DEVICE DESIGN DISCLOSURE

Laser Social Distance Marker (LSDM)

Abstract:

This document discloses the design of a prototype device that uses a dynamic laser beam to trace and display social distancing limits such that its wearer and nearby people are visually informed of the location of the wearers preferred social distancing boundaries as the wearer moves throughout public and private spaces. A prototype of the device has been fabricated and tested for proof of concept purposes. Further development work needs to be done to miniaturize the device and improve performance under bright light conditions. Nonetheless, proof of concept has been demonstrated. The purpose of this disclosure document is to share the intellectual property in hope that one or several companies will commercialize the device and make it available to the public at large.

Designer: Tom Fournier, Tucson AZ USA

Disclosure date: April 29, 2020

Background of the device:

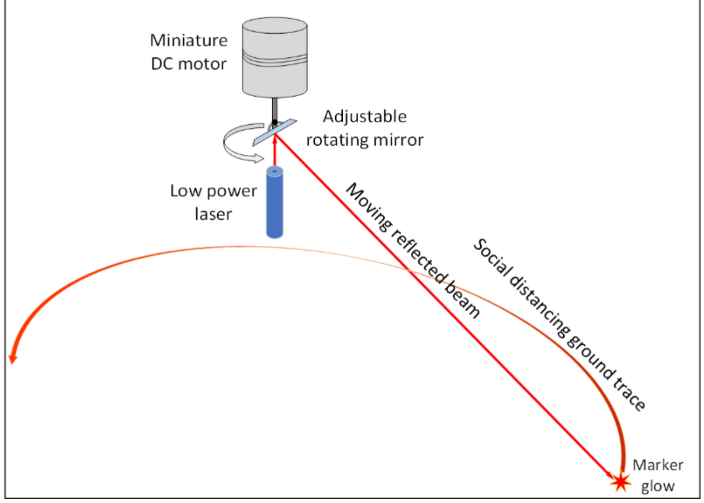
In the wake of the COVID-19 pandemic, practicing appropriate social distancing has become the mandated norm for reasons already well-rehearsed by the public media as well as healthcare professionals and contagion scientists. Knowledge of recommended social distance practices well understood by most people; however, implementing the recommended distance boundaries remains challenging for several practical reasons. One such reason has to do with the difficulty in judging precise distances without markers. That difficulty is compounded by changing visual cues as individuals navigate public and private spaces. Given that the presence of COVID-19 is anticipated to extend months and perhaps years into the future, and given the anxious pressure to gradually open up social interaction, the need to increase precision in our knowledge of actual social boundary locations under dynamic conditions will become increasingly urgent.

Prior art regarding social distance marking has ranged from stationary floor markings to sophisticated electronic devices. The later might include Global Position System (GPS) location via mobile communication devices, wearable WiFi communicators, RFID tags and readers, sonic echo locators, and more. Each of these methods have drawbacks. Floor markings and signs work for queue lines but not for fluid situations where people are in motion. GPS mobile devices, wearable WiFi communicators, and RFID tags with readers all require the people around the user to have matching and reciprocating technologies. Sonic echo locators lack advance visual cues for wearers in motion and require multiple sensors similar to the arrays on car bumpers. The device described here is an adjustable, dynamic, Laser Social Distance Marker (LSDM) that was designed to overcome the shortcomings of other social distancing methods by using well-known technology that is relatively simple and inexpensive.

Summary of the design:

Referring to “FIGURE 1. – LSDM Conceptual Diagram”, the LSDM comprises a red, low power laser, moving mirror, reflection angle adjustment mechanism, direct current motor, and ancillary hardware

