Exploiting Digital Micro-Mirror Devices for Ambient Light Communication

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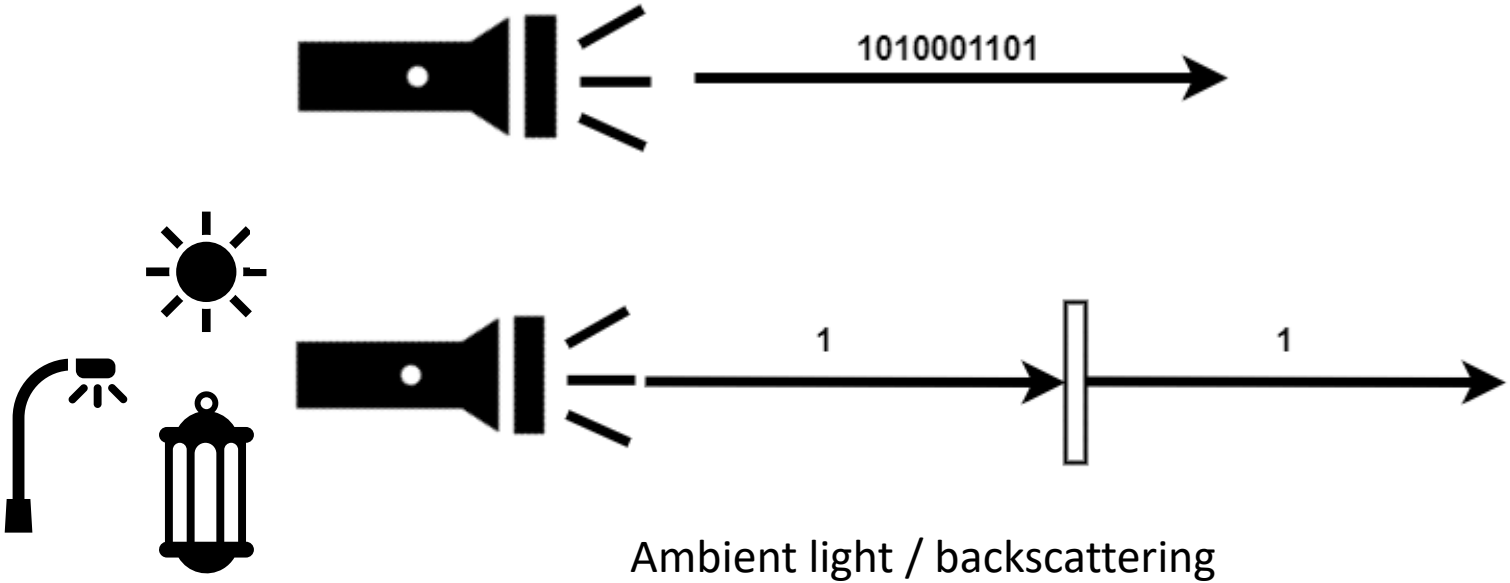
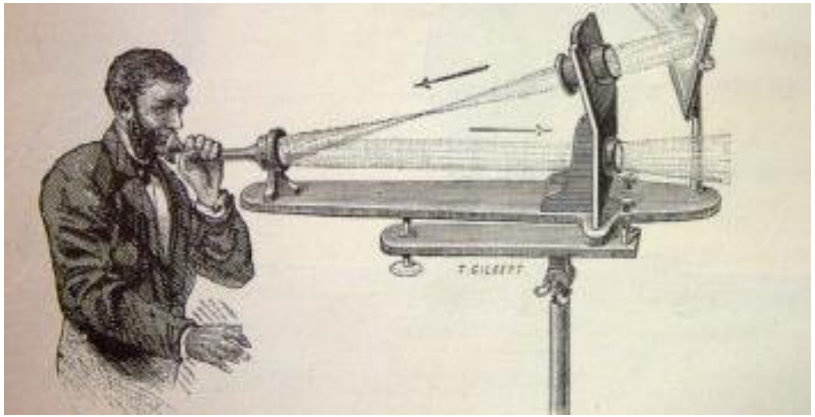
Communication with Light

