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INTEGRATED MULTIFUNCTIONAL GLAZING FOR DYNAMICAL DAYLIGHTING

Annual report 2009

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ABSTRACT

In this project, we study a novel integrated concept and the development of advanced glazing for dynamical daylighting. The novel glazing will combine the functions of daylighting, glare protection, overheating protection in summer and thermal insulation in winter. Novel microstructures will provide redirection of the incident solar radiation, thus providing for chosen angles projection of daylight deep into the room in the same manner as an anilodic mirror-based system, as well as glare protection. The solar gains will be reduced for chosen angles (e.g. for incidence angles in summer at noon). Recently developed solar protection coatings ("M-coatings") will provide the optimized spectral properties of the transmitted sunlight: maximized visible transmission for daylighting and carefully dosed energetic transmission for overheating protection in summer. The solar protection coatings provide simultaneously the low thermal emittance which is necessary in combination with a double glazing in order to ensure thermal insulation in winter. Technological progress will include the improvement of microstructures by selective deposition of micromirrors, easier fabrication of microstructures by sol-gel techniques and the powerful combination solar protection "M" coatings and microstructures.

Starting this project, a set of software was selected in order to model the daylighting and glare protection aspects of the glazing. In order to compare several geometries and assess their performances in a test room, we need to be able to rapidly design multiple structures with variable geometries, model the scattering of light passing through it and the resulting effect in a standard office. For an efficient execution of these 3 steps, we require scripting abilities in the used software. For the modelling part, we want to describe the bidirectional scattering distribution function (BSDF): both in transmission (BTDF) and reflection (BRDF) and this for multiple skies and sun positions. For the daylighting evaluation, we are seeking the illuminance in a plane and the daylighting factors (DLF). The simulations should allow us to identify the determinant criteria for an efficient glazing system.

The choice made in the first weeks then allowed us to rapidly obtain encouraging initial results for the BTDF: the modelled glazing system is redirecting 32.5% of the transmitted light upwards.

Project Goals

In this project we study a novel integrated concept and the development of advanced glazing for dynamical daylighting. The novel glazing will combine several functions:

- Daylighting: redirection of incident radiation and projection of daylight deep into the room, thus reducing electrical lighting.

- Glare protection/visual comfort: angular dependent solar transmission, most effective blocking at incidence angles occurring in summer for direct solar radiation

- Overheating protection in summer: The glazing shall avoid overheating of the building in summer, but provide sufficient natural daylighting and acceptable solar gains in winter.

- Thermal insulation in winter: Double-glazing and the low emissivity properties of the used thin film coating provide thermal insulation in winter.

Novel microstructures will provide redirection of the incident solar radiation, thus providing for chosen angles projection of daylight deep into the room in the same manner as an anilodic mirror-based system, as well as glare protection. The solar gains will be reduced for chosen angles (e.g. for incidence angles in summer at noon). Recently developed solar protection coatings ("M-coatings") will provide the optimized spectral properties of the transmitted sunlight: maximized visible transmission for daylighting and carefully dosed energetic transmission for overheating protection in summer. The solar protection coatings provide simultaneously the low thermal emittance necessary in combination with double-glazing in order to ensure thermal insulation in winter. Technological progress will include the improvement of microstructures by selective deposition of micromirrors, easier fabrication of microstructures by sol-gel techniques and the powerful combination solar protection "M"coatings and microstructures.

The first goal was to select a set of software to model the daylighting and glare protective aspects of the micromirrors in the glazing. The goal is to get a feeling for the most efficient geometrical structure and quantify them.

The second goal was to obtain preliminary results using the numerical modelling.

Acomplished work and results.

