH AESTHETIC APPEAL USING ADVANCED OPTICAL MATERIALS)

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Science of energy efficiency and engineered spreading in light diffusing materials

- ❑“Eliminate” backscattering
- ❑ Small average deviation of ray per particle intersection
- ❑ Easily cast, extruded or injection moulded
- ❑ Colour dependence of spreadng weak

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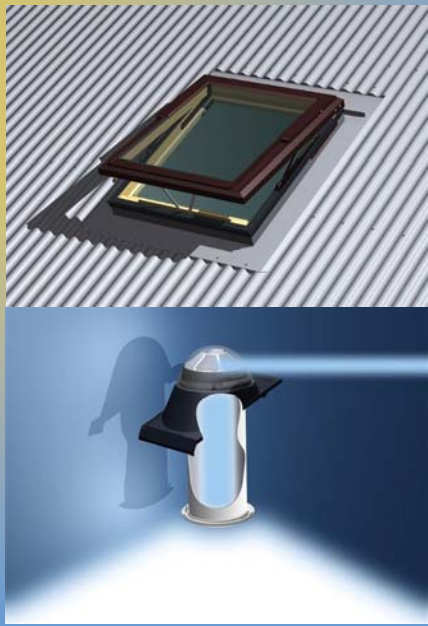

Courtesy Skydome Skylight Systems

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A skylight with special solar control glazing and angular selective mirror light pipe for catching low angle daylight.

Glazing and skylights in buildings

- Thermal comfort
  - heating dominated climate - insulation
  - cooling dominated climate - solar heat gain
  - temperate (Sydney) - control both
- Daylight
  - too intense, usefulness a distribution issue
- View important

Skylights : Solar intensity ($I_o \cos\theta_i$, θ_i = angle of incidence) much higher than a window