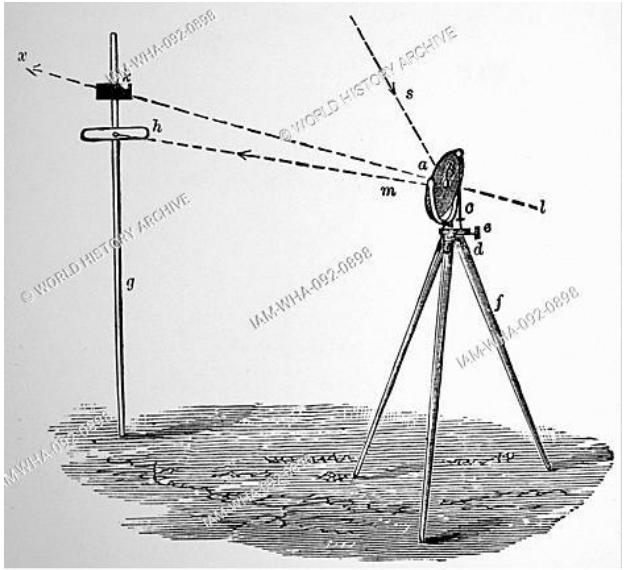
Communication with Light



Ambient light / backscattering communication

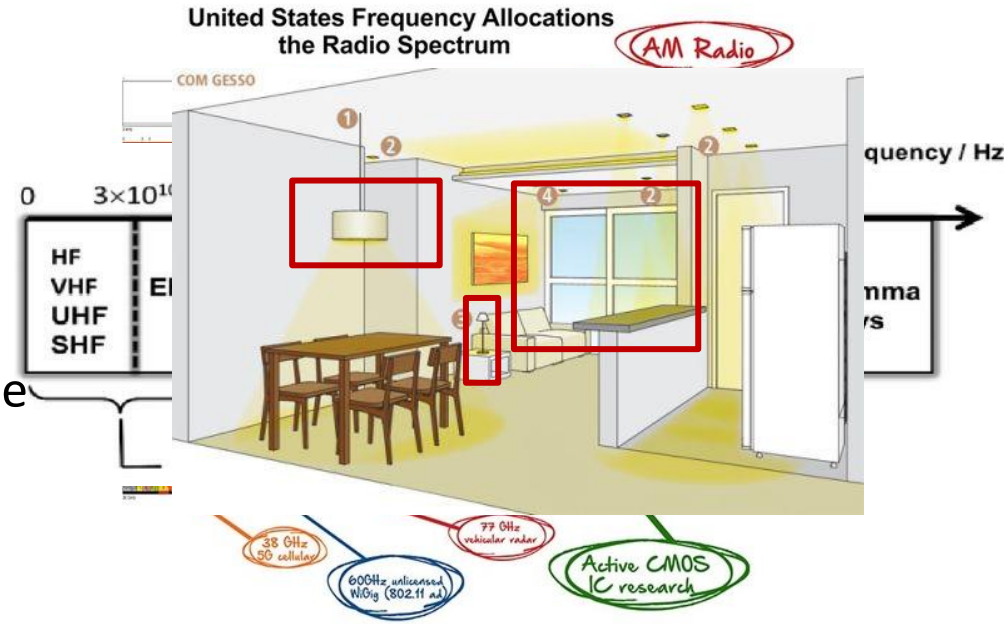
Communication with Light in History





Advantages of Ambient Light Communication

- The RF Spectrum is overcrowded
- The light spectrum is free and unregulated
- Ambient light communication allows us to take advantage of the pervasiveness light



Contributions

- An analytical model -> Provides insight into ambient light communication systems
- A novel platform -> Increases data rate