The selection of a set of software was done regarding the following criteria and objective:

- We need to be able to easily design multiple 3D structures. This function is not available in every raytracing software. When it is, design tools are very specific (for lens design for example) and it is not always easy to obtain multiple models suiting our needs. However, most software provide us with the possibility to import the design form a CAD (computer aided design) tool such as AutoCAD, Solid Works or Rhino. Furthermore, scripting is possible in most CAD programs so we can easily generate the desired geometries. Since an AutoCAD licence is available on campus and because AutoCAD offers multiple scripting abilities (AutoLisp and Visual Basic Application) we will use it if we are required to design the model outside the chosen raytracing software.
- Model the scattering of light passing through the glazing. We want to describe the bidirectional scattering distribution function (BSDF): both in transmission (BTDF) and reflection (BRDF) and this for multiple skies and sun positions. Since this is the most physical part of the modelling, it would be preferable to use forward raytracing to analyse the behaviour of our system.
- Simulate the resulting effect in a standard office. For the daylighting evaluation, we are seeking the illuminance in a plane and the daylighting factors (DLF). If necessary, this part can be done independently, using a previously calculated BSDF in a more architectural, rendering oriented software such as Radiance (backward raytracing).
- For an efficient, rapid and user-friendly execution of these various steps, we require scripting abilities in the chosen software.

Using these criteria, a search for available software was conducted. The following possibilities were found and tested when a demo version was available:

Software	Import 3D	BSDF	Script-able	Price CHF	Comments: pros and cons.
ASAP	√	√	√	13.000	+ Very advanced: optimisation, support, wide spread use) + serious
LightTools	√	√	√	6.000	+ advanced + architecture oriented - complex use
TracePro	**X**	√	√	12.000	- Impossible to import complex 3D models
Radiance	√	**X**	√	0	+ in situ experience - little physical realism for BSDF.
Photopia	√	√	√	0	+ in situ experience + illuminance oriented - Modelling is done on the base of behavioural materials, not physical properties and raytracing
FRED	√	√	√	6.700	+ advanced tool + serious
PhotonSim	**X**	√	√	0	+ in-house development, full control - the soft still needs to be adapted to the more complex geometry of the glazing. - Uncertainty about the duration to achieve this.

Regarding this comparative study, two solutions were studied in further detail:

- **AutoCAD** for design, **Photopia** for BSDF calculation and daylighting evaluation. There is a lot of in situ experience and the person of contact at LTI Optics is very helpful. Furthermore, Photopia offers solution for the daylighting evaluation and there is no need to use a 3rd software for this part. They provide a very good solution for rapid results and to get a feeling for what will give the best result.
- **FRED** as a single program. It provides scripting abilities for the advanced geometrical construction, the setup and running of simulations and for results analysis. It also offers accurate modelling of physical properties for materials and coatings. Colorimetric analysis, spectral variations of the source and other advanced physical modelling features make it a powerful tool. However it is a complex program and not necessary in a first step. It is a very good solution for the advanced studies of the glazing.

Hence we decided to use Photopia combined with AutoCAD to rapidly get a general feeling about the micromirrors structures.

The first step was then to implement a script to generate the geometries in AutoCAD. This was done in AutoLisp, an extension to AutoCAD allowing us to write Lisp scripts using the AutoCAD commands and some math. The resulting scrip takes the following parameters: spacing, depth, width and shape of micromirrors and window dimensions. It generates a 3D drawing in AutoCAD and saves it as a DXF or DWG drawing that can then be imported in Photopia. The layers in this drawing have the appropriate names to be identified as materials in Photopia.

The second step was then to write a script in Photopia to import the drawings, add a light source, position it correctly (elevation and azimuth) and then set the analysis parameters to generate the BTDF. This was done in Photopia's own script language. The outputs are available as graphs (Fig. 1 and 2) and numerically in a text file.

The initial results obtained with Photopia for the BTDF are encouraging: the modelled glazing system is redirecting 32.5% of transmitted light upwards (Fig. 1 and 2).