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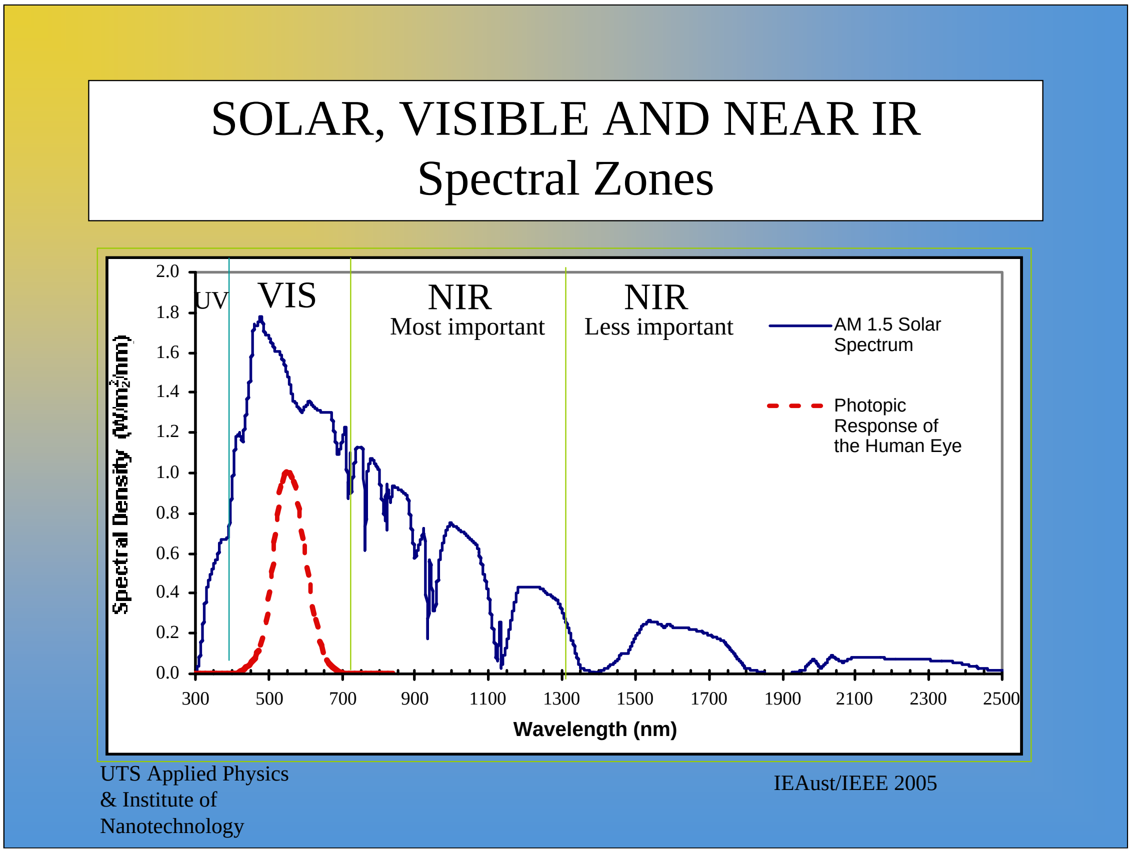
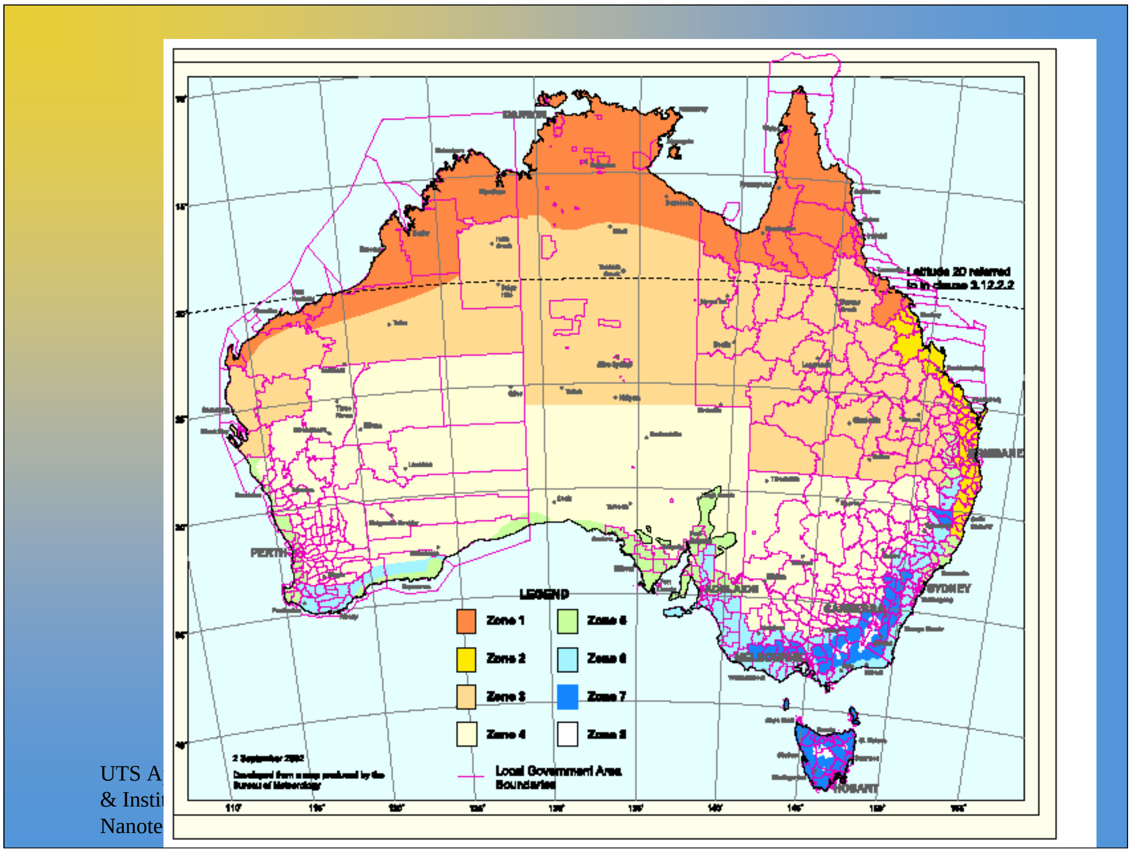


50% of incident solar energy is at wavelengths longer than 700 nm which we do not need for daylighting or vision.



Australia has 8 different climate zones - each requires different energy efficient building designs.

Warm climate spectral engineering in a window or skylight

Need to handle solar spectrum as follows :

- Transmit visible for light and view (preferably with low glare)
- Block NIR component (to reduce solar heat gain)

and ideally (but more important in a cold climate)

- have low thermal emittance
  that is low R in thermal or black body IR $\lambda > 2.5$ µm to ~ 30 µm

Heat gain in absorbing windows

U also affects SHGC since it involves absorbed heat in window finding its way inside, plus direct transmitted solar energy