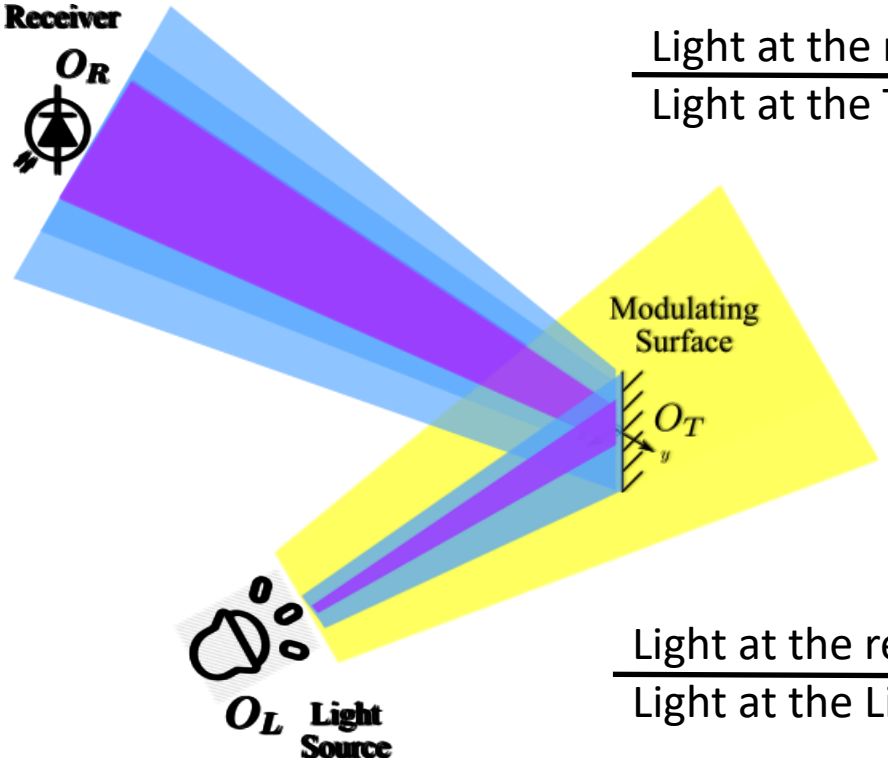
Bridging the Gap

- Previous studies in ambient light communication have been evaluated under vastly different conditions

Name	O_L	O_L Power or Illuminance	D_{LT}	O_T	Surface Type	O_R	FoV	Data Rate	Range
RetroVLC [12]	LED	12 W	Variable[1]	LCD and Retroreflector	Specular	Photodiode	50°	0.5 kbps[2]	2.4 m
PassiveVLC [28]	Flashlight	3 W	Variable	LCD and Retroreflector	Specular	Photodiode	4°	1 kbps	1 m
RetroTurbo [27]	Flashlight	4 W	Variable	LCD and Retroreflector	Specular	Photodiode	20°	8(4) kbps	7.5(10.5) m
RetroI2V [23]	Flashlight	30 W	Variable	LCD and Retroreflector	Specular	Photodiode	30°	125(1000) bps	101(80) m
Chromalux [6]	Sunlight(Direct) / Flashlight	3-6 klx / 400-700 lx	N/A / N/S	LCD and Metal Sheet	Specular	Color Sensor	Variable	1 kbps	50 m / 10 m
Luxlink [2]	Sunlight(Direct) / LED	10-26 klx / 2 klx	N/A / N/S[3]	LCD and Diffuser	Diffuse	Photodiode	1°	80 bps / 1 kbps	65 m / 3 m
TwSL [3]	Sunlight(Diffuse)	3 klx	N/A	Paper	Diffuse	Photodiode	N/S	127 bps	4 m

