Bringing colours to solar collectors: a contribution to an increased building “integrability”

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ABSTRACT
One main obstacle to facade integration of solar thermal collectors lies in the formal characteristics and low flexibility of available products. Major problems are the black and irregular appearance of their absorbers, their low dimensional flexibility and large size at the façade scale, and finally the lack of dummy elements. This paper presents a revolutionary though simple solution to all these problems, consisting in a novel coloured glass, able to mask absorber and piping while letting the solar energy pass through.
Different colours can be produced and combined with different diffusing surface treatments on the glass outer side, finally offering a broad palette of novel glazing.
These resulting glazing not only hide the black colour of the absorber and its imperfections, but can also be used as facade cladding on the non exposed areas of the building envelope, opening the way to the concept of active solar facades and offering a new level of freedom to architects.

Keywords: Architectural integration, Colour, Multifunctionality, Solar collectors, Thin film

1. INTRODUCTION
Façade integration of solar thermal collectors is still very rare, even though it would greatly increase the potential area available for solar thermal installations. One main obstacle to façade use can be seen in the difficulty to architecturally integrate presently available collectors which have not been developed with this implementation in mind.
Fundamental integration issues lie in the black and irregular appearance of the collector absorber visible through the transparent glazing, in the low dimensional flexibility of available products and in the lack of dummies* (*non active elements having the same appearance, and able to complete the façade system. Dummies are common in the photovoltaic field) (Fig.1). Such specificities are a real barrier to façade integration, especially if we consider the size of collector fields at the façade scale: easily a third of the whole façade area!
Finding novel solutions is then urgent considering the high interest of façade applications for solar heat production, especially when aiming at high solar fractions,
The work presented here is one of the possible answers, and is based on the new vision of solar collectors seen as multifunctional building elements for façade cladding and heat collection.

2. THE COLOUR IDEA

2.1 Coloring the absorber
One first idea to overcome the problem of the absorbers’ black colour, imposed to maximize the solar energy absorption, is to choose a lighter colour, thus accepting some efficiency reduction. This approach has been taken by some manufacturers, but the colours remain still very dark (dark blue, dark green, brownish reflection). Another approach is to use TISS (thickness Insensitive Spectrally Selective) paints, which offer a much broader colour palette, but at the cost of a higher efficiency loss. These approaches have either limited coloured improvement, or significant efficiency impact. Moreover, they don’t solve the problems of absorber surface irregularities or visible piping, nor the missing dummies.