$SHGC = T_{sol} + A_{sol}U/h_o$

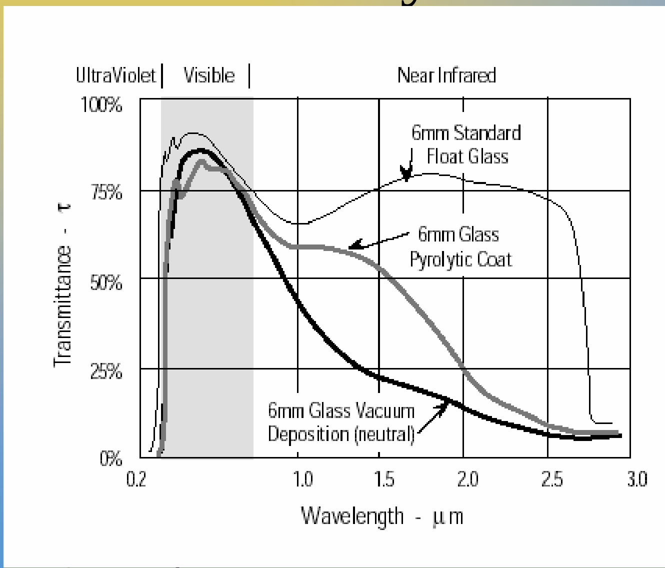
A_{sol}= solar absorptance
h_o = external surface heat loss coefficient

NIR reflecting windows will have SHGC and T_{sol} close together and stay cooler than those which absorb (as do most windscreens)

External conditions such as wind speed and outside temperature alter h_o and hence impact of absorbed energy

Heat entering a building from the sun via glazing is in two parts; directly transmitted solar energy and solar energy first absorbed then thermally transmitted by convection or radiation.

Low e pyrolytic(tin oxide) glass and multilayer AR coated silver



Note both of these Reflect NIR solar While nanoparticle doped layers absorb it. SHGC affected by absorption and re-radiaiotn

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Existing systems which allow in light and block some NIR radiation.

Solar and visible transmittance

These are the two most important parameters in assessing window energy performance and are defined as follows in terms of the spectral transmittance T(λ) of the window, S(λ) the normalized Air Mass 1.5 (AM1.5) solar energy spectrum, and the Normalized spectral sensitivity of our eyes Y(λ)

$$T_{sol} = \int_0^\infty d\lambda S(\lambda)T(\lambda)$$

$$T_{vis} = \int_0^\infty d\lambda S(\lambda)T(\lambda)Y(\lambda)$$

These give total solar energyand visible light energy getting in once actual solar flux on window is known. Daylight in (see next slide)

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The calculation that is used to compare different window materials for lighting gain and solar thermal control.

Luminous efficacy and energy efficiency

Lumens through a window

$$L = K_m A \int d\lambda S(\lambda) T(\lambda) Y(\lambda)$$

K_m = 683 lW^{-1},the luminous efficacy at the peak photopic eye response wavelength of 555nm, S(λ) is the spectral solar energy flux density distribution on the window and Y(λ) is the eye's photopic response function.

S olar heat gain through a window

$$\Phi_{in} = [SHGC] \int d\lambda S(\lambda)$$

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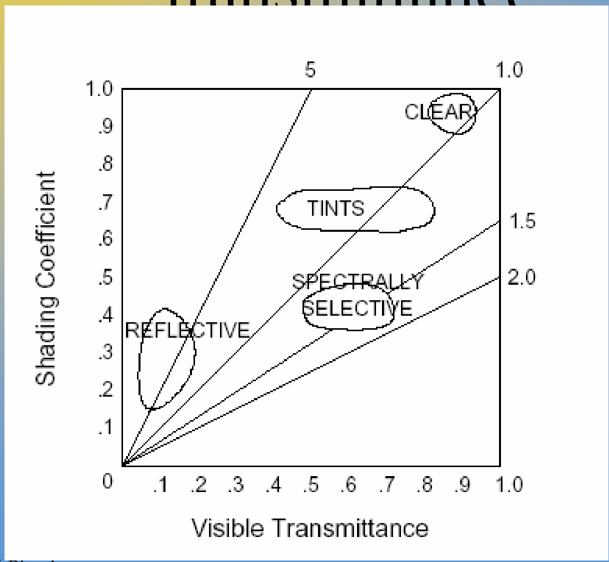
Energy efficiency in lighting is measured by luminous efficacy(light quantity units = lumens, energy Watts) . SHGC is the solar heat gain coefficient. S is the measure of solar energy flux density at wavelength lambda.

Solar blocking versus visible transmittance



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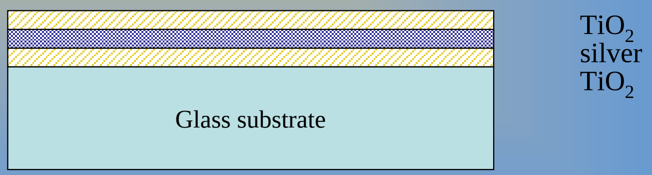
Balancing light gain and heat gain - a compromise approach is usually needed.