- Range: 1 m to 101 m
- Data rate: 125 bps to 8 kbps

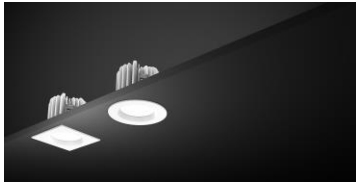
Quantifying the Role of Each Component

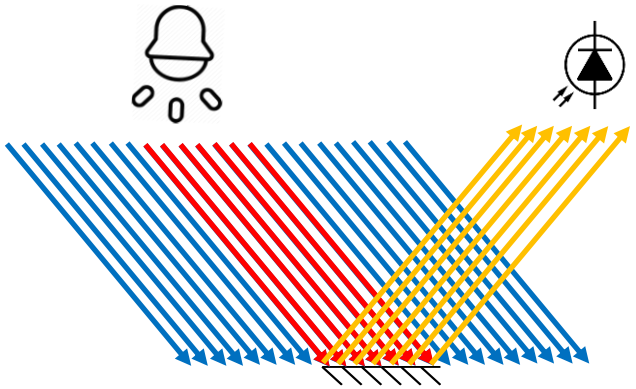


$$\frac{\text{Light at the receiver}}{\text{Light at the Transmitter}} \; ?$$

$$\frac{\text{Light at the receiver}}{\text{Light at the Light Source}} \; ?$$

Quantifying the Role of Each Component





Quantifying the Role of Each Component

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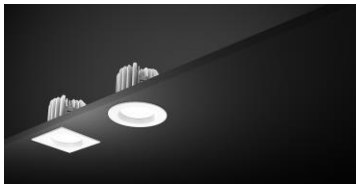

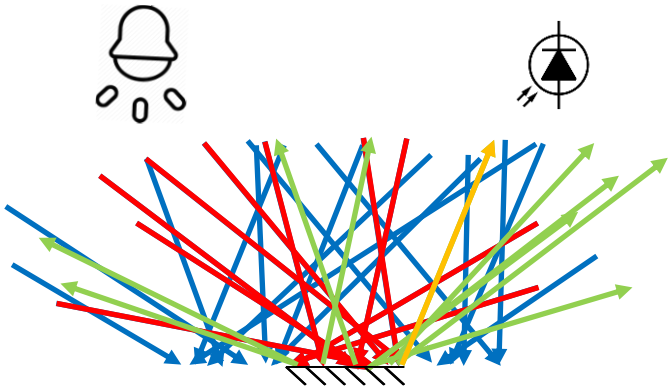

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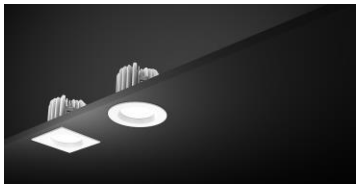

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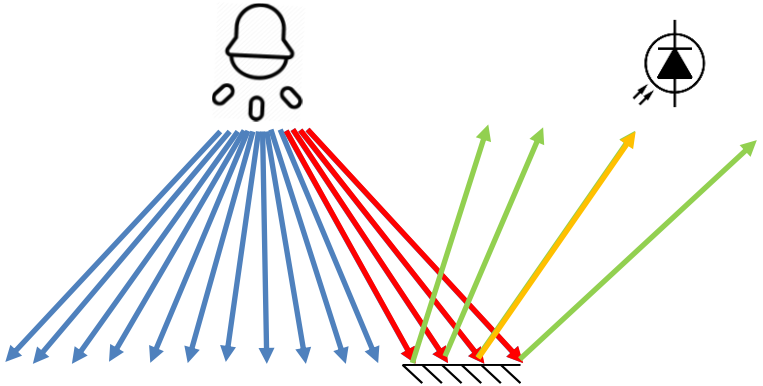

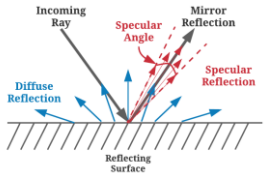

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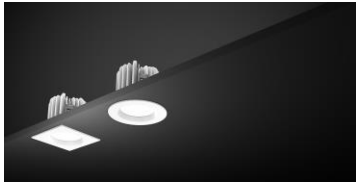