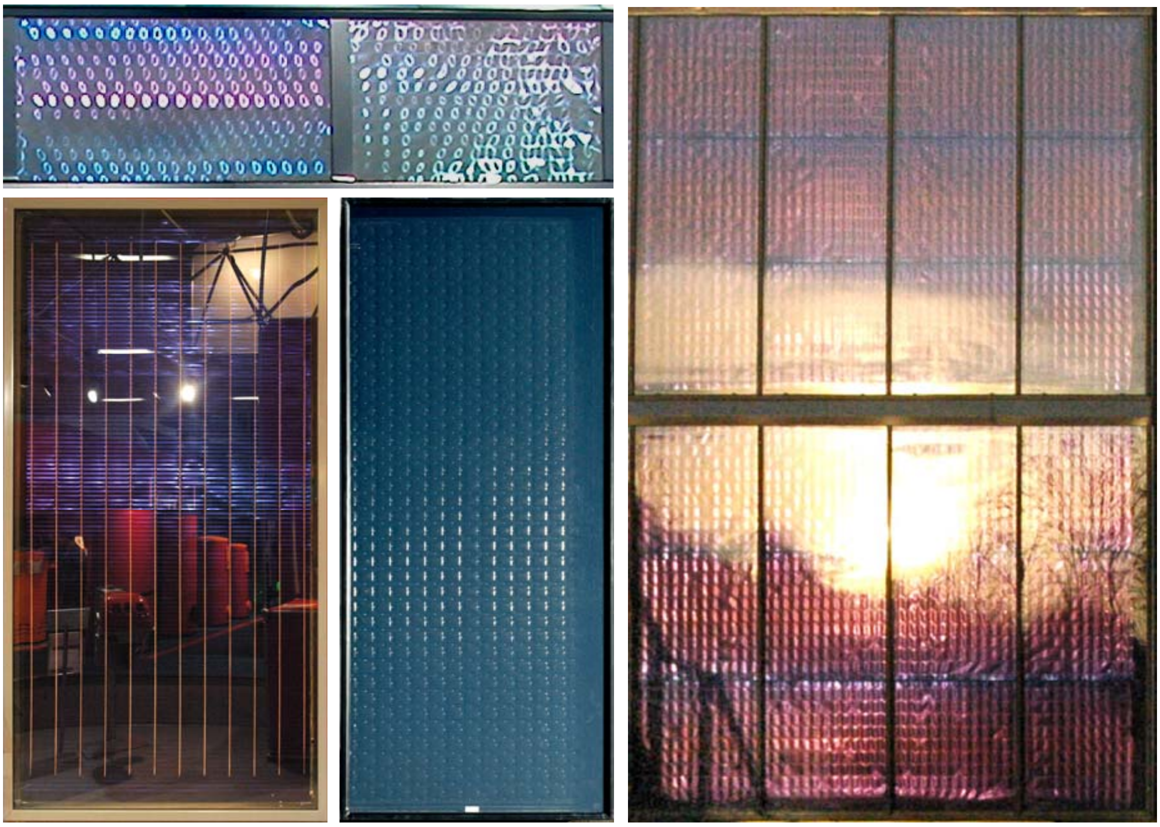

Fig.1: Standard glazed flat plate collectors: absorber surface imperfections, black colour and welding marks are visible through the glazing

2.2 Coloring the glass

One way to solve all these problems is to provide a coloured front glass able to hide the absorber and the piping behind. This new glass has to be non-transparent in the visible range, but must still let the rest of the solar spectrum reach the absorber to keep the solar collector working. As the visible part represents only a small portion of the sun's energy, the collector performances will be only marginally affected. The proposed solution consists in combining two different treatments applied to the collector glass. On the inner side of the glass is deposited a coloured filter reflecting only a narrow band of energy in the visible range, on the outside a traditional diffusing treatment (Fig. 2).

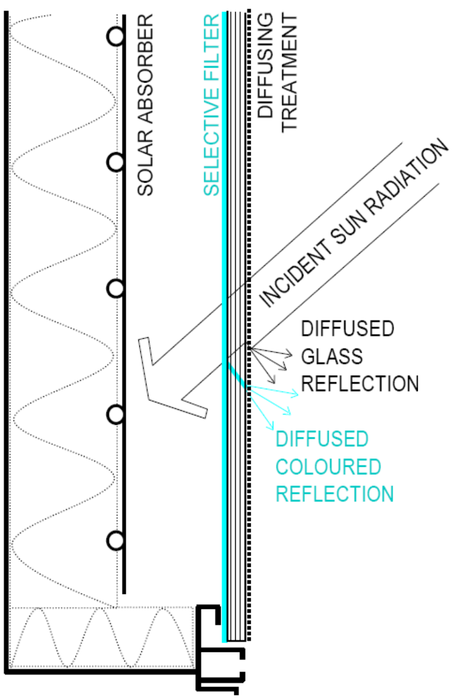

Fig. 2: LESO Coloured glazing working principle: selective filter in, diffusing treatment out.

2.3 Thin film filters

The technology producing the desired colour effect is based on thin films interference filters, using successive layers of TiO_2 and SiO_2 deposited by magnetron sputtering. A large palette of colours can be obtained by varying thickness and/or number of layers.

As the reflected part of the spectrum is narrow, it induces only low losses, but produces a visible colour, determined by the position of the reflected peak in the photopic range (Fig. 3).