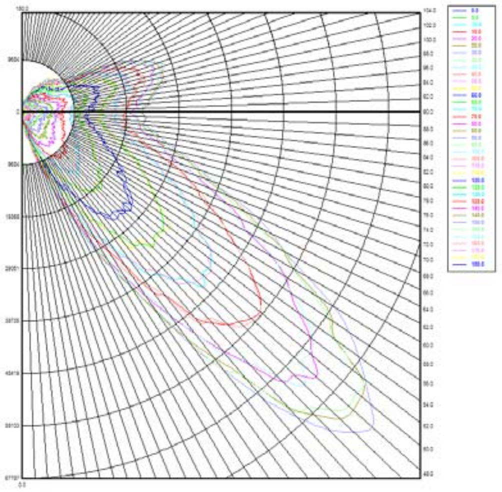

Fig. 1: Polar representation of the angular distribution of the transmitted light. The coloured lines stand for the various horizontal angles.

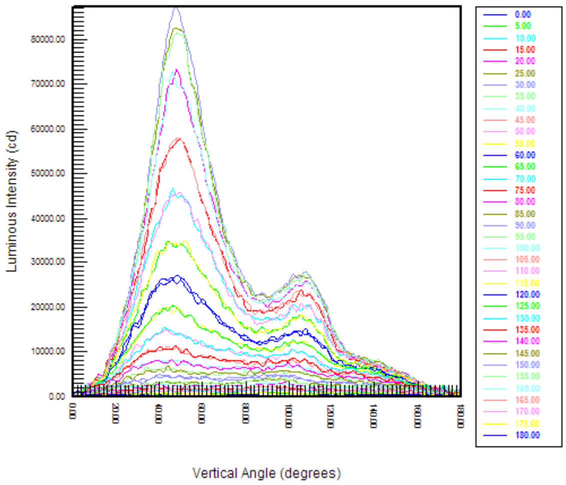

Fig. 2: XY representation of the angular distribution of the transmitted light. The coloured lines stand for the various horizontal angles.

2009 Evaluation

A competent candidate was identified and hired as collaborator at LESO-PB. André Kostro had done his Masters thesis in our group, on the topic *PhotonSim: Development of a Monte Carlo raytracing software for the simulation of solar concentrators.* He received the ABB innovation award 2007 for this work.

- The framework for computer simulation defined, suitable software tools were identified and tested.
- The first raytracing simulations of microstructured glazing were performed with promising results.

Outlook for 2010

- Study specifications for microstructures for the different building types, design of novel microstructures by computer simulations and optimisation.
- Simulate the daylighting impact of the glasses.
- Improve existing microstructures by selective evaporation of mirror coatings (creating micromirrors on transparent microstructures).
- Creation novel microstructures by lithographic techniques, sol-gel techniques with subsequent embossing, and subsequent selective evaporation of mirror coatings.
- Optically characterize the novel glazing by photogoniometry (special equipment LESO).

National Collaborations

- Collaboration with the research group of Prof. Peter Oelhafen, Institute of Physics, University of Basel
- Access to lithographic techniques for microstructuring at EPFL-CMI
- Access to electron microscopes and to the facilities of TEM sample preparation at the Interdepartmental Center of Electron Microscopy EPFL-CIME
- Collaboration with Dr. Rosendo Sanjines and Henry Jotterand, Laboratory of Thin Films Physics, Prof. Laszlo Forro, Institute of Complex Matter Physics, EPFL. Experiments on magnetron sputtering and X-ray diffraction analysis
- The research group of Prof. Libero Zuppiroli (LOMM at EPFL) provides access to their new ellipsometer

International Collaboration

Collaboration with Polymer Competence Centre PCCL, group Dr. Dieter Gruber, University of Leoben, Austria, on theory and modelling of thin film optics

Industry Contacts

- Partnership with SWISSINSO: technology transfer of magnetron sputtering and research on novel coatings for innovative solar collector glazing
- Collaboration with GLAS TRÖSCH for production of prototype glazing by industrial scale magnetron sputtering
- ASULAB (SWATCH GROUP) donated equipment for vacuum deposition of thin films, suitable for multilayer deposition
- CTI project on sol-gel deposition of nanostructured selective solar absorber coatings in collaboration with the Swiss solar collector manufacturer ENERGIE SOLAIRE SA

Invited talk

A. Schüler, ***Advanced nanostructured coatings for innovative solar facade glazing***, SwissINSO Open House at EPFL, November 3rd, 2009