Thin film solution for daylight transmittance plus solar blocking via NIR reflectance

Each film
~ 18 to 20 nm thick

18 to 20 nm of Ag normally blocks all light but transmittance is induced by the high index coatings either side

Thin Film stack



In practice products use a double or triple stack (6 or 9 layers) for best results.

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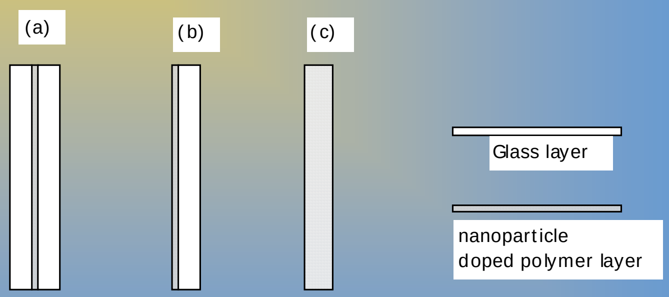
A basic vacuum coated system for solar control with daylight - usually a little more complicated than that shown above, but uses same principle- produced in large sputtering lines e.g. at G.James in Qld.

Laminate foils doped with nanoparticles for cheap solar control glazing in cars and buildings



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Different configurations of glazing showing how nano-particles can be incorporated, in laminate, in a polymer foil on the surface or in a bulk polymer skylight.

Photo of PhD student Stefan Schelm with samples of laminate with different concentrations of LaB6 nanoparticles

Underlying science

Surface plasmon resonance in conducting nanoparticles

- Dipole moment on a sphere has an absorption resonance at frequency defined by Rl[dielectric constant(ε)] = -2(ε of host)
- Very strong (high Q) and narrow band
- As conductivity drops resonant wavelength increases
- Thus NIR resonances need weaker conductors than gold, silver and TiN.