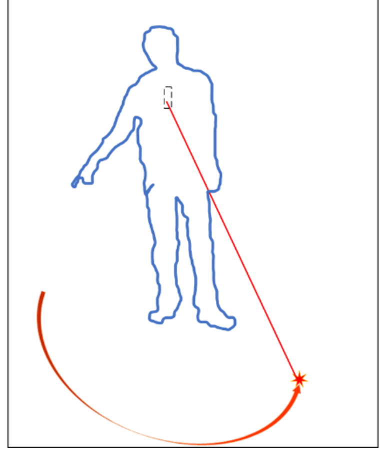
FIGURE 1. – LSDM Conceptual Diagram



(not depicted) such as battery, switch, wiring, enclosure, and lanyard. The laser is positioned vertically and shines on a rotating mirror. The mirror's angle is adjusted to cause the reflected beam to shine on the floor at a chosen distance lateral from the source. As the motor rotates the mirror, the laser spot moves on the floor in a circular arc. The motor rotation speed is chosen such that the repetition of the arc trace is faster than the flicker fusion threshold for human vision, approximately 35 – 60 Hertz.[1] That translates into 2100 – 3600 rpm. Above the flicker fusion threshold, the laser beam illuminating the floor appears as a continuous arc rather than a moving dot.

When assembled in its enclosure, the device is meant to be worn at chest level by the user such that the laser and rotating mirror trace an arc on the floor in front of the user as he or she stands or walks. See "FIGURE 2. – Wearing the LSDM". The red laser arc displays the pre-set social distancing boundary for the wearer and nearby people to see. That boundary display moves with the wearer, serving as a precise continuous measurement and – importantly – a vigilant reminder to the user and others nearby.

FIGURE 2. – Wearing the LSDM



The LSDM is designed so that the angle of the rotating mirror can be adjusted. In this way the user can set the social distancing boundary – i.e. perform optical calibration. This ability to adjust serves two important purposes. First, it allows the user to set the social boundary distance according to their personal safety preference. Second, it allows the device to be calibrated to work with virtually any body size. The following paragraphs and diagrams describe why optical calibration for body size is required and how the full range of human body sizes are accommodated.

The geometry of optical calibration is determined by the Law of Reflection and basic trigonometry. As depicted in "FIGURE 3. – Law of Reflection", the angle that a light ray will reflect from a mirror

[1] Alyse Brown, Molly Corner, David P. Crewther, Sheila G. Crewther, "Physiological Measures of Magnocellular Neural Efficiency", *Frontiers in Human Neuroscience*, US National Library of Medicine, National Institute of Health, 2018; 12: 176, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5960665/

