Demo: VisibleBits: Illuminating Mixed Reality with Li-Fi Information Spotlights

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Abstract

Light Fidelity utilizes light to enable high-bandwidth, low-interference networking and complements traditional radio-frequency links. We demonstrate that Light Fidelity's precise spatial data confinement makes it a natural fit for mixed reality: By exploiting line-of-sight propagation with mixed-reality headset spatial awareness, we create "information spotlights"– which are localized optical zones that provide context-specific data, such as museum exhibit details or retail product information. This avoids radio frequency based localization, which is both computationally intensive and not supported in today's commercial headsets. We present VisibleBits, a proof-of-concept Light Fidelity transceiver integrated with a Meta Quest 3 that converts optical signals into a visual serial protocol, overcoming hardware limitations. In our demo, users receive exhibit-specific real-time information, which is then overlaid onto their mixed reality headsets as they enter a Light Fidelity illumination zone.

CCS Concepts

• **Hardware** → **Networking hardware**; **Sensor devices and platforms**; **Wireless devices**; • **Human-centered computing** → *Ubiquitous and mobile computing*.

Keywords

Light Fidelity, Information Spotlights, Mixed Reality

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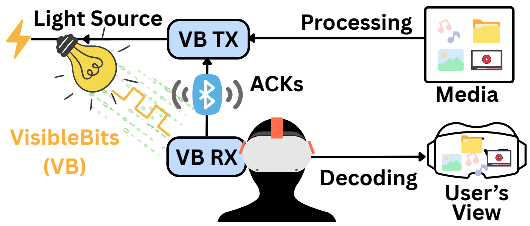
1 Introduction

Over the past decade, two technologies have gained interest: Mixed Reality (MR), which augments the physical world with digital information, and Light Fidelity (Li-Fi) [2, 5], which employs visible light as an alternative to traditional radio frequency (RF) signals [3, 6]. MR systems, such as head-mounted displays, provide immersive experiences by overlaying digital content onto a user's physical environment. In contrast, Li-Fi operates in the vast visible light spectrum (430–770 THz), offering high-bandwidth and low-interference compared to the congested sub-6 GHz RF bands.

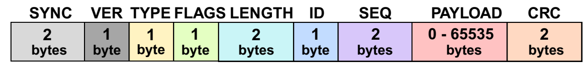
Li-Fi possesses unique characteristics such as high data rates, reduced interference, and line-of-sight (LoS) propagation, making it ideal for improving MR applications. Furthermore, its property of spatial confinement enables the creation of "information spotlights": highly localized zones where users can access context-specific data, such as exhibit details in a museum or product information in a retail store. The visible nature of Li-Fi allows users to see the data-carrying light source, resulting in a more intuitive MR experience.

Building on these characteristics, our thesis is that MR and Li-Fi are deeply complementary. Luminaires can serve as spatial anchors, functioning as information spotlights: narrow optical broadcast zones that encode object- or area-specific data, which MR headsets can detect when users are within that cone of light. This approach enables immediate, privacy-preserving, and calibration-free access to information, such as "this shelf, not the next; this exhibit, not the room". Using Li-Fi over RF addresses challenges such as multipath effects, complex trilateration techniques for indoor localization, the need for RF fingerprinting, multi-antenna ranging, and the native hardware support limitations of current commercial MR headsets. Li-Fi reduces computational complexity and costs while improving interactivity for mixed reality.

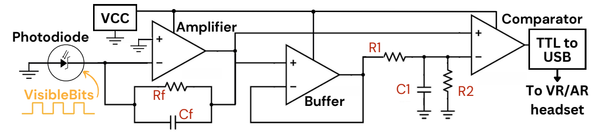
To demonstrate this synergy, we present a proof-of-concept system, VisibleBits, which integrates Li-Fi with a commercial MR headset. Our prototype features a custom Li-Fi transmitter that acts as the information spotlight, while a custom Li-Fi receiver tracks these optical transmissions. Current MR headsets offer limited flexibility for integrating custom hardware. The receiver tackles this by translating the optical transmissions into a serial protocol, effectively abstracting



