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# Poster Abstract: Data Communication using Switchable Privacy Glass

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## ABSTRACT

Switchable privacy glass can electronically change its state between opaque and transparent. In this work, we propose to exploit the electronic configurability of switchable glass to modulate natural light, which can be demodulated by a nearby receiver with light sensing capability to realise data communication over natural light. A key advantage is that no energy is used to generate light, as it simply modulates the existing light in the nature. We demonstrate that the proposed data communication using switchable glass modulation can achieve 33.33 bits per second communication with a bit rate below 1% under a wide range of ambient luminance.

## KEYWORDS

Switchable Glass, Natural Light Communication, Visible Light Communication.

## 1 INTRODUCTION

Switchable glass can electronically switch the state of the glass from opaque to transparent by simply applying a voltage to it [1]. By removing the voltage, the glass can be brought back to its opaque state [2]. In this work, we propose to convert a switchable glass into a data transmitter that can transmit a digital stream by controlling the voltage and thus modulating the light emitting states of the glass. Then any nearby object with light sensing capability can demodulate the light and hence act as a receiver.

In this work, we implement the proposed modulation/demodulation techniques in a complete end-to-end prototype, demonstrate that the proposed concept is feasible and achieve a data rate of 33.33 bits per second with a bit rate rate below 1% under a wide range of ambient luminance.

## 2 SWITCHABLE GLASS PRELIMINARY

As shown in Figure 1, a switchable glass is made up of liquid crystal particles. When there is no voltage applied, the liquid crystal particles are distributed throughout the polymer matrix randomly and block most of the light. When a rated voltage is applied across the glass, the liquid crystal particles orient themselves to allow light pass through them making the glass transparent.

(a) voltage applied (b) no voltage

**Figure 1: Appearance of switchable glass with/without voltage applied**

### 2.1 Voltage Control Circuit

The supplied switch only has two voltage values, 0V (opaque) and 57.7 (transparent). To experiment with different voltage values, we design and build our own circuit as shown in Figure 2. We connect two MOSFETs in serial back to back and connect a diode in parallel of each for rectification. When we output a 5V DC on gates of MOSFETs, there is a closed circuit between MOSFETs and a turn-on voltage applied on glass is 57.7V. When there is no voltage applied on MOSFETs, the circuit is open and turn-off voltage applied on glass. We obtain different turn-off voltages by applying different combinations of capacitors C1 and C2, so that the turn-off voltage cannot be an arbitrary value.

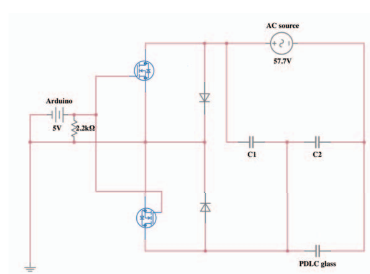


**Figure 2: Diagram of voltage control circuit**

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## 2.2 Signal Transition Analysis

From Figure 3, we make the following observations: low-to-high transition is very quick, only about 5ms, but high-to-low transition is much slower and depends on the turn-off voltage applied. Specifically, the higher the turn- off voltage, the higher the steady-state value, and the quicker the signal reaches its steady-state value. If quicker high-to-low transition is desired, which is required for achieving higher data rates, then a higher turn- off voltage should be selected.

We also notice that the signal is noisy behaving like a sine wave. The presence of noise means that for high turn-off voltage we may not get a clear transition from low-to-high or high-to-low, which could make it challenging for synchronising the transmitter and the receiver, so that turn-off voltage of 26.8V provides higher data rates but sacrifices reliability. To balance between short symbol duration (high data rate) and synchronisation (reliability), we choose 7.3V as the turn-off voltage.