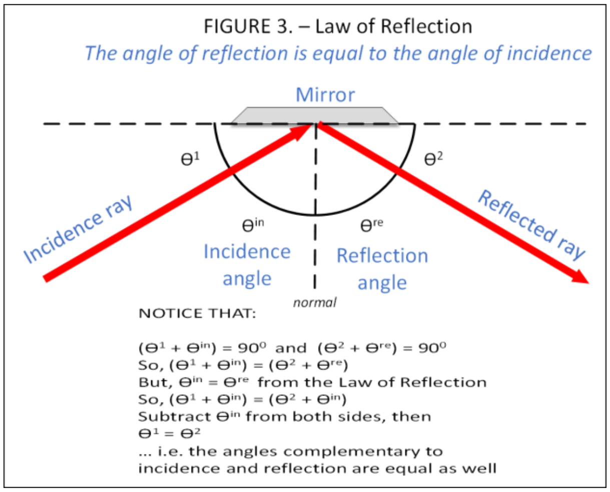


FIGURE 3. – Law of Reflection

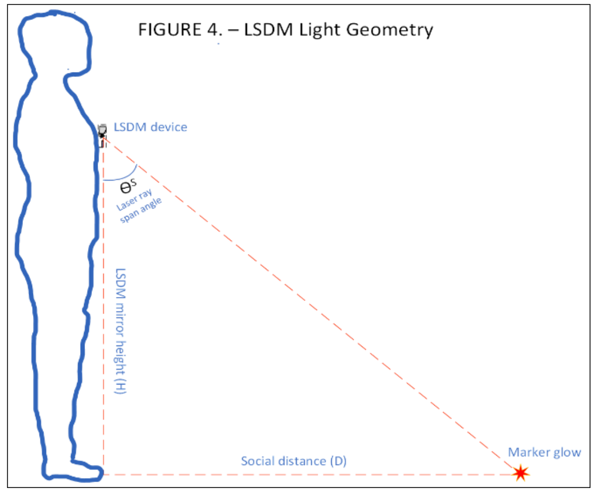


FIGURE 4. – LSDM Light Geometry

surface is equal to the angle of incidence at which the light arrived on the surface.[2] For our purposes, we will refer to the sum of the incidence angle and the reflection angle as the "Laser ray span angle" and give it the symbol Θ^S. When our LSDM is worn on the chest, the laser is vertical and pointing upward toward the mirror. Therefore, the laser ray span angle creates a triangular geometry as shown in "FIGURE 4. – LSDM Light Geometry". That light geometry rotates as the mirror rotates causing the marker glow to trace an arc in front of the user.

By applying basic trigonometry to the laser light triangle, we can calculate the laser ray span angle needed to realize a desired social distance given the chest height of the user. From that span angle we can determine the angle that the mirror must be set to. In order to understand the relationship between the mirror angle and the social distance marker glow, compare "FIGURE 5. – Shallow Mirror Angle" to "FIGURE 6. – Steep Mirror Angle" and imagine that we are changing the optical calibration of

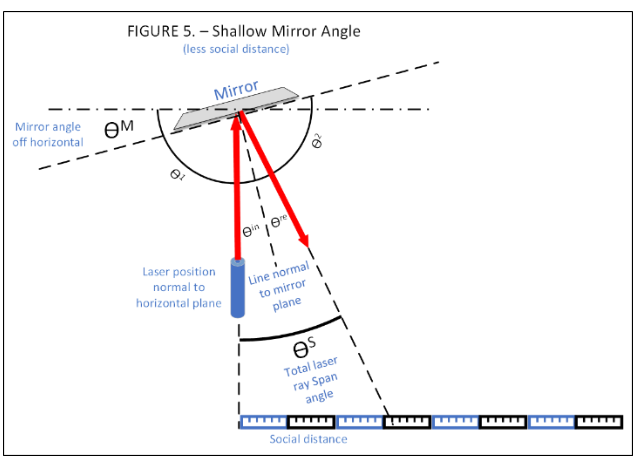


FIGURE 5. – Shallow Mirror Angle

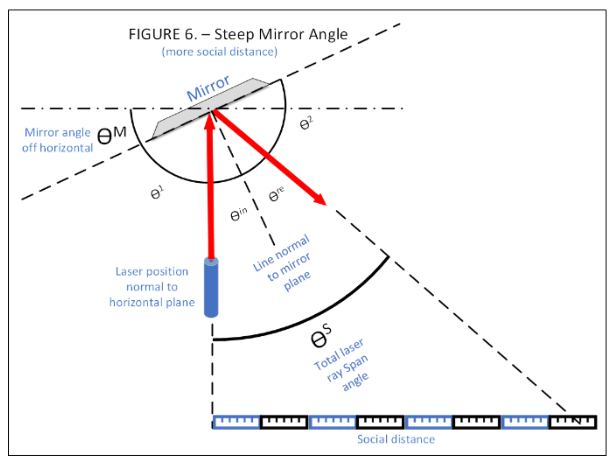


FIGURE 6. – Steep Mirror Angle

the system by moving the mirror from a shallow angle to a steep angle off the horizontal plane.

Since the vertical orientation of the laser is fixed as the mirror angle (Θ^M) increases, the angle of incidence (Θ^{in}) also increases along with the mirror angle. However, the Law of Reflection mandates

[2] See: "Law of Reflection", *HyperPhysics, Light and Vision*, http://hyperphysics.phy-astr.gsu.edu/hbase/phyopt/Fermat.html

that the angle of reflection (Θ^{re}) must increase in step with and equal to the angle of incidence (Θ^{in}). Since the span angle (Θ^{S}) is the sum of (Θ^{in}) and (Θ^{re}), the span angle increases by a factor of twice the mirror angle increase. Put another way:

- Suppose the mirror begins in a horizontal position such that $\Theta^{m} = 0^{0}$.
- Given that the laser is normal to the horizontal plane, the line normal to the mirror would then lie on top of the laser, and Θ^{in} would be 0^{0} as well.
- For every degree that the mirror is tilted, Θ^{m} and Θ^{in} each increase as well by one degree.
- In other words, Θ^{m} and Θ^{in} are always equal.
- But Θ^{in} and Θ^{re} will always stay equal by the Law of Reflection.
- And since Θ^{s} is the sum of Θ^{in} and Θ^{re}, $\Theta^{s} = 2(\Theta^{in})$.
- So $\Theta^{s} = 2(\Theta^{m})$ because Θ^{m} and Θ^{in} are always equal.
- And $\Theta^{m} = 1/2(\Theta^{s})$.

Comparing the lower portions of figures 5 and 6, notice that this relationship between the mirror angle and the span angle determines the horizontal length of social distance that will be marked off by the LSDM.

Referring again to the triangular light geometry of FIGURE 4, social distance (D) is the triangle leg opposite to span angle (Θ^{S}), and LSDM mirror height (H) is the triangle leg adjacent to span angle (Θ^{S}). Therefore, from trigonometry, (Θ^{S}) is the angle whose tangent is (D) divided by (H).

Eq. 1. $\Theta^{S} = \tan^{-1} (D/H)$

Since we've already determined that the mirror angle is half the span angle,

Eq. 2. $\Theta^{M} = [\tan^{-1} (D/H)]/2$

If we assume a desired social distance of say six feet (72 inches), we can use Eq.2 to calculate the mirror calibration angle for virtually anybody assuming the user wears the LSDM on a lanyard at chest height and we know the chest height dimension.

Chest height is approximately 75% if total body height.[3] We can apply this approximation to a variety of body heights. Let's consider four examples. The average U.S. female is 63.6 inches in total height and the average U.S. male is 69 inches.[4] We can also take into consideration some extremes of human dimension, say seven and a half feet (90 inches) and three feet (36 inches). Applying these four height examples to the 75% chest height approximation and using Eq. 1 and Eq. 2, we can calculate the full range of mirror calibration angles needed to make the LSDM device practical. Results are presented below in Table 1. – Calculated Mirror Angles.

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[3] Ing. Jaroslav ILEČKO, "The simulation of human gait in Solid Works", Department of production systems and robotics, Faculty of Mechanical Engineering, Technical University of Košice, Slovakia, http://www.rusnauka.com/31_PRNT_2008/Tecnic/36223.doc.htm

[4] U.S. CDC, "Measured average height, weight, and waist circumference for U.S. adults aged 20 and over", https://www.cdc.gov/nchs/data/nhsr/nhsr122-508.pdf

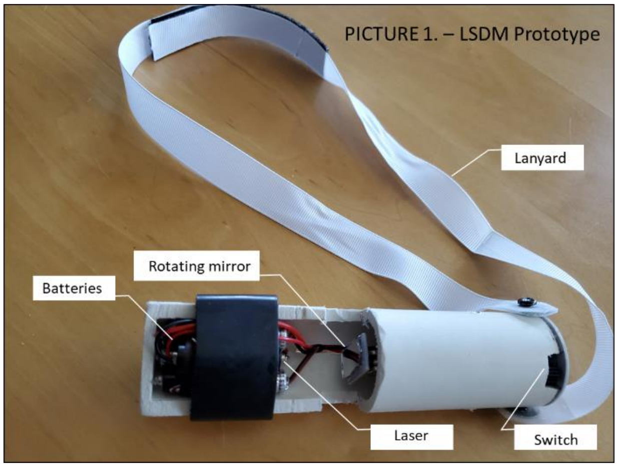
Table 1. – Calculated Mirror Angles

Person Type	Total Height Inches	Chest Height (H) Inches	Social Distance (D) Inches	Span Angle (Θ^S) Degrees	Mirror Angle (Θ^M) Degrees
Very tall	90.0	67.5	72	46.8	23.4
Avg. male	69.0	51.8	72	54.4	27.2
Avg. female	63.6	47.7	72	56.5	28.3
Very short	36.0	27.0	72	69.4	34.7