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Table 3: A taxonomy of passive VLC systems

Light Source \ Surface Type	Specular (includes retro-reflectors)	Diffuse
LED	RetroVLC [13] PassiveVLC [29] RetroTurbo [28]	
Sunlight (Cloudy Day)		Tweeting with Sunlight (TwSL) [4]
Sunlight (Clear Day)	ChromaLux [7]	Luxlink [3]

0.5 kbps - 4 kbps
1 m - 10 m

1 kbps 50 m

Contributions

- An analytical model -> Provides insight into ambient light communication systems
- A novel platform -> Increases data rate

Bridging the Gap

- Previous studies have focused solely on a single type of modulating surface

Name	O_L	O_L Power or Illuminance	D_{LT}	O_T	Surface Type	O_R	FoV	Data Rate	Range
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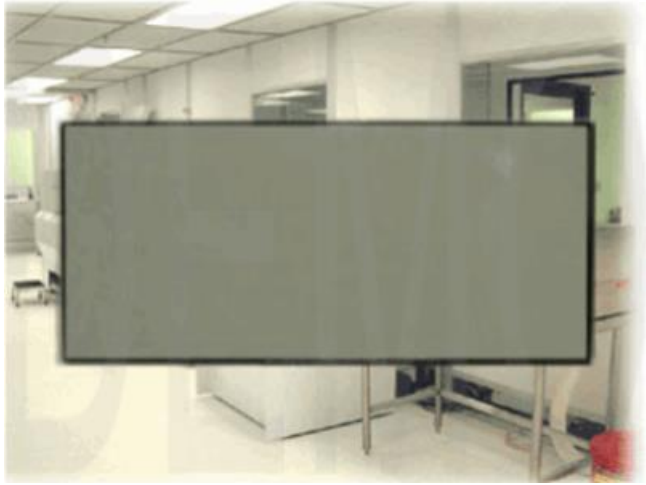
Limitations of Liquid Crystal Shutters

