VERISA (VIRTUAL ENVIRONMENT FOR REAL-TIME INTERACTIVE SAFETY AWARENESS)

Paper – 402

Nathaniel Leon[1], Scott Wohlstein[2], Jim Webb[3]

[1] Johns Hopkins University, WSE, Baltimore, MD, USA
[2]The Photonics Group, West Chester, OH, 45069, USA
[3]Jim Webb, G.L. Services, London, United Kingdom

Abstract

VERISA is an environment wherein safety and regulatory standards set the boundaries of 3D CAD environments to provide a real-time risk model which can be viewed in virtual and/or augmented space. This paper will detail the Phase 1 development of the environment and future goals to make this valuable tool available.

In current laser safety modeling, orientation in graphical space is not intuitively coupled with hard numbers. It certainly does not make a product or experiment developer's function easier or efficient. Conversion between numbers and metrics and design or NHZ/MPE/LCA designation is left to the LSO and no matter how rigorous the study, subject to interpretation.

VERISA is designed to integrate or be added to commercially available and open source CAD software so users can see and manipulate in a virtual world the hazards which exist or could exist in new experiment configuration or piece of equipment before it exists and without subjecting personnel to hazards.

Introduction

VERISA will add design and risk mitigation elements to 3-D computer models allowing safety hazard analysis prior to physical fabrication. Assembly and commissioning will then present greatly reduced light emission risks to operators, users, and the public.

These elements will be based and bounded within accepted and validated principles as provided in ANSI, IEC, and federal standards for accessible laser light emissions.

Most of the basic analytical definitions already exist in 3-D modeling tools on the market:

1. Full 3D definitions of all mechanical components;
2. Ray tracing (both localized and full image);
3. Definitions for surface reflectivity (specular and diffuse) and absorption;
4. Complete optical component properties for all elements within the optical train;
5. Accepted emissions standards (ANSI, IEC, and federal) for allowable, safe, marginal and hazardous emissions;
6. Laser TEM modes

The key is to integrate all these capabilities into an operational environment that is straight forward to use and allow the end user to review and understand the risks associated with their experiment or product design. Once produced the model will be viewable in an interactive virtual environment using commercially available 3-D goggles (see Figure 1) and controllers to allow the user to manipulate components and use their hand as a sensor and beam profiler to obtain feedback on the emissions levels along the primary beam line and stray reflections when they occur.

The Real-World Problem

The current safety modeling of laser-based systems has not made use of intuitive visual/graphical space coupled with hard verifiable/validatable numbers as exists with Finite Element Analysis (FEA) or fluid dynamics. These tools are in general use and help to ensure proper and safe operation once systems are commissioned by allowing the user to evaluate and determine the safety factors on structural and other components and systems.

Ultimately, the conversion between numbers and metrics and designs that allow for the establishment of the Laser Control Area (LCA), Nominal Hazard Zone (NHZ), and Maximum Permissible Exposure (MPE) designations, are left to the Laser Safety Officer (LSO) or Laser Safety Advocate (LSA).

Even the simplest laser system has multiple variables that should be addressed and understood by the experiment and end user to ensure safety of all who may work in and adjacent to the NHZ or LCA.

Integration of Parts Solution

As noted the current state of technology readiness is mature enough in each of the constituent parts to create an efficient VERISA ecosystem, specifically:

- Laser safety calculations and algorithms
- CAD/CAE-based optical modeling
- Standards and regulatory code database access (API)
- Virtual and Augmented Reality engines

The user will be able to develop a proposed system or review an existing system in the safety of an VR or AR environment with information developed in the process outlined in Figure 3.

Once developed, a VR/AR environment can be manipulated to evaluate the hazards which could exist once the system is implemented or exercised. With minor additions to build in the necessary operational controls the authors are identifying several commercially available VR systems on the market which have the necessary capability. These systems have the necessary Software Development Kit (SDK) packages which typically offered to "write in" connectivity.

The hardware required for the distributed model is reduced to visual hardware (visors or a monocle) with SaaS accessed from the Cloud.

Figure 1: VR Immersion
showing tethered type headset

When interacting in the VR or AR environment, developers and users should recognize that it will not be necessary to re-render the entire environment to maintain useful realistic environment. This type of system modeling will be optimized to only occur on the beam line itself, and those changes will only occur propagating from the change.

For instance, if the orientation of a mirror is changed, then only the safety-related effect is to be calculated and modelled after the mirror. If a lens is moved, there will be at least three down line beams to be evaluated, starting from the point of incidence on the lens.