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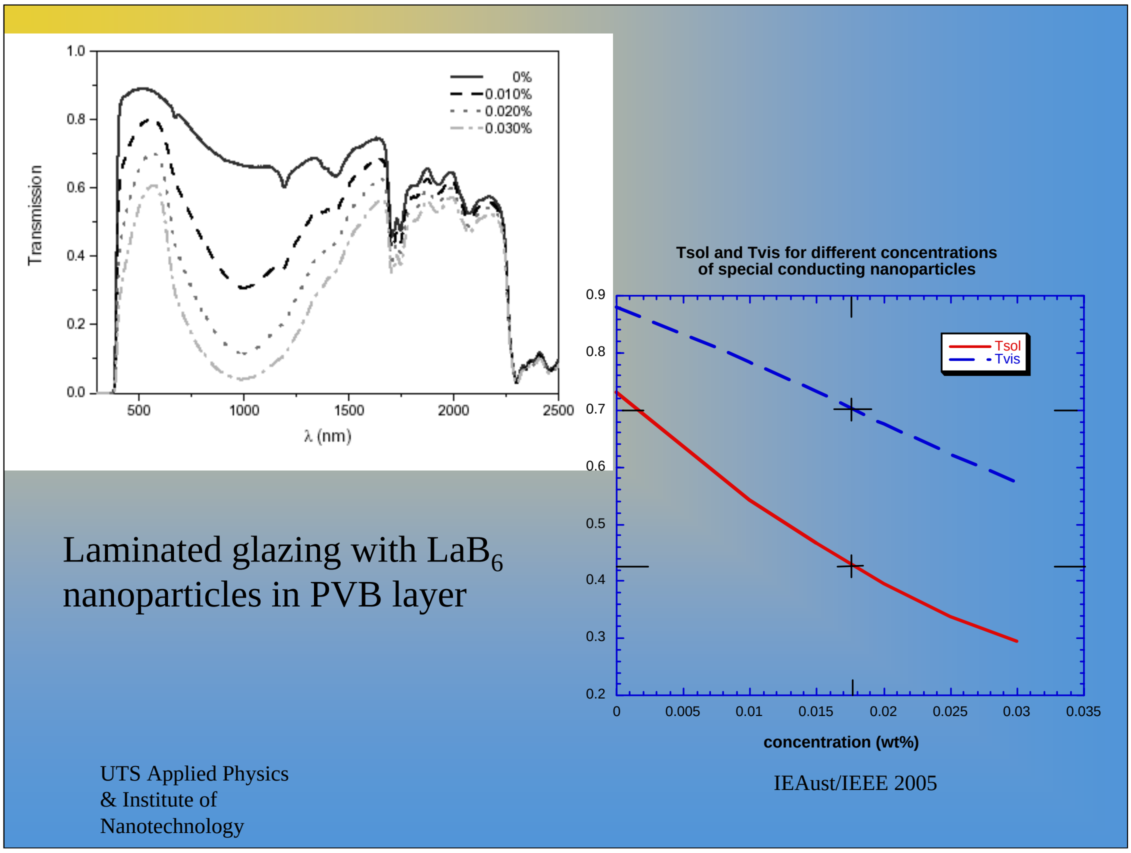
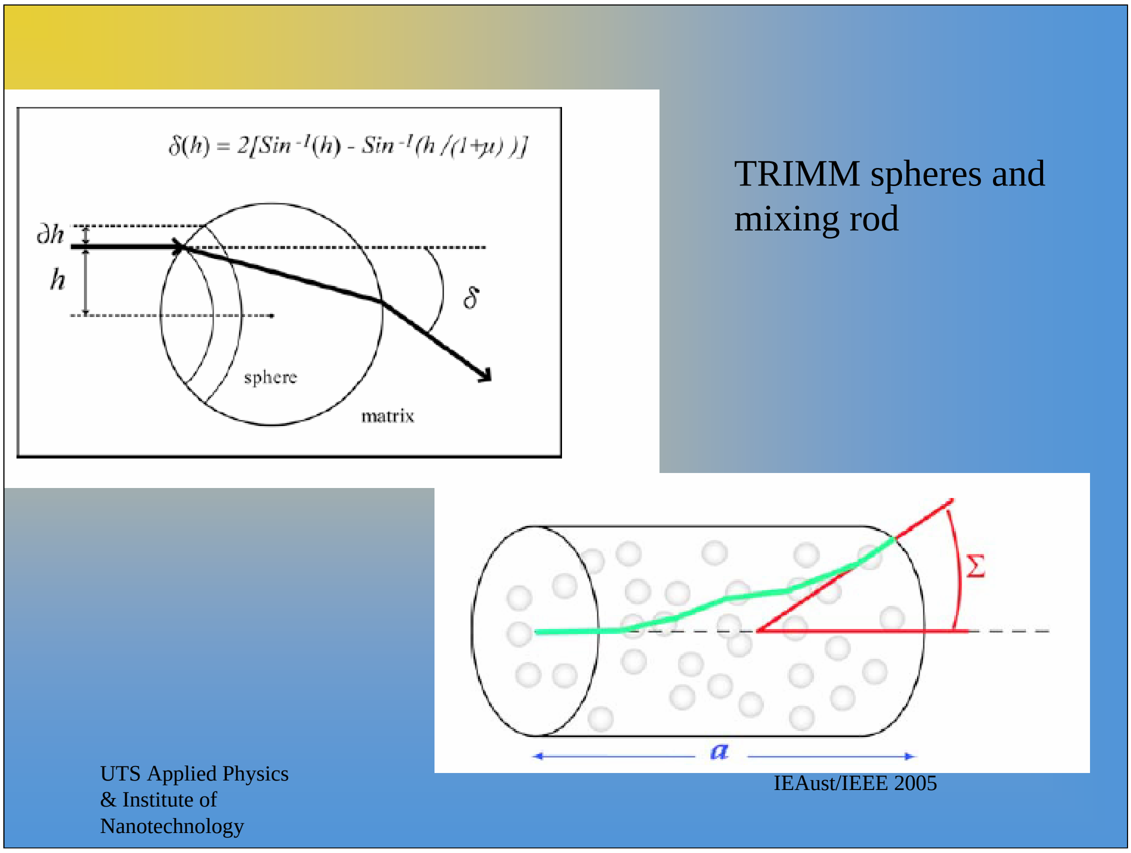
Metals have unusual dielectric properties at NIR wavelengths and some also at visible wavelengths (a negative dielectric constant!) - result is small particles can resonantly absorb incident radiation very efficiently at a particular wavelength range.



Transmittance versus nanoparticle concentration (note it is very small in a 0.7 mm thick laminate layer). Impact on light (top blue curve) and heat gain(red curve) . + on right plot is where a car windscreen has to be above visually.