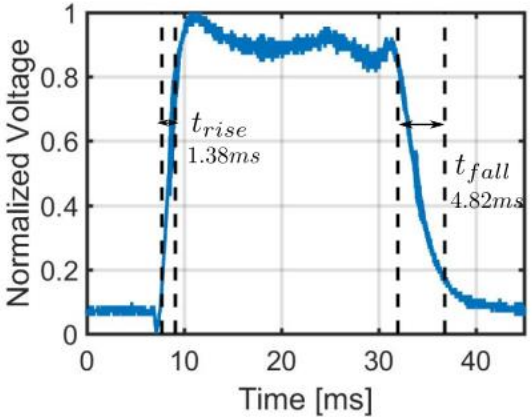


air → 100%

Ambient Light → LC clear → 50%

LC opaque → 10%

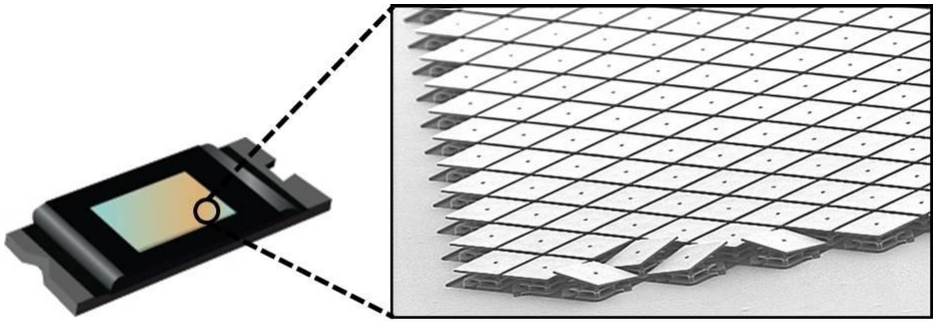
- 50% attenuation in light intensity



- Slow response times

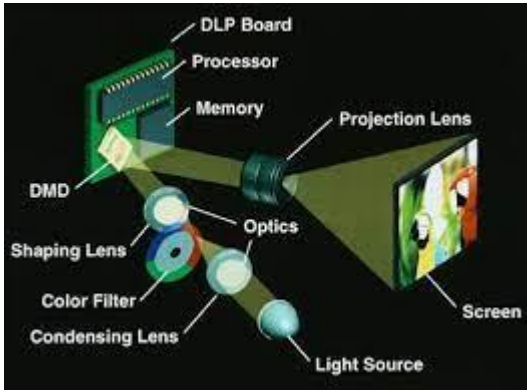
Fastest light backscattering datarate ever demonstrated was 8 kbps.

DMD as a Projection Device

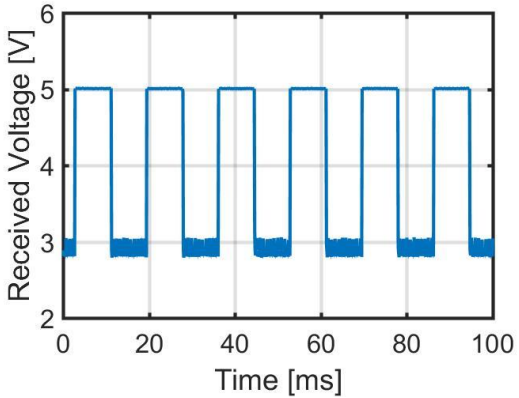


Digital Micromirror Device (DMD)