This will greatly reduce the processor load and related latency of the system. For instance, the beam line shown in Figure 2 takes approximately 3 seconds with a single processor once the basic parameters are collected and defined. Once the beam line definition is finalized, the resultant analysis of the incident surface will be accomplished in milliseconds.

Basic Setup Environment

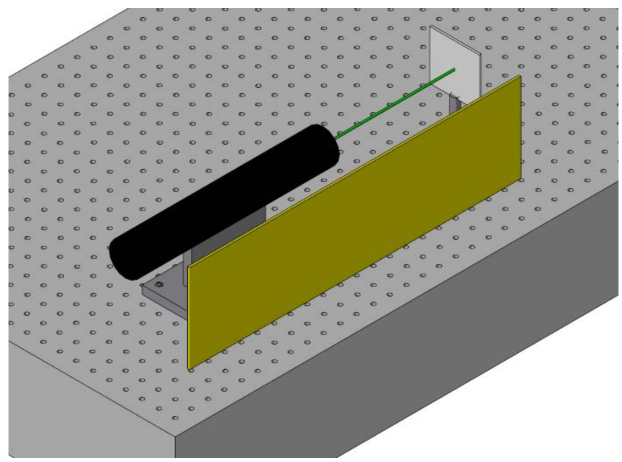

Figure 2: Basic Setup Environment
showing a laser source, target, and barrier

As simple as it is shown in Figure 2, that setup presents 10 or 13 operational variables based upon the laser source's operational dynamics (CW or pulsed):

1. Wavelength
2. Operational Dynamics
   a. CW (power)
   b. Pulsed (energy)
      i. Energy
      ii. Pulse Repetition Rate
      iii. Pulse Width
      iv. Duty Cycle
3. Beam Diameter
4. Divergence / Convergence
5. Target characteristics
   a. Absorption

b. Reflection
c. Transmission

6. Location of Guard/Barrier (assumption is 100% opaque)
   a. X plane to beam line/target (shown as a target)
   b. Y plane to beam line/target (show as a guard)
   c. Z plane to beam line/target (not shown)

Laser safety professionals make assumptions about these variables (e.g.; the installation in a room with a ceiling acting as the Z-plane barrier). VERISA will allow safety professionals, laser systems designers, and users to visually confirm assumptions on more complicated systems.

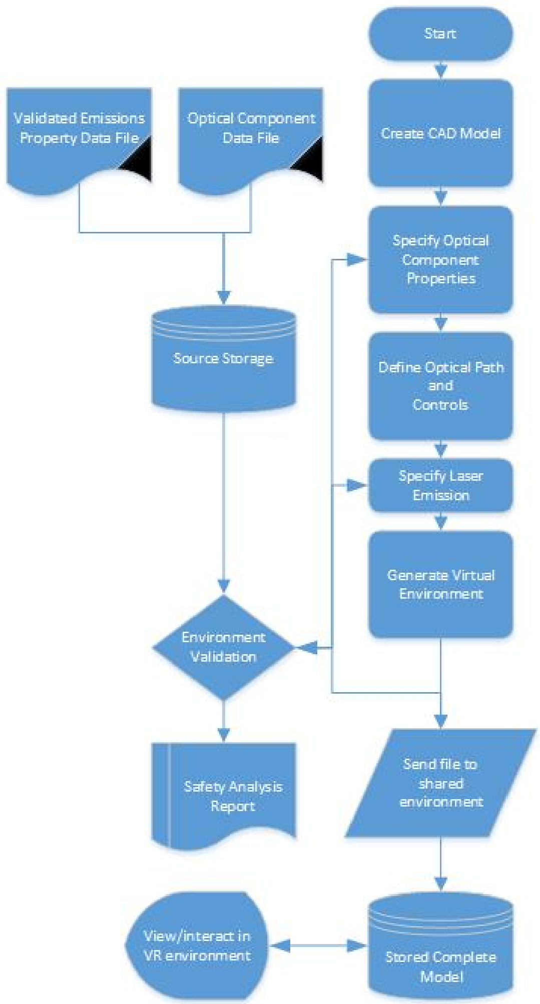

Figure 3: Data Flow in VERISA

Phase 1- Baseline Model

The first phase of the VERISA concept is to create a basic laser system transmitting through air to a target. This system will allow the user to evaluate and analyse various hazards, while varying the following feature within the model. The models shown here are rendering in less than 10 seconds. Once rendered they can be viewed and manipulated in real time.