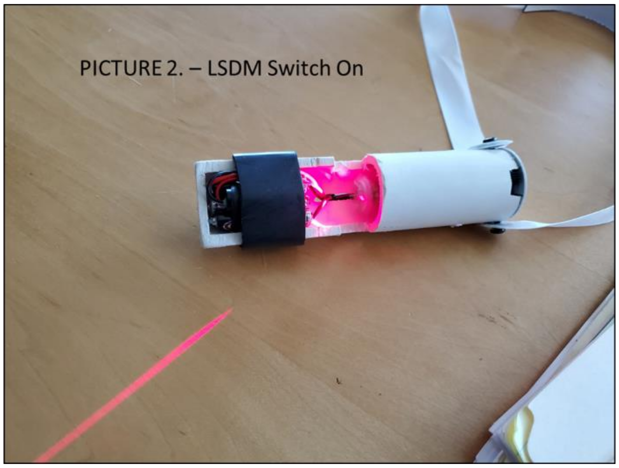
It should be noted that, the LSDM may alternately be worn at belt level via a clip. The triangular light geometry remains the same though the height dimension (H) is smaller. The calculated mirror angles are greater. Belt level wearing has the advantage of the wearer's arms and hands not interfering with the light beam; however, it also has the disadvantage of less device stability due to increased motion of the waist in comparison to the chest.

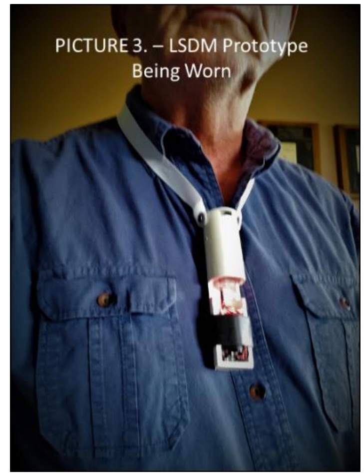
LSDM Prototype:

For proof of concept purposes, a rough prototype of the LSDM was fabricated from scrap items occupying the designer's garage shelves. These included a laser taken from a laser pointer, a DC motor taken from a touchless soap dispenser, a corner chip from a broken mirror, and a piece of plastic plumbing pipe. A commercial LSDM would need refinement in several ways as discussed below. "PICTURE 1. – LSDM Prototype" is a snapshot of the prototype device with component labels added. "PICTURE 2. – LSDM Switch On" shows what the device looks like when the laser is powered up and the mirror is rotating.



