COLLEGE OF ENGINEERING
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MEMORANDUM FOR RECORD

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SUBJECT: LiMoST-Net Progress - Week 2

1. The purpose of this memorandum is to report our progress in accordance with our predetermined schedule.

2. The specific purpose of this memorandum is to review the objectives of week 2 and what we have accomplished.

3. Over the course of the week, we went off on our own time to accomplish what we could for the projected goals, then came back together to consolidate our efforts. This utilized our free time since our schedules usually conflict. We worked based off of the Week 2 Schedule:

Week	*Date*	*Projected Goals*	*Comments*
2	10/2/16	Research: Photo receivers RGB LED's/LED drivers Optical filters (color prism)	Photo receiver types and specifications. LED technologies and specifications. Optical filter/splitter options Rx side sensor.

4. Photo receivers. There are many types of light sensors with various performance characteristics. Our project requires a high speed detector with a relatively high sensitivity which can be easily and affordably implemented into our design. Photo-Junction devices, such as the photo-diode, fit our requirements and seem to be the best detector technology for our application. Advantages of utilizing a photo-diode detector include fast response times in the order of 5ns, relatively inexpensive, selective passband wavelengths, and built in daylight filtering. If, after testing, a higher sensitivity detector is required a photo-transistor may be used. Photo-transistors are photo-junction devices like photo-diodes with an included amplification stage which results in a gain of 50-100 times that of a photo-diode.

5. RGB LED's. White light can be a particularly hard color to produce using current LED technology. Typically light is produced by using an infrared or blue LED coated in a phosphor. The infrared or blue light excites the phosphor producing visibly white light. The problem with using this technique is phosphor has a delayed response time resulting in slow state transitions and slow baud rates. To mitigate this issue an RGB LED can be used as red, green, and blue can be directly generated without the need of a phosphor coating. This also has the added benefits of multiplying the effective bandwidth by three times since each LED channel can be modulated independently to transmit three data streams in parallel, and granting us the ability to produce multiple output colors other than white.

6. LED modulation and driving schemes. Something to be at least aware of with LED modulation and driving is flicker. The maximum flickering time period (MFTP) is defined as the maximum time period over which the light intensity can change without the human eye perceiving it. A frequency greater than 200 Hz (MFTP < 5 ms) is generally considered safe. For data rates, IEEE 802.15.7 has three physical (PHY) types for VLC. PHY I operates from 11.67 to 266.66 kb/s, PHY II operates from 1.25 to 96 Mb/s, and PHY III operates between 12 and 96 Mb/s. PHY I and II are defined for a single light source, and support on-off keying (OOK) and variable pulse-position modulation (VPPM). PHY III (what we are looking at) uses multiple optical sources with different frequencies (colors) and uses a particular modulation format called color shift keying (CSK). CSK modulation is similar to frequency shift keying in that the bit patterns are encoded to color (wavelength) combinations. For example, for 4-CSK (two bits per symbol) the light source is wavelength keyed such that one of four possible wavelengths (colors) is transmitted per bit pair combination.

Modulation	Optical clock rate	FEC	Data rate
4-CSK	12 MHz	RS(64,32)	12 Mb/s
8-CSK		RS(64,32)	18 Mb/s
4-CSK	24 MHz	RS(64,32)	24 Mb/s
8-CSK		RS(64,32)	36 Mb/s
16-CSK		RS(64,32)	48 Mb/s
8-CSK		None	72 Mb/s
16-CSK		None	96 Mb/s

Table 3. *PHY III operating modes.*

Figure 11 below shows the CSK system configuration for PHY III with three color (bands i, j, and k) light sources.

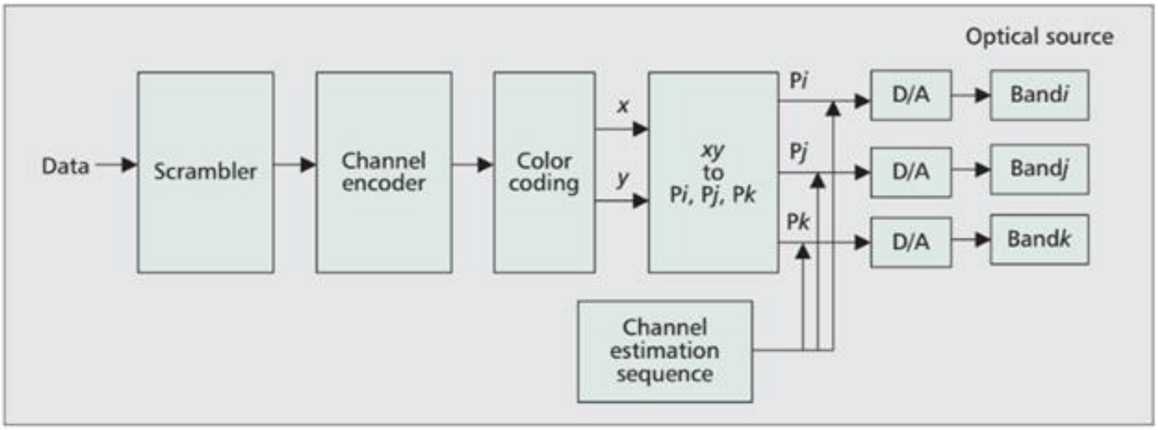

Figure 11. *CSK system diagram for PHY III. The data is scrambled to ensure randomness before encoding and mapping to intensity values which are then sent to three distinct wavelength optical sources.*