This Baseline Model will be developed to demonstrate a correlation with systems interactivity as well as predictions and physical tests of a real system. The variability from the input deck (virtual menu) includes all parameters that are understood to affect safety as noted in the problem definition.

Since every optical element will change the characteristics of the beam profile, changes in the diameter and convergence/divergence and may also result on multiple beam lines this we can see how this will quickly increase the number of variables and hazards to consider will quickly increase especially when optical elements are designed to be movable. As shown below a simple alignment experiment with a mirror, beam splitter and lens result in five (5) different beam lines:

1. Originating beam
2. Beam from mirror to lens
3. Near surface reflection of lens
4. Far surface reflection from lens
5. Transmitted by divergent beam through lens

Figure 4 and Figure 5 highlight a significant stray beam going off the table to one side. This beam has much more intensity than the equivalent beam in the properly aligned system.

Being aware in advance of where this being is going must be considered to ensure the safe alignment of the system especially when high powered Class 4 lasers are being utilized and there is a significant possibility that this reflected beam presents a hazard to the person doing the alignment because even with 5% reflection it has an irradiance in the Class 4 range.

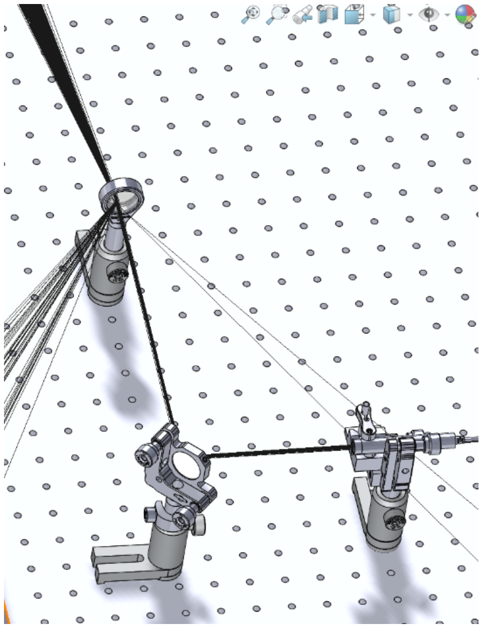

Figure 4: Misaligned Baseline Model

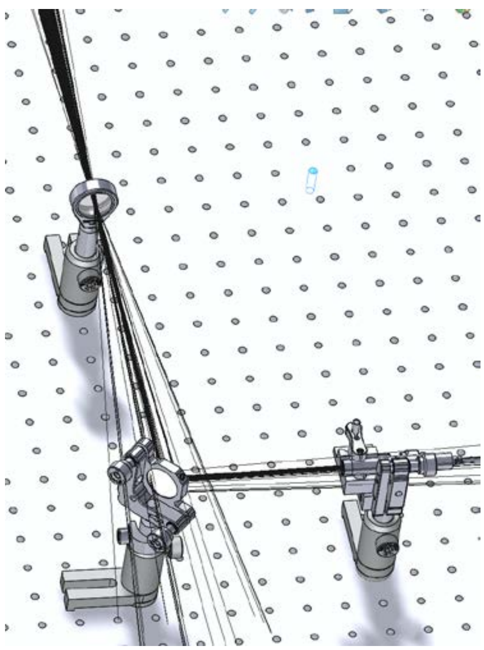

Figure 5: Aligned Baseline Model

Developing the Input Deck

The input deck of variables will be prepared through the traditional methods for supplying input for materials and lamps (the laser) currently used in conventional CAD systems. This material information would then be verified and transferred into a VR environment generator.

Examples

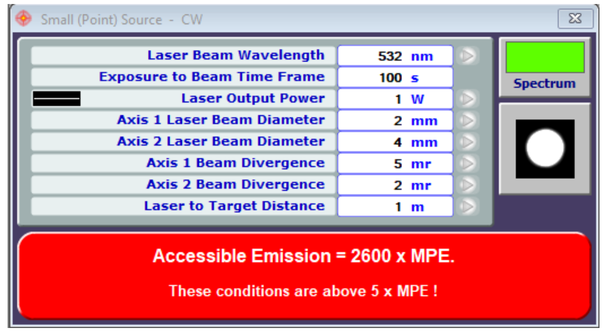

Figure 6: Defining Laser
(adapted from LaserSafe PC)

The variables each optical element will also be input by the users. The optical element variables include