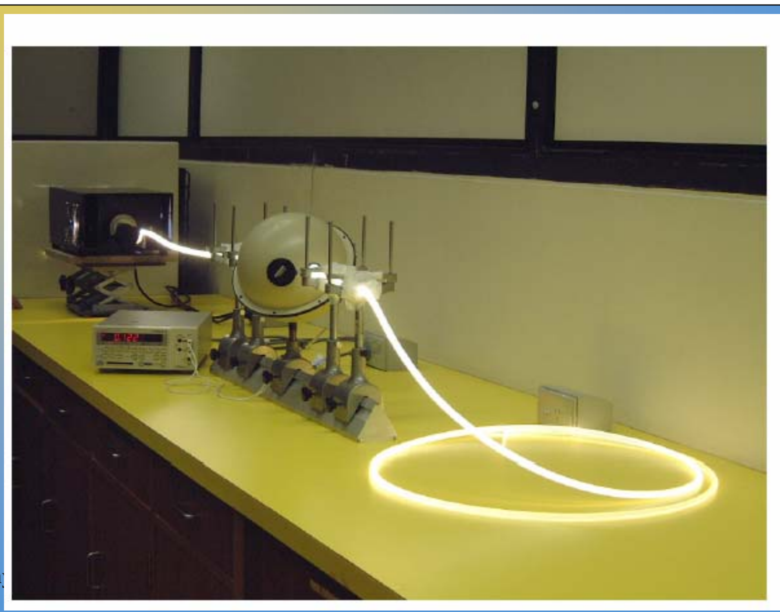
Light distribution systems

- Diffusers for luminaires
- Diffuse skylights
- Light pipes which continuously emit
- Signs, displays, data projectors, “neon” replacement
- “Piping” of daylight in solid light guides



Light deviation in large clear polymer particles with close refractive index to their host polymer - in a sidelighting rod or a light mixing rod, deviation per encounter is small - so total is easily engineered. Programs can calculate the total deviation - walls keep it in until deviation gets big enough.

“Supersidelight” doped polymer



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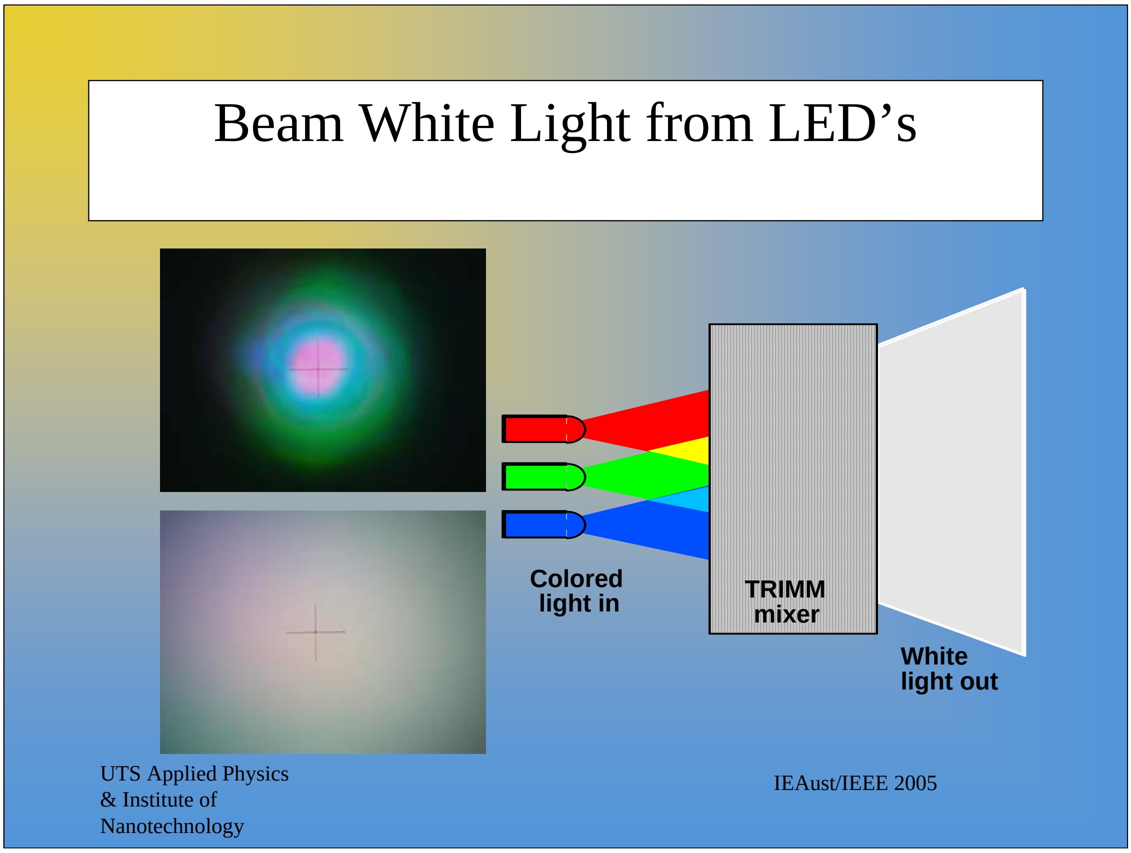
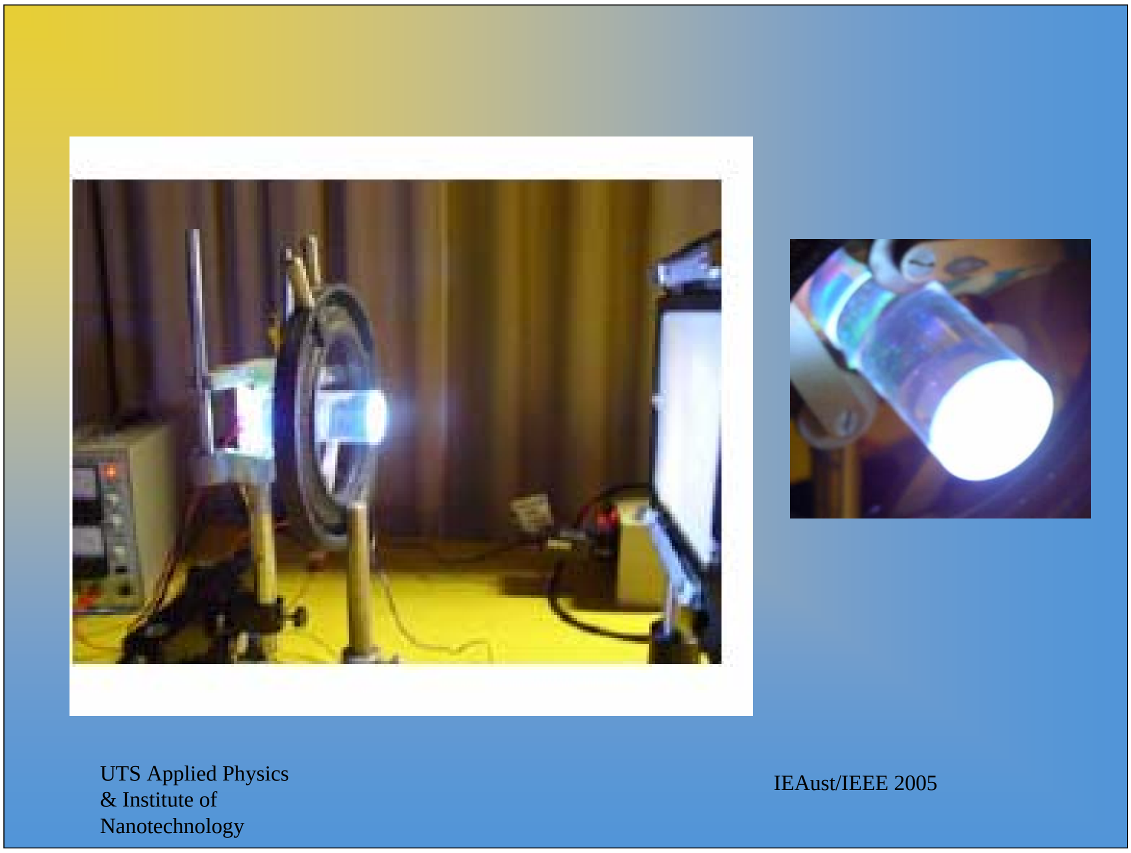
Continuously illuminating supersidelight flexible polymer made in a one step process by TRIMM doping can achieve combination of transport and sidelight to any distances from a few cm to 30 metres; set up shown is for measuring output as a function of distance from source .

