Optical Measurements and Evaluations of Switchable Privacy Displays

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Switchable Privacy Displays (SPD) can improve the use of e.g. mobile devices and codriver displays in cars. In 'private' mode, spying in public spaces is prevented and drivers are not distracted. We performed numerous measurements to extract the relevant (key) parameters, such as luminance vs. viewing angle.

1 Introduction

Data security is in high demand, for example for PIN input at ATMs. Fixed privacy is rarely used in mobile devices as it is inconvenient. Switchable privacy enables either multiple viewers (public) or a single on-axis viewer (private); see Fig. 1. Details on use and SPD technologies are described in [1] and [2].

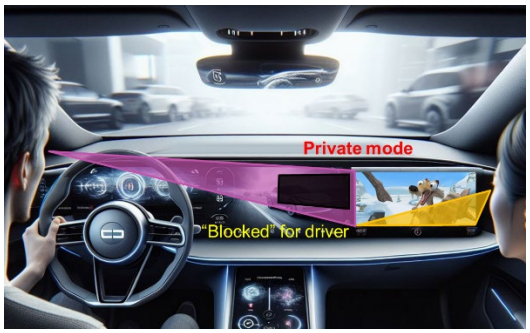

Fig. 1 *Example of a Switchable Privacy Displays (SPD).*

2 Definitions in a Car and SPD Parameters

The geometry of SPDs in cars can be very different; a typical example is shown in Fig. 2, see also [1].

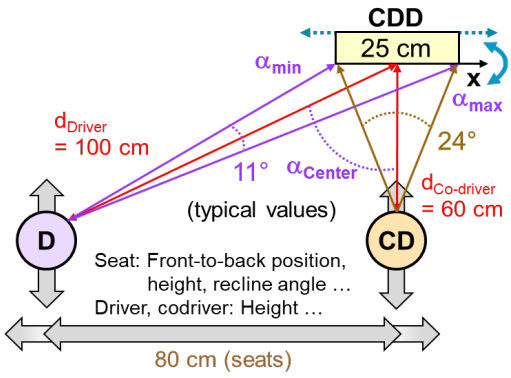

Fig. 2 *Typical geometric conditions for SPDs in cars.*

Fig. 3 shows a typical measurement result for the luminance over the horizontal angle α. Relative values and a divided vertical axis are used here for clarity. This figure is employed for the definition of key performance parameters (KPP) of SPDs marked by the labels 'O' and are defined below.

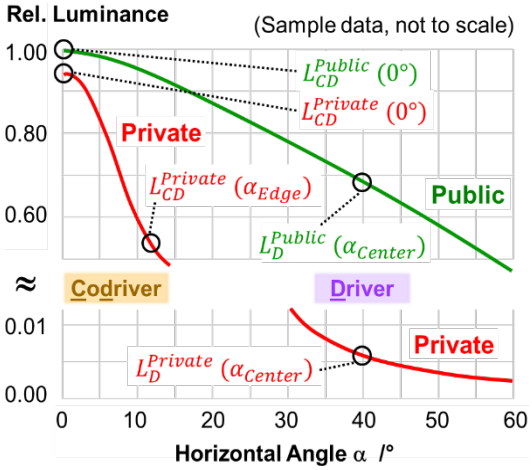

Fig. 3 *Most relevant parameters for SPDs in automotive.*

(1) Switching ratio SR is defined as the ratio of the luminance for the driver at the horizontal angle α (usually referring to the center of the display; however, the angles for the left or right edge can also be important) divided by the luminance for the driver at an on-axis view (α = 0°) in private mode. This parameter classifies the 'blocking' performance of the SPD. SR should be as low as possible to avoid driver distraction.

(2) Switching ratio for the driver SRD at the center (α_{Center}) of the display defined as ratio of the luminance for the driver in private mode divided by the luminance in public mode. This parameter describes the "blocking" performance of an SPD film or layer (not backlight). SRD should be also as low as possible.

(3) Luminance degradation ratio of LRCD for the codriver at α = 0° when switching between private and public mode. This value describes how closely Dual Backlight LCDs are adjusted, or the efficiency of the SPD film or layer.

(4) Luminance ratio LDCD defined by the luminance values for driver and codriver in public mode. This is a 'comfort' value of the perceived brightness of the driver and should be high.

(5) Uniformity UCD of the luminance for the codriver in private mode expressed as luminance

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ratio of α_{Edge} vs. $\alpha = 0°$. The threshold value can be derived from Contrast Sensitivity Function (CSF) assuming a Field of View (FOV) of 2x α_{Edge} and the typical observer distance (e.g. 60 cm) via cycles per degree (e.g. 0.005 cpd).

The corresponding formulas are as follows:

$$SR(\alpha_{Center}) = 100\% \frac{L_D^{Private}(\alpha_{Center})}{L_{CD}^{Private}(\alpha=0°)} \quad (1)$$

$$SRD(\alpha_{Center}) = 100\% \frac{L_D^{Private}(\alpha_{Center})}{L_D^{Public}(\alpha_{Center})} \quad (2)$$

$$LRCD(0°) = 100\% \frac{L_{CD}^{Private}(\alpha=0°)}{L_{CD}^{Public}(\alpha=0°)} \quad (3)$$

$$LDCD(\alpha_{Center}, 0°) = 100\% \frac{L_D^{Public}(\alpha_{Center})}{L_{CD}^{Public}(\alpha=0°)} \quad (4)$$

$$UCD(\alpha_{Edge}, 0°) = 100\% \frac{L_{CD}^{Private}(\alpha_{Edge})}{L_{CD}^{Private}(\alpha=0°)} \quad (5)$$

These formulas provide a quick way to compare various SPDs and are easier to understand than 2D (see below) or 3D angular charts.