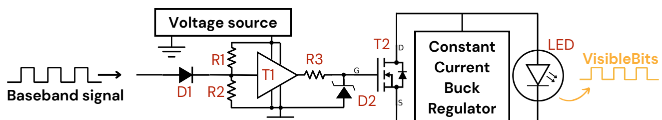
(a) VisibleBits system overview



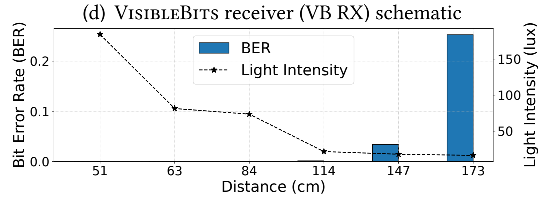
(c) Transmitted downlink packet structure



(d) VisibleBits receiver (VB RX) schematic



(b) VisibleBits transmitter (VB TX) schematic



(e) BER vs distance at 230.4 kbps

Figure 1: (a) The VisibleBits system enables reliable media streaming via a Li-Fi downlink and RF (BLE) uplink. (c) VisibleBits transmits data as per a defined packet structure. (b) and (d) show the Li-Fi transmitter and receiver schematics respectively; the receiver is interfaced to an MR headset. (e) shows the link reliability evaluation.

the communication link as a "visual serial bus." This design allows seamless integration of our receiver with the headset.

2 Design and Evaluation

VisibleBits consists of a Li-Fi transmitter and a Li-Fi receiver, both equipped with a BLE radio, as shown in Figure 1(a).

VisibleBits Transmitter. The transmitter is adapted from modBulb [1] and consists of four main components: a power supply, a baseband generator, a driver circuit, and a high-power LED. A commodity microcontroller generates the baseband signal through the UART peripheral on a GPIO pin to encode audio or image payloads. This signal is then fed to a MIC4429M gate driver, which switches a DMN6068 power MOSFET. The MOSFET, which supports high-speed switching, functions as a relay, driving a single-element monochrome LED. To ensure a stable output, an LM3406 buck regulator maintains a constant current across the LED.

Packet Structure. The transmitted packets from the VisibleBits transmitter follow a set packet structure as shown in Figure 1(c). A packet starts with a fixed synchronization sequence, followed by the software version, packet type (data or ACK), packet length, transmitter ID, packet sequence number, data payload, and CRC for error detection.

VisibleBits Receiver. The receiver design is based and adapted from Li-FiAR [4]. An SLD-70BG photodiode captures the modulated light and generates a corresponding current. This current is then converted into a voltage signal by an LTC6268 transimpedance amplifier, which has a 500 MHz gain-bandwidth product suitable for high-speed reception. The resulting voltage signal is boosted by an MCP6491T buffer amplifier and then digitized by an NCS2200 comparator. Finally, this digital signal is sent through a UART-to-USB serial converter to interface with the MR headset.

Communication Protocol. VisibleBits uses a custom protocol that handles lost or corrupted packets with retransmissions. The receiver verifies the integrity of each packet using a CRC check and monitors packet IDs to detect any packet losses. If a segment is error-free, the receiver sends a BLE ACK to the transmitter, which then sends the next segment of packets in its buffer. If a packet is lost or corrupted, no ACK is sent, and the transmitter retransmits after a timeout.

Link Reliability. We evaluate VisibleBits's performance in an indoor setup with the transmitter mounted on the ceiling and the receiver connected to the headset, with the user standing vertically below in direct LoS. The transmission baud rate was set to 230.4 kbaud, and the distance (d) between them was varied. As shown in Figure 1(e), the system performs reliably with a maximum BER = 0.25 even under low light conditions (15 lux), at a range of 1.73 m.

3 Demonstration

We demonstrate VisibleBits's ability to stream media over visible light. We program the transmitter to transmit exhibit-specific media, such as audio clips or streams of images. The LED bulb will be mounted to a frame or ceiling, approximately 0.5-1.25 m above the user's head. The user will wear an MR headset with a VisibleBits light receiver. The user visualizes or listens to relevant exhibit-specific information on the headset only when they enter the information spotlight zone. A video of VisibleBits is available below: https://youtu.be/RAiSScq1J4w

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