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Building Integration of Solar Thermal Systems – TU1205 – BISTS

Optical modelling of BISTS (a ray-tracing approach)

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Overview

- Optical modelling
- Ray trace methodology
- Optical efficiency simulations
- Solar radiation collection for a BISTS
- Practical Example :
  - Design a BISTS
  - Model optical performance
  - Predict solar radiation collection for given installation

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Optical modelling can be used to:

- Theoretically predict how the solar radiation interacts with the various BISTS components and determine optical performance of the system
- Determine important attributes such as ***optical efficiency***, ***angular acceptance***, ***flux profiles*** and ***solar radiation collection*** for given installation scenarios

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Remember :

- Optical modelling is a theoretical approach. So It's accuracy will depend on how well the BISTS and solar radiation properties have been simulated and on the assumptions made.
- Experimental characterisation is essential to determining with good/high accuracy the optical performance of a BISTS. However it will do so for a limited set of scenarios. Appropriate combination of modelling and experimental results is the key!
- The output from the optical modelling can be used carry out thermal modelling

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Ray trace methodology

- Sunlight simulated by equally spaced parallel rays incident of the collector aperture
- The solar collector/system is simulated as a collection of components (e.g. the glass aperture, the absorber etc.)
- Its ray is trace from its origin to the next point of intersection with one of the collector components

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Ray trace methodology

- At its intersection with a collector component the appropriate laws are applied to calculated the new direction of the ray and energy exchanges
- Each ray is traced until it reaches the absorber or exits the collector

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BISTS components

- Glass/dielectric such as covers, lens
- Reflectors
- Absorbers

A BISTS can be made from a number of components of different geometries. Each component can have its own properties e.g. reflectance, absorptance, refractive index

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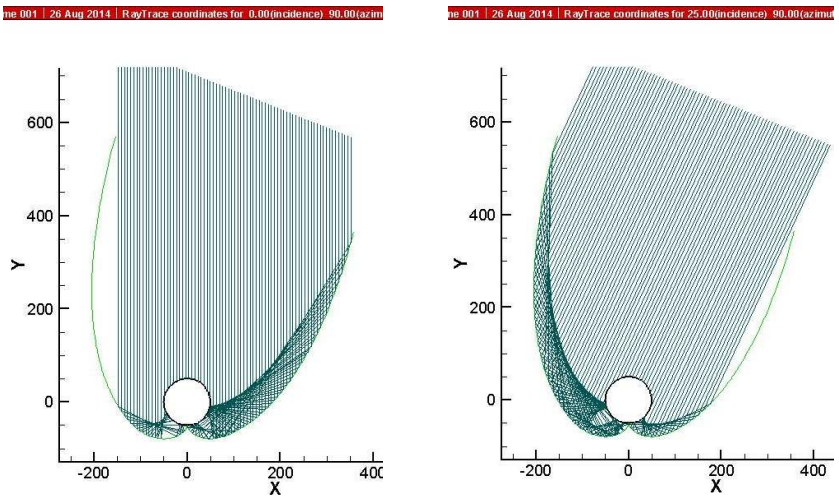

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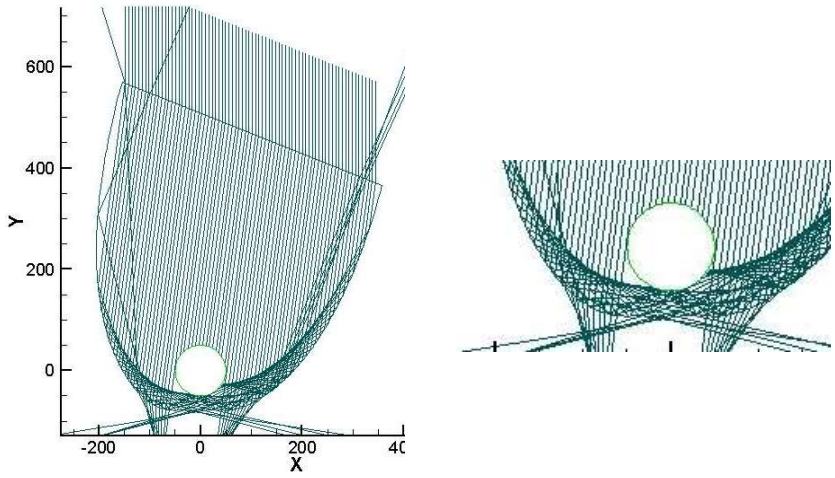