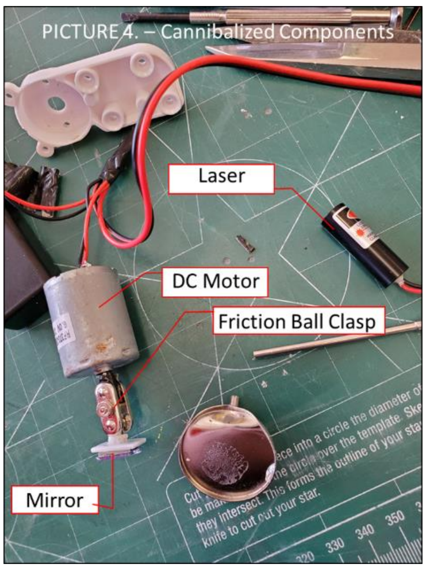
PICTURE 1. – LSDM Prototype

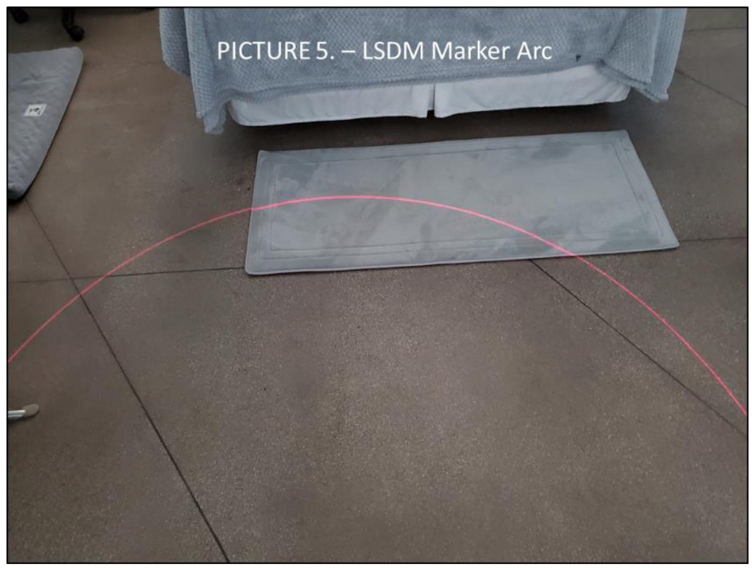

PICTURE 2. – LSDM Switch On



"PICTURE 3. – LSDM Prototype Being Worn" shows the size of the device in its prototype embodiment. Note that the size was determined by the available DC motor. A much smaller motor can be used for the commercial version of the device since the load on it is minimal. The designer believes a refined commercial LSDM device would be roughly the size of a typical felt tip pen used for white board presentations.

"PICTURE 4. – Cannibalized Components" shows several of the major prototype components against a table grid background of 1-inch squares. Aside from giving a sense of the relative size of the components, the picture also shows how the mirror is mounted to the motor shaft via an adjustable friction ball clasp.



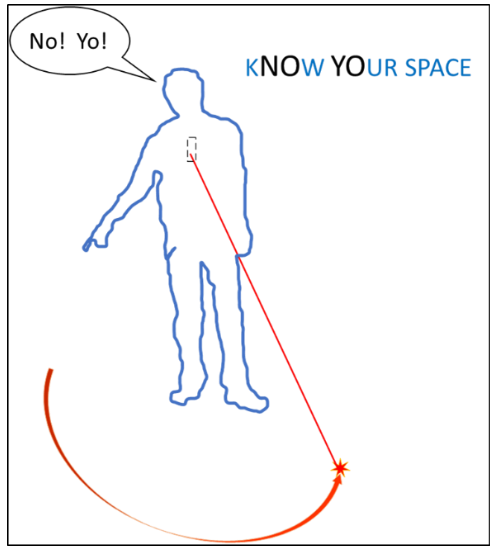


"PICTURE 5. – LSDM Marker Arc" shows what the marker arc looks like from the wearer's point of view. The arc precedes the wearer as he or she walks. In the case of the prototype, the outward radius of the arc is easily adjusted by switching off the device and applying a slight pressure to either edge of the mirror (top or bottom) depending on whether the goal is to increase or decrease the arc radius. The mirror is held to the motor shaft by the friction ball clasp (PICTURE 4.) which allows adjustment without the use of tools. Note that testing of the prototype revealed the laser arc washes out in bright light. Therefore, the device is limited to indoor use during the daytime and either indoor or outdoor at night. Whether day or night, indoors or out, any bright lighting conditions will make the arc difficult to see. This can be mitigated by sourcing a more powerful laser for the commercial version of the device.

Commercializing the LSDM:

As communicated above, the goal of this disclosure is to encourage commercialization of the LSDM device by one or several companies. No fees or royalties are sought by the designer. From a design refinement perspective, commercialization will, at minimum, require:

- Miniaturization starting with sourcing a smaller motor,
- Brightening the marker arc by sourcing a more powerful laser,
- Custom designing a thin-walled enclosure,
- Sourcing or custom developing a rechargeable battery pack,
- Finding a better commercial name than LSDM … Maybe it's a "No! Yo!"



You can contact the designer by going to www.tfournier.com and clicking on "Contact".

You can see a demonstration of the device at the following link: https://youtu.be/k1PfqFgLESE