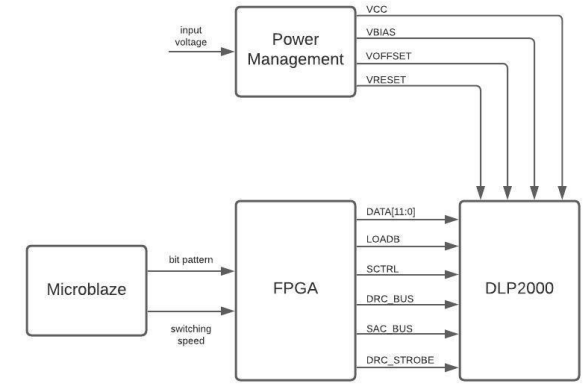
Array of micromirrors

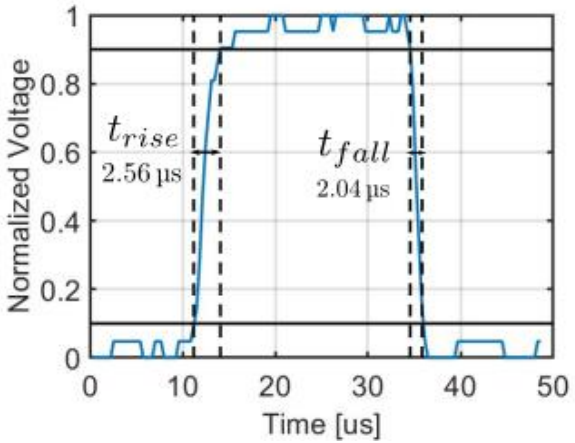


- Off-the-shelf DMDs can only be modulated at a frequency of 120 Hz



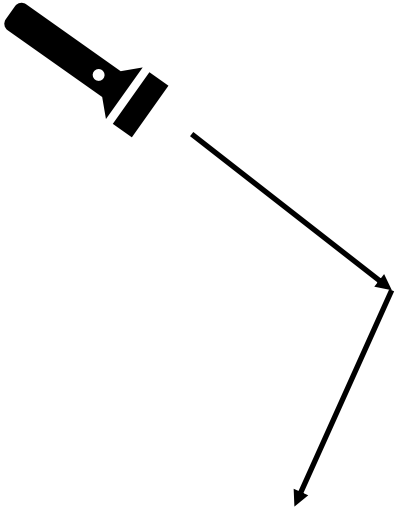
DMD as an Ambient Light Modulator

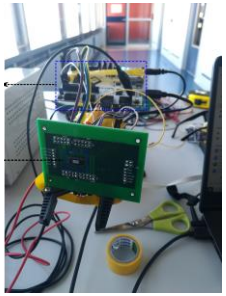


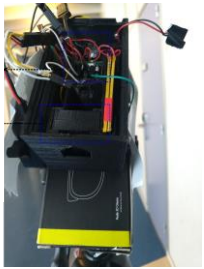


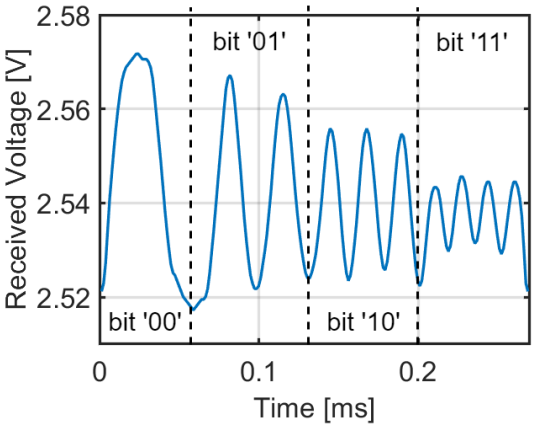
- The DMD controller is redesigned to allow for a fast-switching time
- The whole DMD-array is modulated as a single-pixel device
- The response time has increased from 8.3 ms (120 Hz) to 4.6 us (217 kHz)

Experimental Setup





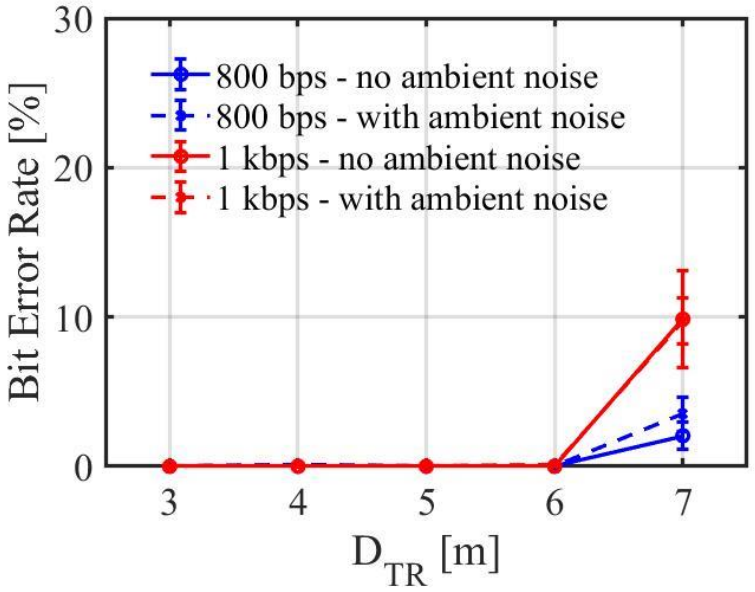




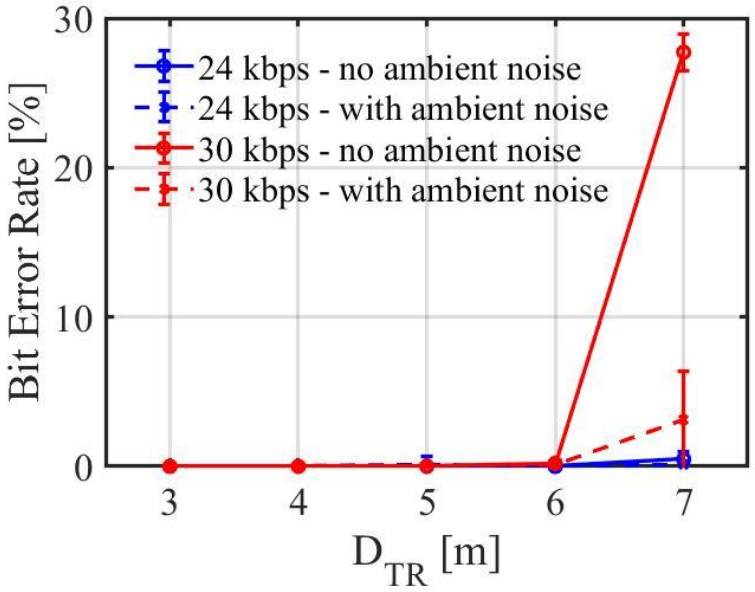
- The message “Hello world!” is sent 100 times in each experiment, and each experiment is repeated 30 times