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Optical efficiency

- It defines how good is the BISTS in collecting solar radiation
- For a given incidence angle of solar radiation it can be calculated as the ratio of the energy reaching the absorber over the energy incident on its aperture:

$$n_{opt} = E_{col}/E_{inc}$$

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Optical efficiency

- For some BISTS optical efficiency can be a strong function of the direction of the incident solar radiation. For example BISTS that use concentrators or lens.
- For BISTS with flat geometry (non-concentrating) the optical efficiency also vary with the incidence angle of solar radiation but only due to the effects of reflectance on glass aperture for example.

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Optical efficiency

- To fully optically characterise a BISTS its efficiency needs to be determined for the full range of incidence angles of solar radiation on its aperture

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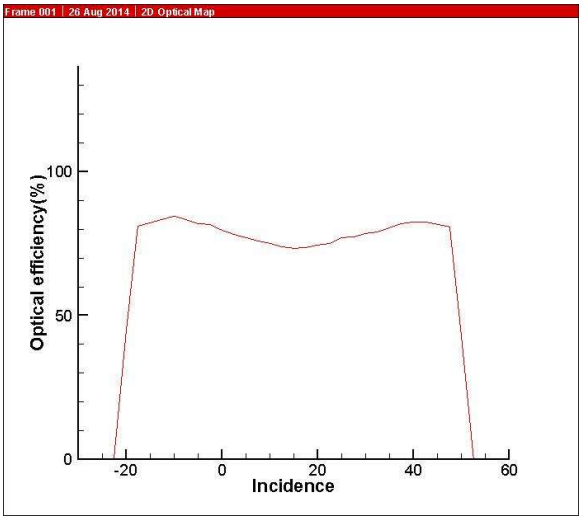

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Flux distribution

- The solar flux distribution on different components of the system can be predicted for given direction of the incidence angle of solar radiation
- This is particularly important for BISTS employing concentrators such as CPC or Fresnel

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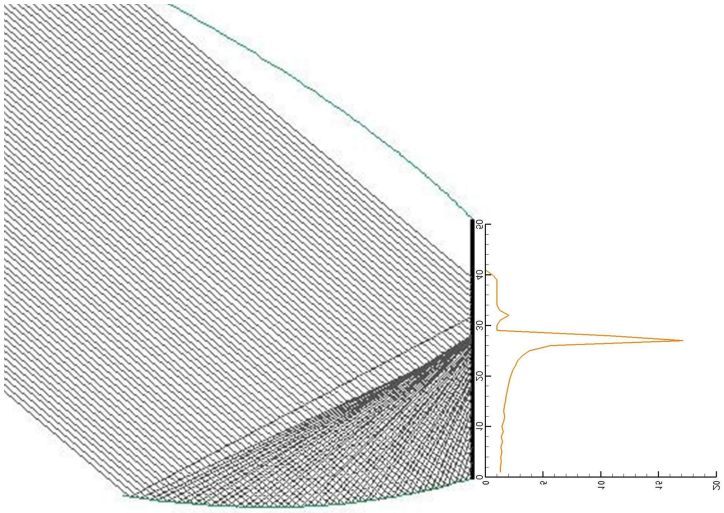

