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Design and evaluation of a detection system for external water condensation on low *U*-value windows

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Abstract

A laser detection system was developed and mounted in Uppsala, Sweden. A blinking commercial laser was set up so that the beam hit the surface to examine. A photodiode detects part of the beam, either the part that passes through the glass or the part that is reflected by the glass. By means of several lasers and corresponding photodiodes, several panes (either as loose samples or as fully installed windows) can be checked simultaneously as to whether there is condensed water on the surface or not. The system can operate in two modes; transmission or reflection mode. The reflection mode has the advantage that all the measurement equipment can be kept indoors, but the transmission mode gives a clearer result. It might also be easier to align the detection system for the transmission mode. The physical property that is measured is the visibility through the sample (window), which is also the most interesting parameter.

Keywords: External water condensation; Energy efficient windows; Water detection; Dew detection

1. Introduction

Low-emissivity and solar control coatings in windows can considerably reduce the energy needed for heating and cooling buildings. The heat conductance of such windows, the *U*-value, can be as low as 1 W/m^2 K. For the glazed area of a window, values down to 0.5 W/m^2 K can be realised. In some climates, especially in the northern parts of Europe, where the radiative cooling towards a clear night sky can be high, this has led to a new phenomenon; external water condensation on windows. Such condensation forms small drops across the outside surface, which make it foggy and thus obstruct the view through the window. The phenomenon is physically related to the formation of condensation on the inside of poorly insulated windows [1,2], but cannot for obvious reasons be easily cleared away. In Sweden it has happened that window customers have been advised not to install the best possible window from an energy perspective in order to avoid this problem [3].

A pre-study of the influence of different coatings on the dew formation is presented in [4]. This paper presents results from tests with a test box with internal heating facilities, which was designed to monitor the occurrence of external condensation using a light beam and a detector. The light beam is scattered by the condensation layer and the detector signal is thus affected. The test facility allows three small glass panes (30 cm × 30 cm) to be tested simultaneously.

Previous systems have been developed to measure the amount of water vapour in air based on high-resolution absorption spectroscopy with tunable diode lasers, see for instance [5]. To detect dew on a glass surface, measurement equipment has been developed which measures the change in surface resistance as dew formation takes place, as in [6]. Other techniques have been developed to measure and quantify dew on crops and foliage [7]. A similar detection technique is also used to measure the dew point of humid air. To our knowledge, however, no system similar to ours has been developed and documented for detection of external water condensation on windows in buildings.

It is a simple system which in principle measures the visibility through the window, a parameter of high importance for the building occupants. Since the clear night sky is extremely hard to simulate in a laboratory environment, all tests have been conducted outdoors under the real night sky.

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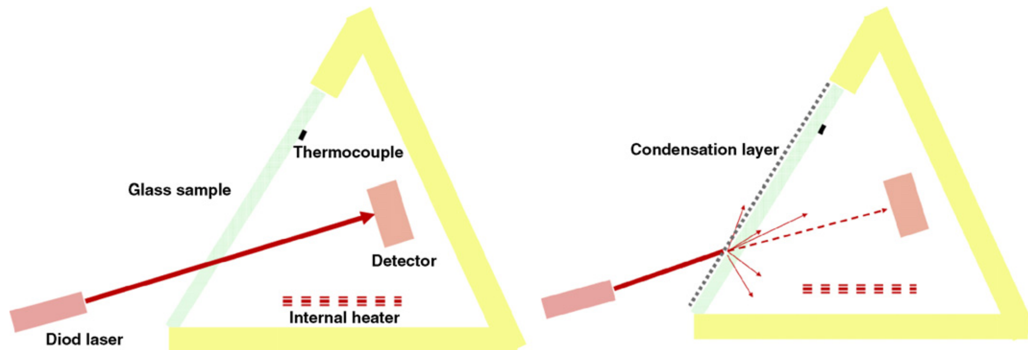

Fig. 1. Sample Test Box. Left subfigure shows the test box when there is no condensation present and the right subfigure shows the test box when there is condensation on the glass sample.

The object of this study has been to test and evaluate the simple detection system that can be used to measure the occurrence of water condensation on small test samples as well as on real windows. Previous studies have been based on calculations [8–12]. Real comparative tests on full size windows with different external coatings would be very time consuming and expensive. With the small test box presented here, windows with different U-values can be simulated and several surfaces can be tested and evaluated simultaneously. Moreover, the same detection principle can be used on real windows in order to monitor occurrence of condensation in a real building.

2. Measurement equipment

The measurement system we have designed is based on the same principle as that of the human eye. A light beam from a source outside the window is scattered by condensation on the window and does not reach the eye un-deflected. Thus objects are seen more or less blurred by the eye. In our simple system the source is a diode laser and the eye a silicon detector. The detector was placed inside a polystyrene box and the laser was supported on an adjustable fixture outside the box. The design can be seen in Fig. 1. The walls of the box were made of 30 mm polystyrene with a U-value of around 1 W/m^2 K. Thus around half of the heat dissipated by the small electric heater inside the box escapes through the glass test panes, which in our case were single panes with a U-value of 5.9 W/m^2 K. The front surface with the test panes is tilted 27° from the horizontal plane, thus providing a free clear sky for the tested surfaces [13]. The main reason for this is to “force” condensation to occur more frequently than on a normal window for comparative purposes. The lasers were positioned at a low angle in order not to obstruct the viewing angle against the sky. When there is no condensation on the glass as in the left subfigure of Fig. 1 each laser beam goes straight through its glass sample and hits its detector. When there is condensation, the beam is scattered and the light does not hit the detector. This is indicated in the right subfigure of Fig. 1. A photograph of the test box is shown in Fig. 2. On the left-hand side of the box, meters for outside temperature and humidity are shown. The meters are screened from the sky and ground. The three detectors were positioned inside a small box with an entry hole for the laser beam to minimize the amount of stray light reaching the detector. A photograph of the detector box can be seen in Fig. 3.

Fig. 2. Picture of Sample Test Box. Three glass samples are mounted on the front. The lasers, each one pointing at a glass surface, are on the board in front of the box. The three detectors are inside the box.

The temperature of each glass pane was measured by a thermocouple positioned on the inner surface of each test pane. The temperature of interest for dew formation is the temper-

Fig. 3. Close-up of one of the detectors. The detector is shielded with a box so that as little stray light as possible reaches the detector.