DMD and LC Shutter Evaluations

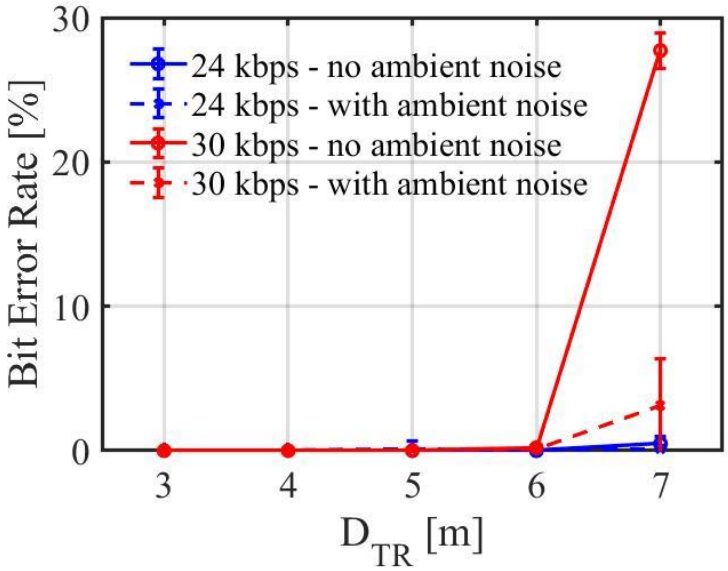
Liquid Crystal Shutter

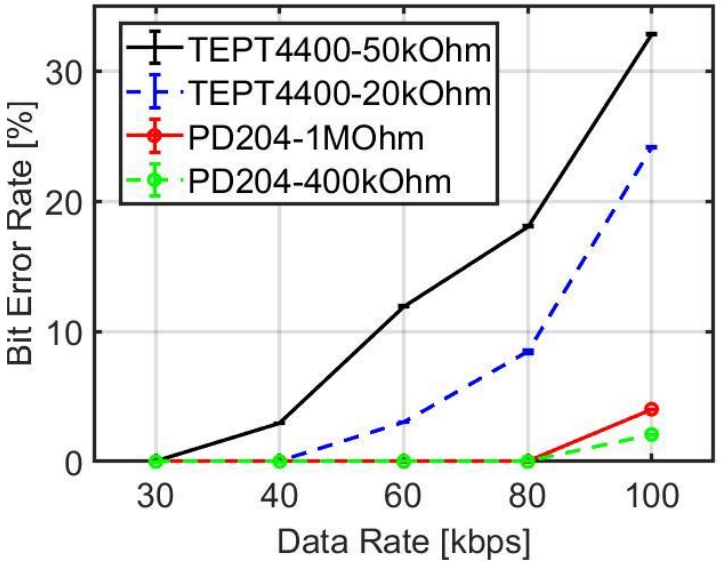


Digital Micromirror Device



DMD Evaluations with Different Receivers





Conclusion

- We developed an analytical tool to provide insights into different ambient light communication systems

- We present PhotoLink, that exploits a different type of optical surface: digital micro-mirror devices (DMDs).
  - We can achieve a data rate of 30 kbps, increasing the data rate over a factor of 30 compared to state-of-the-art studies.

THANK YOU