3 Optical Measurements of Switchable Privacy

We performed numerous measurements on nine SPDs. Due to limited space, we present only luminance values here. See [2] for further measurements and evaluations. Fig. 4 shows the angular luminance characteristics of two SPDs over the horizontal angle in both public and private modes. Relative values are used for easier comparison. It is clear that the two LCDs differ significantly in terms of KPPs; for example, LDCD for LCD “1”’ is much better than for LCD “2”. However, UCD shows opposite results for uniformity.

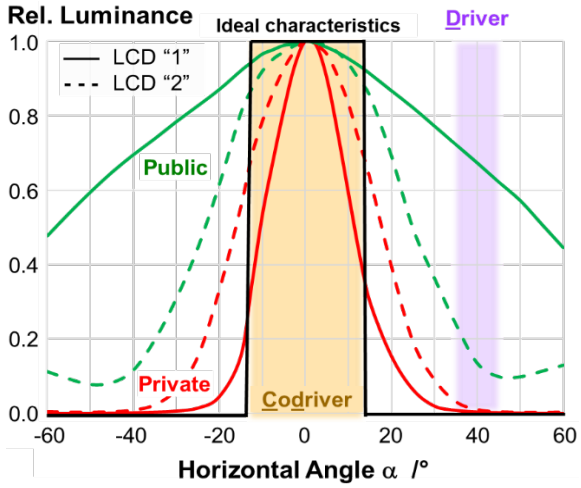

Fig. 4 *Examples of two very different in-car SPDs. The curves include viewing angle properties of the displays.*

The Switching Ratio SR extracted from Fig. 4 is plotted in Fig. 5. LCD “1” has only about 1/3 of “2” at a driver angle of 40°. All KPPs for these two example displays are listed in Tab. 1. LCD “1” performs better than LCD “2” in all areas except uniformity.

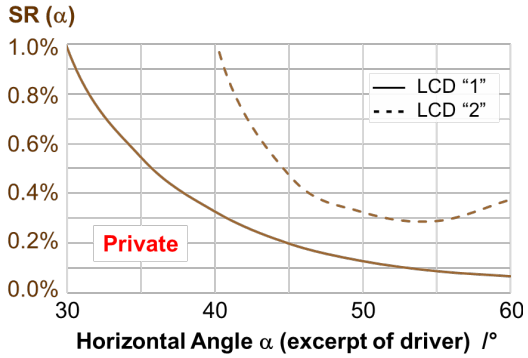

Fig. 5 *Switching ratio SR, see (1) for SPDs of Fig. 4.*

KPP / Display	SR (40°)	SRD (40°)	LRCD (0°)	LDCD (40°)	UCD (11°)
LCD “1”	0.3%	0.44%	98%	68%	35%
LCD “2”	1.0%	7.7%	96%	16%	70%

Tab. 1 *Comparison of “extreme “SPDs using KPPs (§ 2).*

The “blocked” luminance $L_D^{Private}$ is essential for traffic safety especially when night (no ambient light reflections). It should be as low as possible below 0.5 cd/m². Fig. 6 provides a design rule, for example, based on a given SR of a technology, which then sets the maximum $L_{CD}^{Private}$.

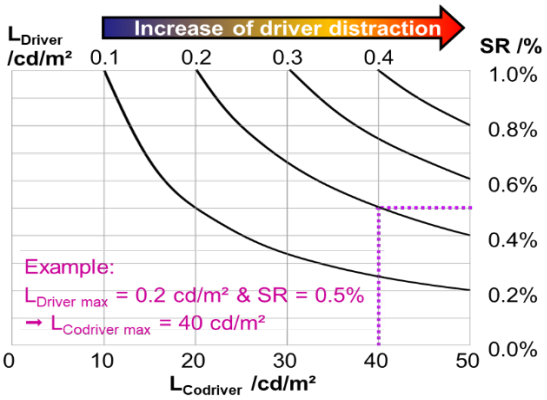

Fig. 6 *Cross-dependency (1) of SR, L_{Driver} and $L_{Codriver}$.*

4 Summary

Switchable privacy for codriver displays is becoming popular in the automotive industry. SPDs must avoid distracting the driver and display content for the codriver. We performed multiple optical measurements with prototypes. Our findings help to design and implement switchable privacy displays.

References

[1] K. Blankenbach, S. Reichel: “Switchable Privacy Displays for Automotive Applications,” SID Information Display magazine **40**:20-23 (2024). https://doi.org/10.1002/msid (open access).

[2] K. Blankenbach, A. Alauddin, B. Civanlar, S. Reichel: “Switchable Privacy Displays with Liquid Crystals and Collimated Backlight: Techniques and Measurements (invited),” SID Display Week Symposium 2025; Digest of Technical Papers **56**:862-865 (2025)