After scrambling and channel coding, the logical data values (zeros and ones) are transformed into xy values, according to a mapping rule on the xy color coordinates by the color coding block. The scrambler is necessary to create pseudo-random data and prevent data-pattern-dependent color shifts. The data parts of the frame are subject to the FEC block for error protection. These xy values are transformed into intensity Pi, Pj, and Pk.

$$Xp = PiXi + PjXj + PkXk$$
$$Yp = PiYi + PjYj + PkYk$$
$$Pi + Pj + Pk = 1$$

On the receiver side, xy values are calculated from the received light powers of 3 colors, and xy values are decoded into the received data.

7. Rx Optical filtering. In order to demux the R+G+B light back into separate red, green, and blue data streams some scheme of optical filtering will have to be used. Dichroic interference filters are capable of selectively allowing light to either pass with minimal attenuation or reflect depending on the input lights wavelength and angle of incidence. Combining two dichroic coated triangular prisms results in a three way optical filter which separates input light into its red, green, and blue components. Although other optical filtering techniques are capable of splitting light into its components they can be expensive and cumbersome. Dichroic cube prisms are mass produced for use in video projectors making them extremely affordable and easy to acquire. A major disadvantage of using a dichroic filter is that the filters pass band performance is directly related to the input lights angle of incidence. Since the Rx device will be in motion with respect to a stationary Tx device the lights angle of incidence will be in constant motion. Testing will have to be performed to determine if this filtering method is adequate for our needs or if added optics are required to collate and homogenize the ambient lights angle of incidence.

Image 1: Two stage dichroic filter

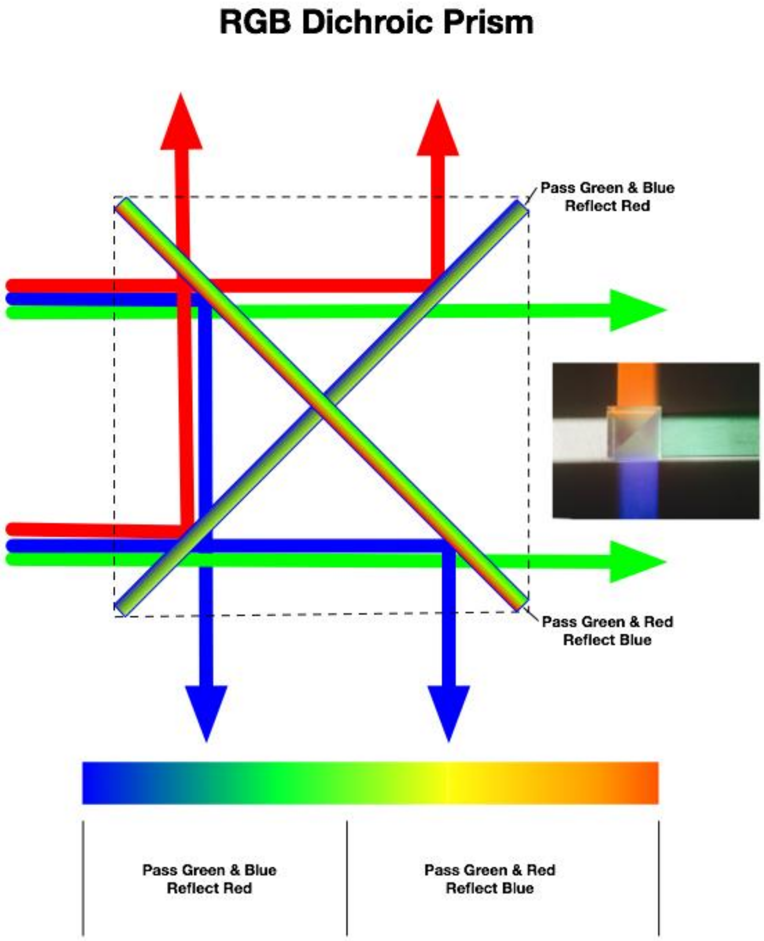

Image 2: Dichroic cube RGB filter.

8. If you have any questions, comments, or concerns, please feel free to contact us at:

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1 Attachment:
Documentation

Documentation:

All material pertaining to our project can be found on GitHub:
https://github.com/NathanRuprecht/EENG4910_SeniorDesign

Articles in GitHub under “References” used in this week’s report:
Research – 802.15.7 Short Range VLC
Research – 802.15.7 VLC Modulation and Dimming