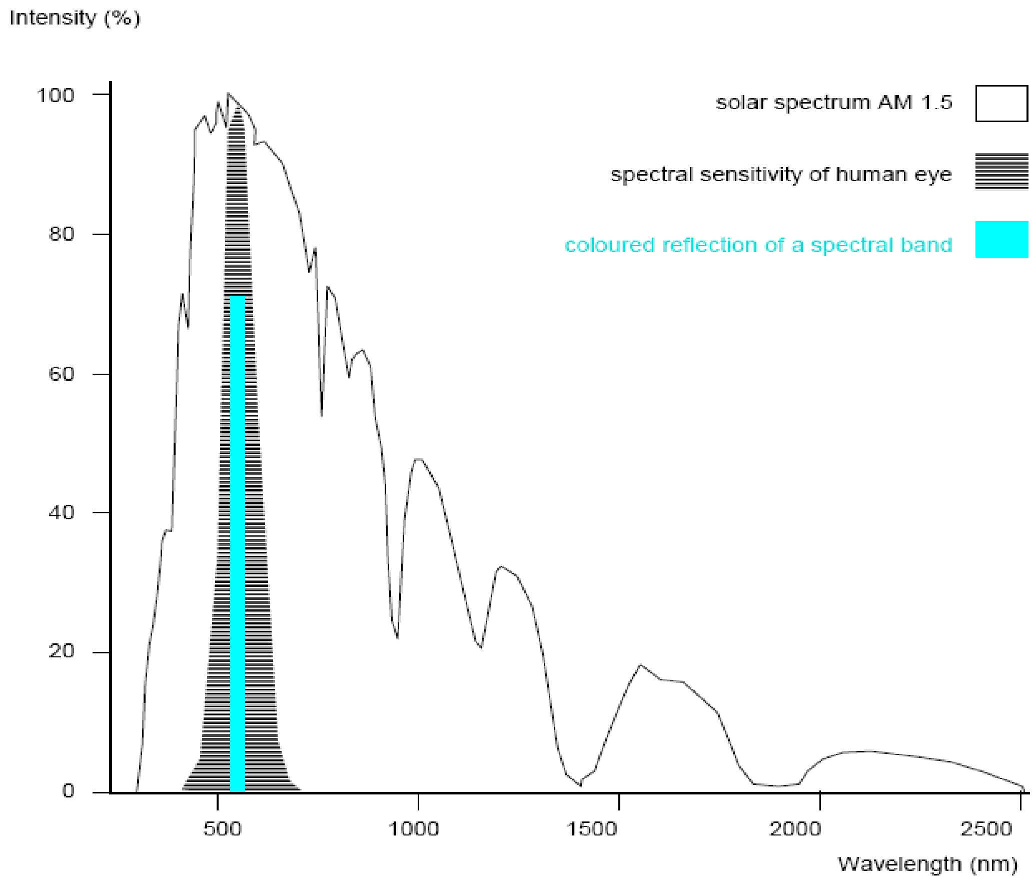

Fig 3: Spectral characteristics of the interference selective filters: only a very small part of the solar spectrum in the visible range is reflected back by the filter (4-6 %. The rest of the solar spectrum can reach the absorber.

The result is a strong coloured reflection from the treated glass, masking any dark elements behind it, but needing direct lighting to work (no reflection in case of shadows) (Fig. 4).