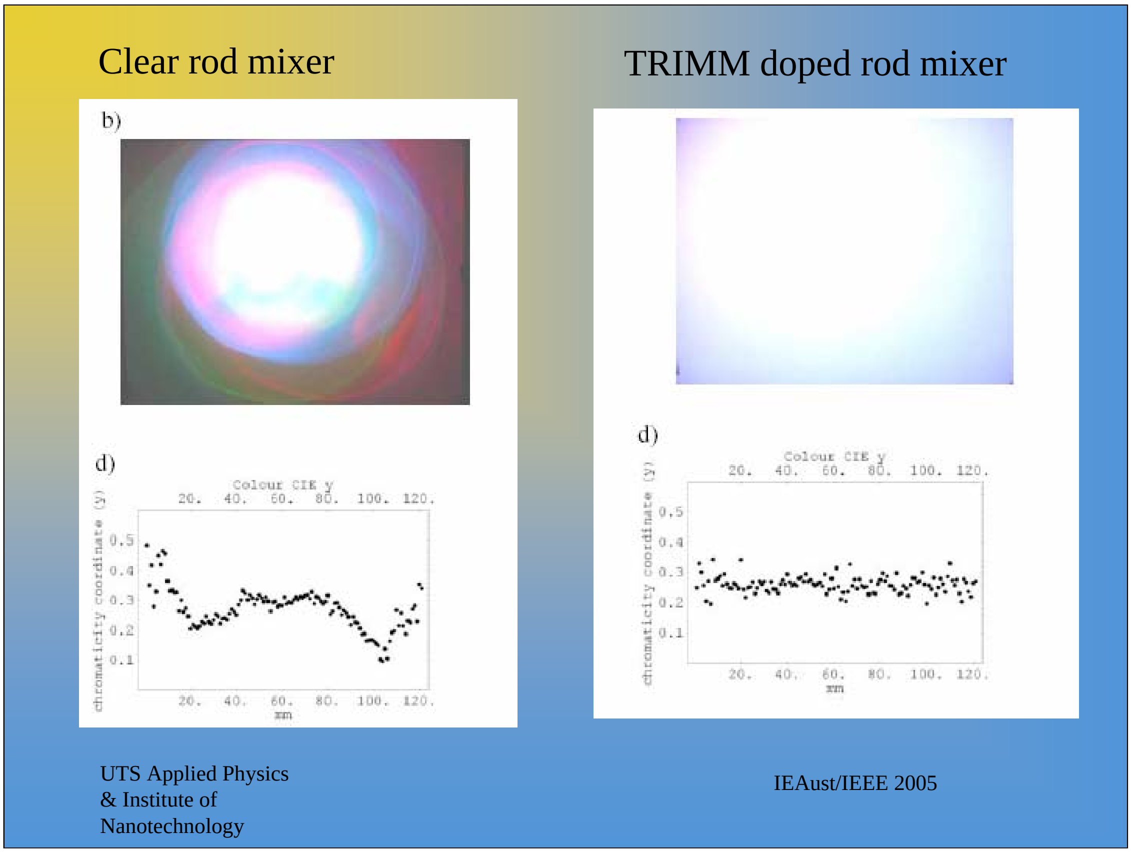
A display fridge lit not with a fluoro tube but with a superside lit polymer in which source is at end and can be external to fridge using light guide(fibre optic) principles to save much thermal energy gains from the lamps currently used and if done with Leds can last 10 years.