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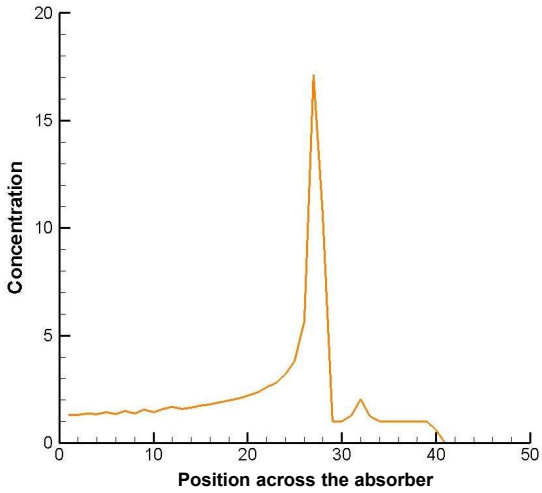

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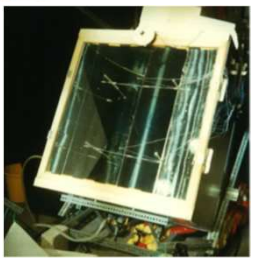
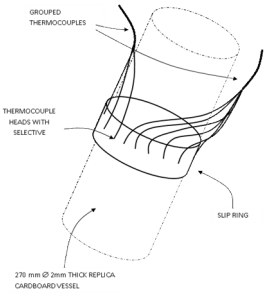
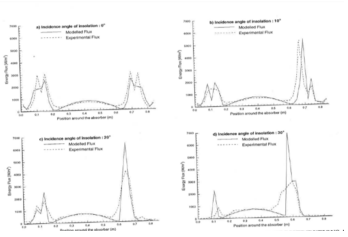
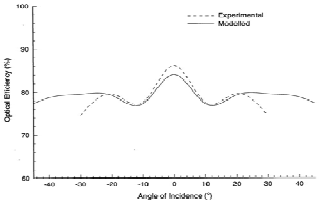


Solar flux distribution







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Solar radiation collection

- Once the optical performance of a BISTS has been determined, solar radiation collection for a given installation can be estimated
- Location (geographic latitude), orientation and tilt angles can be used to define the BISTS installation
- Using hourly solar radiation it is possible to calculate solar radiation collected by the BISTS (hourly, daily, weekly, seasonally, annually)

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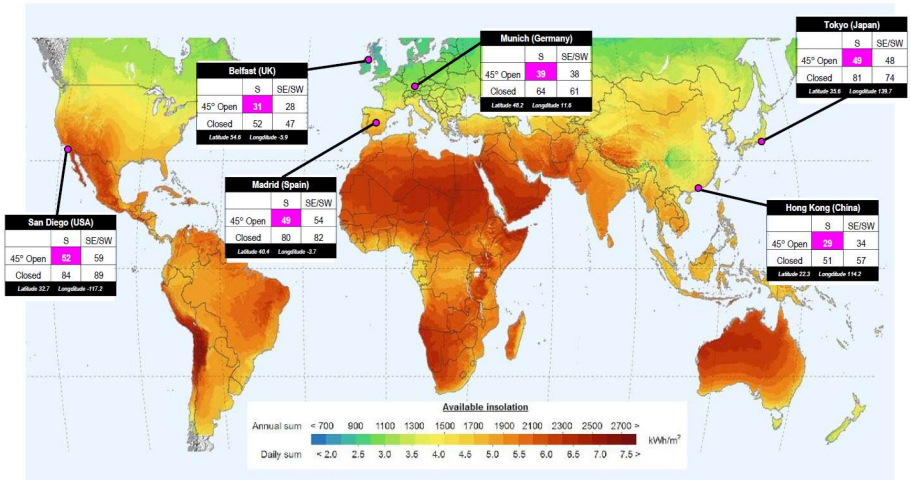
Predicted electrical energy yield per square metre (kWh/m²/year) of blind relative to available insolation



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Practical example

- Conceptualise a BISTS which combines glass/reflector/absorber components
- Optically characterise the BISTS using ray trace
- Assume an installation defined by:
  - ✓ geographic location
  - ✓ orientation and tilt angle (i.e. façade or roof integration)
- Estimate solar radiation collection for a given period

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Do you think you now have a good understanding of

- What optical modelling is and how it can be used to investigate the properties of a BISTS
- The principles of the ray-trace methodology
- Optical performance and solar radiation collection of a BISTS for a give installation

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