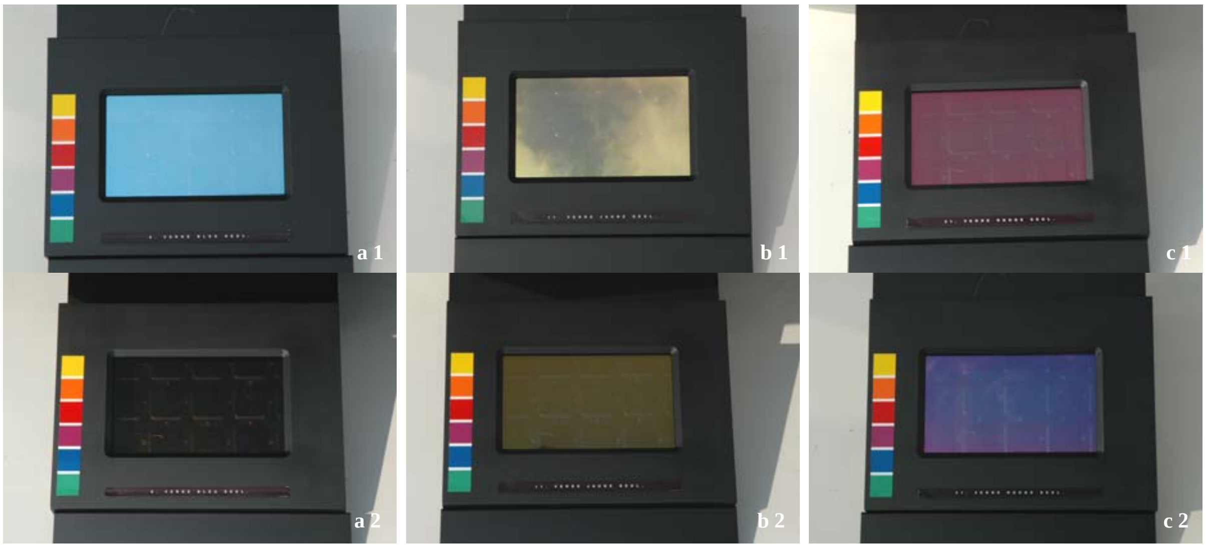

Fig.4: Demonstration box showing the effect of sun (up) and shadow (down) on different colour samples: a1-a2: blue coating; b1-b2: yellow coating; c1-c2: red coating

Moreover, due to the very principle of these filters (interferences), some colours can present an angle dependency that could limit their use in an architectural environment. Both these problems are overcome by the additional diffusing treatment applied to the outer side of the glass.

2.3.1 Diffusing treatments

Some collector manufacturers are already using diffusing treatments (acid etching, sandblasting) or structured glass (pyramids, bubbles…) as a strategy to smoothen their absorbers' visual defects. Combining the coloured filters with one of these diffusing treatments proved to be the ideal solution to achieve the desired colour/masking effects under all weather conditions, while reducing the angle dependency of the colour and avoiding the unpleasant mirror aspect of the glass.
Fig. 2 shows the principle of the double treatment for the front and back sides of the glass. The successive results on the absorber visibility are shown with the help of a demonstration box mimicking the structure of a solar collector (Fig 5a to Fig 5c).

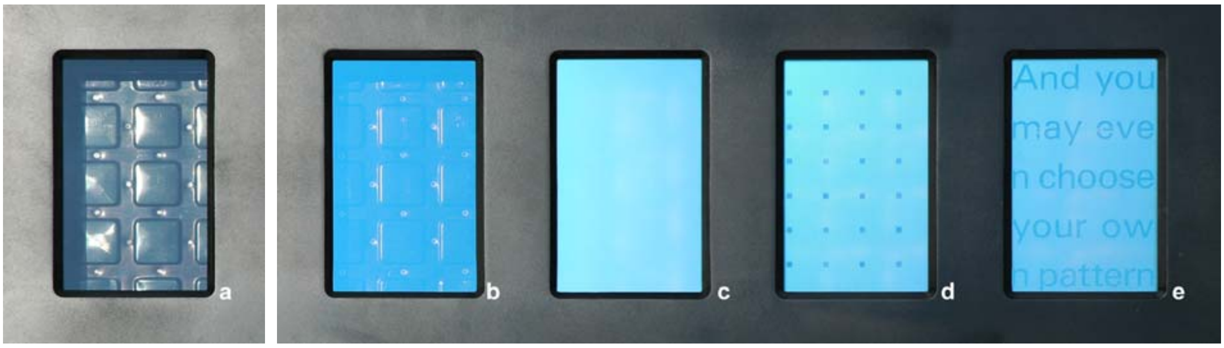

Fig. 5: "Demobande" showing blue coated glasses with different diffusing treatments patterns and resulting different levels of absorber visibility: Fig. 5 a: untreated white glass, with the absorber highly visible; Fig. 5 b: glass coated with the interference filter (blue hue), with the same absorber partly masked; Fig. 5 c,d,e shows the final glass, with interference filter and a standard acid etching (invisible absorber behind)

Added to the colour choice, the possibility to choose from different diffusing treatments (structured or acid etched glass) greatly widens the options for the collectors' appearance. Structured glass already comes in a reasonably wide range of standard finishing, and acid etching further offers the possibility to customise the treatment selecting on demand patterns (Fig. 5d) or even text (Fig.5e) to suit customers' design (Fig.6).