Mixing colours homogenously and energy efficiently to produce new colours including white for novel LED based lamps- colour lighting with no filters and many colour options !



A prototype new generation white light lamp using colour mixing principles.



Mixing and colour uniformity mapped on right .vs. unmixed on left.

Solar Related Options

- Direct - windows, skylights, translucent walls
- Indirect - flexible light pipes
- PV power + lamps - solar cells , energy efficient lamps
- Various hybrids of above

UTS has developed some of these,
Why are they best at present costs ?

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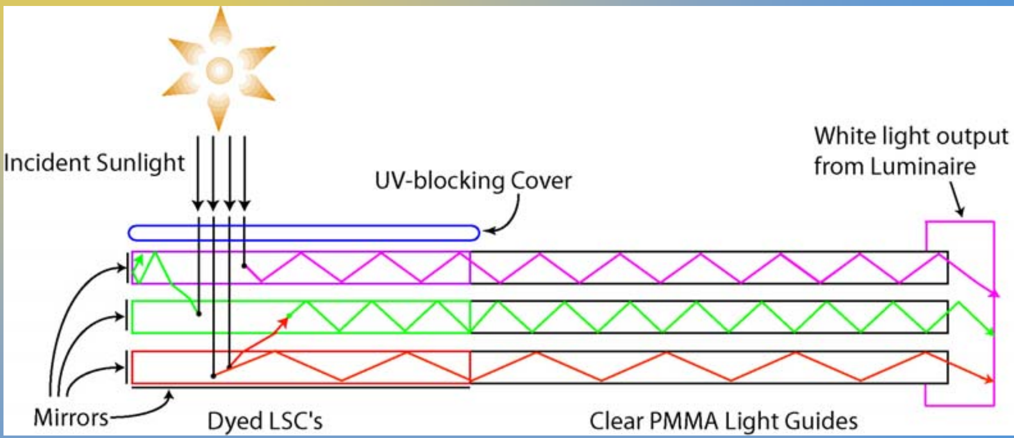
Fluorescent solar concentrator



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The new daylighting system developed at UTS and currently being commercialised in Sydney, Australia.

Measuring LSC-light pipe performance

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Measuring performance - note light is coupled into clear light guides for remote delivery anywhere in a building - only short guide lengths shown in this special experiment here, but can be many metres (to 20 at least) distant.

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Schematic of one type of domestic installation - product coming available late next year from Fluorosolar Systems Pty Ltd - a start up company in Sydney; a web site will soon available for lodgment of interest.

CONCLUSION

NOVEL POLYMERS AND NANO BASED MATERIALS ARE OPENING UP A WHOLE NEW RANGE of COST EFFECTIVE ENERGY EFFICIENT OPTIONS IN BUILDING SYSTEMS

with exciting and attractive new aesthetic features and design options

THANK YOU

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