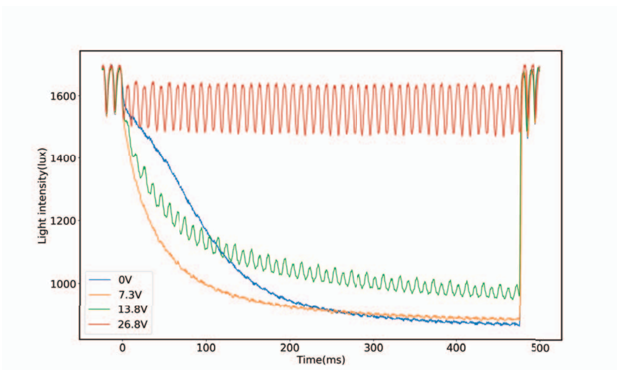


**Figure 3: High-to-low and low-to-high transitions of received light signals with different turn-off voltages**

## 3 ON-OFF MODULATION AND DEMODULATION

### 3.1 modulation

Since PDLC glass always need a period of time for state transformation, we employ On-Off keying for modulation. We assign ON (transparent) and OFF (opaque) with data bits '1' and '0' respectively. A preamble is necessary for receiver to collect mean values and slope of light signal of both states for demodulation. We set preamble as '1010101010' so that we can collect value of '1' and '0' for five times to be more accurate. Another effect of preamble is to determine when the transmission start, receiver can detect pattern of preamble then start demodulating.

### 3.2 demodulation

As we have got preamble already, we propose to calculate the mean value and slope for each '1' and '0' in it. However, the original symbol has too much background noise, we have to implement a low pass filter before calculating slopes. After filter, the inflection may be advanced or delayed slightly, so we discard first 30% and last 30% values for each duration and just calculate the slope of middle part. Then we get $meanThreshold = \frac{min(Mean_1)+max(Mean_0)}{2}$ and $slopeThreshold = \frac{min(Slope_1)+max(Slope_0)}{2}$. At first, we determine each symbol by comparing its mean value with $meanThreshold$, it is called mean value demodulation. Then we improve our algorithm by comparing both $meanThreshold$ and $slopeThreshold$ called slope demodulation. An example of demodulation is shown in Figure 4.

**Algorithm 1** Slope demodulation

**if** *slope* < *slopeThreshold* **then**
  **return** bit '0'
**if** *slope* >= *slopeThreshold* **then**
  **if** *meanValue* > *meanThreshold* **then**
    **return** bit '1'
  **else**
    **return** bit '0'

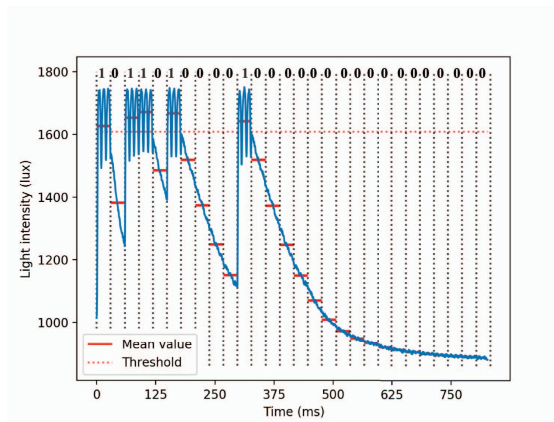


**Figure 4: Received signals and mean values of each of them**

## 4 EVALUATION

In each experiment, we use 7.3V as turn-off voltage and 30ms as symbol duration. Transmitter generates and transmits 1000 random bits, repeats 10 times, which are 10000 bits in total. We apply both demodulation methods and compared against the transmitted bit to compute the total Bit Error Rate (BER). From table **??**, BER decreases slightly when external luminance increases and slope demodulation performs better, it could reduce BER by 30% from mean value demodulation. Thus, we have experimentally demonstrated the feasibility of modulating natural light with switchable glass. We have used ON-OFF modulation to achieve a data rate of 33.3 bps while keeping the BER below 1%.

## REFERENCES


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[2] Kaufui V Wong and Richard Chan. 2014. Smart glass and its potential in energy savings. *Journal of Energy Resources Technology* 136, 1 (2014), 012002.