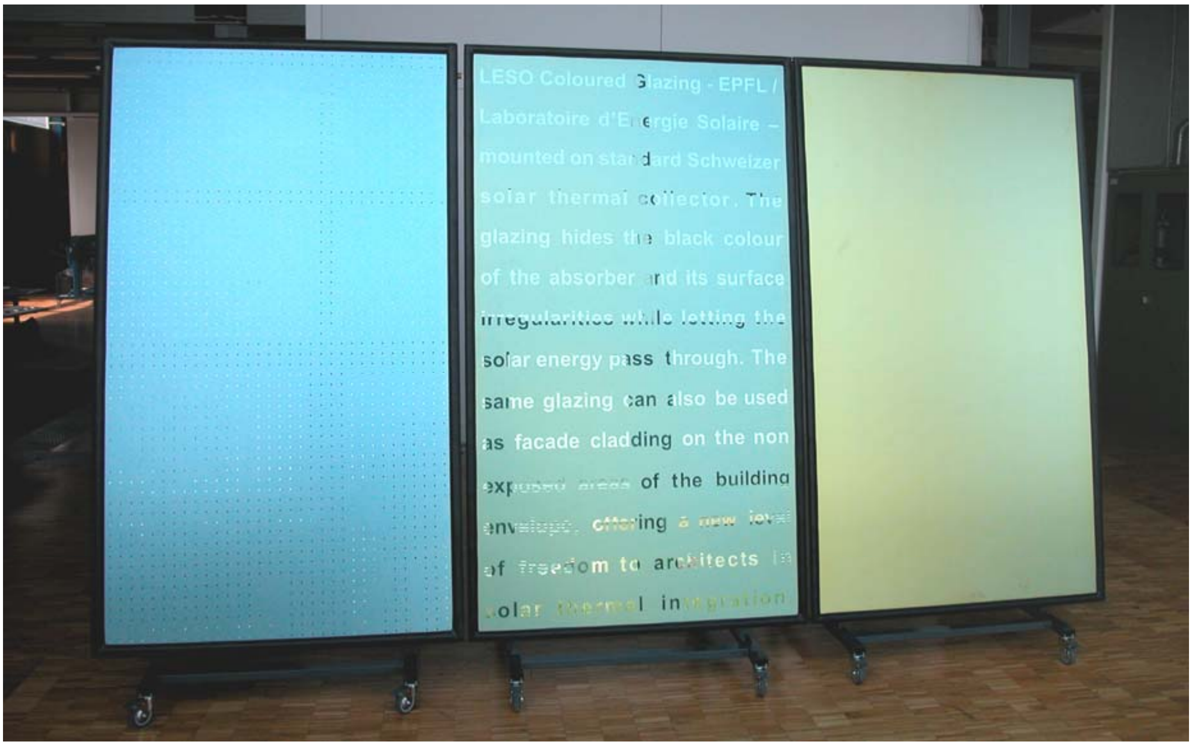

Fig.6: Three resulting up scaled glazing mounted on standard market collectors (real picture). From left to right: Blue coating plus manual acid etching with regular pattern resulting from non etched small squares; green coating plus manual acid etching with personalized text pattern; yellow coating plus homogeneous acid etching.

2.3.2 Use in architecture

Solar collectors equipped with these glasses become multifunctional building elements, serving as façade cladding and heat collectors. When mounted in front of collectors or dark background, the appearance of these treated glasses is similar to the one of coloured glasses used in standard claddings to protect the insulation. This gives a crucial new freedom to architects, as there is no longer a visual difference between areas equipped with collectors and areas with only glass covered insulation. Therefore the collectors areas can be dimensioned and positioned based only on best exposed areas of the façade and amount of heat to be produced.

2.4 Application example

The following simulation illustrates the possibilities offered by the new glazing described above. Starting from an existing building situation, recently retrofitted using standard coloured glasses to protect the newly applied insulation (Fig. 7.a), an analysis of the best exposed areas and the needed amount of collectors has been conducted (Fig. 7.b). The building appearance resulting from the implementation of added solar collectors and new glasses (small squares pattern) as insulation protection has been simulated (Fig.7.c), showing the feasibility of such operation. Moreover the amount of well exposed areas to be equipped with collectors can be freely chosen according only to heat needs.

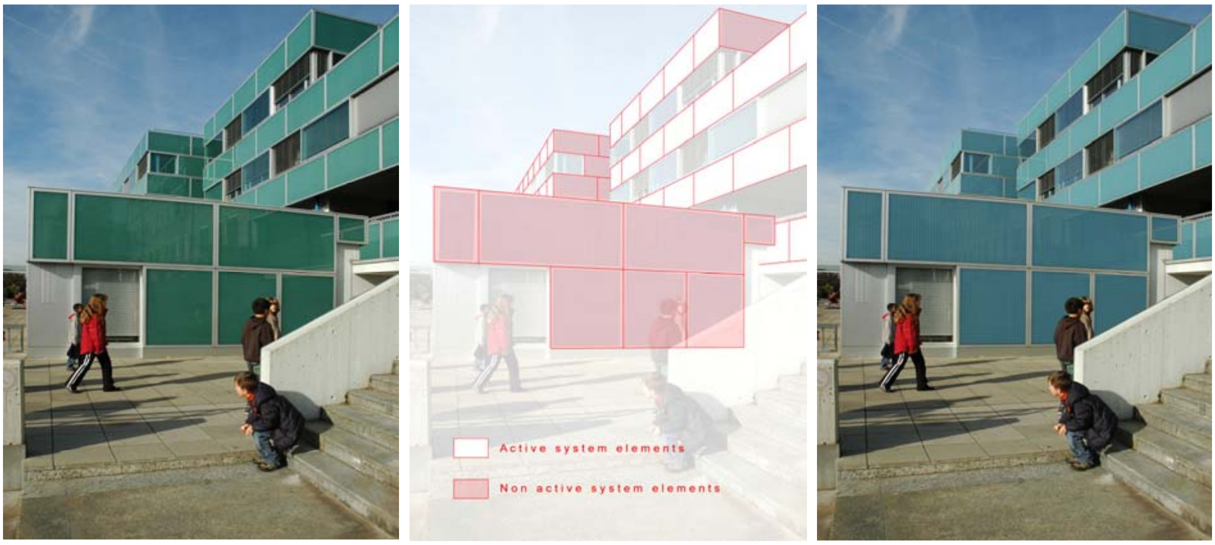

Fig 7.a (left): Primary School in Pully, CH: building renovation (Devanthéry & Lamunière 1998-99) using coloured glass cladding over opaque envelope parts; Fig. 7.b (center): The standard glazing could be replaced by the new glazing. In the exposed facade areas they would be used as collector glazing and in the non exposed ones they would be used as facade cladding over insulation.Fig.7.c (right): Integration simulation, using a blue coated acid etched glazing with small squares pattern. The building still looks very similar to the original: the facades are homogeneous, and the solar system doesn't affect the building appearance.

4. CONCLUSIONS

Integration of solar thermal collectors into facades will soon become crucial as one answer to the growing demand of solar energy in buildings. As the present situation shows, the general very low quality of the existing collectors' integration limits their use to a small portion of the building stock. The newly developed glazing aims at helping to unlock this situation by modifying the global aspect of solar collectors: the black absorber and its visual defects can be hidden by a coloured glass, whose texture can be used from an architectural point of view. As the same glass can cover active and non active areas, the architect will be free to choose a coherent part of the facade to be clad, and equip only the thermally needed portion with absorbers.

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