- Type of optical element or target
  - Lens
  - Mirror
  - Target / Absorber
- Material including surface finish if appropriate
- Coatings if present

Photopia Appearances

Search...

er	Name	Type	Description
	ZERO0000	Reflective	black surface
	WHTPC125 (S)	Transmissive	0.125" translucent white polycarb.
	WHTPC125	Transmissive	0.125" translucent white polycarb.
	WHTAC150 (S)	Transmissive	0.150" translucent white acrylic
	WHTAC150	Transmissive	0.150" translucent white acrylic
	WHTAC125 (S)	Transmissive	0.125" translucent white acrylic
	WHTAC125	Transmissive	0.125" translucent white acrylic
	WHTAC040 (S)	Transmissive	0.040" translucent white acrylic
	WHTAC040	Transmissive	0.040" translucent white acrylic
	White Rubber	Reflective	white rubber material
	White PCB	Reflective	white PCB material
	White ABS	Reflective	white ABS plastic
	Water/Water	Refractive	water/water interface
	Water/Air	Refractive	water/air interface
	BLACK1	Reflective	semi-gloss black paint
	Vacuum Metalized	Reflective	vacuum metalized plastic
	Tran 90%	Transmissive	constant 90% transmission, 0% reflection
	Tran 80%	Transmissive	constant 80% transmission, 0% reflection
	Tran 70%	Transmissive	constant 70% transmission, 0% reflection
	Tran 60%	Transmissive	constant 60% transmission, 0% reflection
	Tran 50%	Transmissive	constant 50% transmission, 0% reflection
	Tran 40%	Transmissive	constant 40% transmission, 0% reflection
	Tran 30%	Transmissive	constant 30% transmission, 0% reflection
	Tran 20%	Transmissive	constant 20% transmission, 0% reflection
	Tran 10%	Transmissive	constant 10% transmission, 0% reflection

Table 1: Bulk properties for materials
(adopted from SW and Photopia)

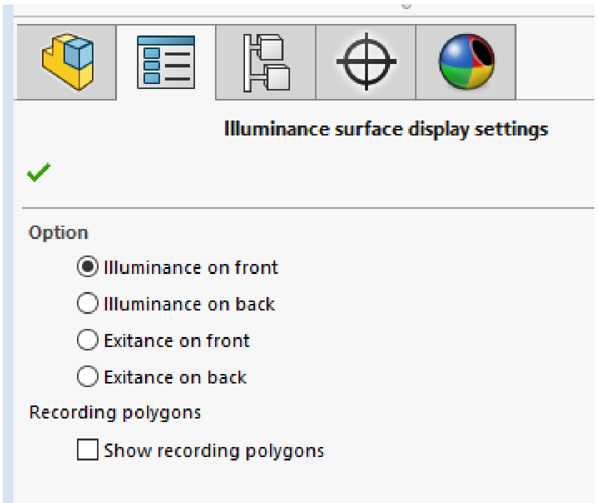

Table 2: Predefined sensor (illuminance) surfaces
(adapted from SW and Photopia)

The surface and bulk properties will be contained in a validated database of materials and properties maintained by VERISA. Qualified users will have access to the database, so the necessary parameters can be utilized by the CAD and photonics software. Users will also be allowed to submit new materials and sources to VERISA for consideration and validation.

Once a virtual model is created and installed into the VERISA environment, the operator/user will be able to use their hand to:

- Manipulate components from source, through transmission, to detection in terms of scaling and positioning, and;
- Act as the detector and beam mode analyser.

Additionally, the system will allow the user to visualize hot spots or surfaces where beams contact surfaces.

Model Functionality

In addition to the optical material characteristics and illuminance of the various surfaces, the control limits for the mechanical elements will be established in the CAD model.

Most professional level CAD software have the tools that will allow the user to fix components with respect to one another and to control their limits of movement. These types of controls must be transferred into the VERISA environment so that the model can be exercised by the user to determine the effects of those movements as they relate to changing the nature of the beam hazards which will exist.

Once in the VERISA environment, one will be able to move the components by operating the controls as one would in a normal optical set up. For instance, kinematic mounts would be operated by turning the alignment screws, and if the setup has a gimbal mount, the user would be able to adjust the orientation using joy stick controls or other mechanism as defined in the model.

Planned Model Results

In addition to the standard tabular information output expected of such software, VERISA will be able publish:

- Iterations of design of NHZ/MPE/LCA to safe levels;
- Boundaries (standards and code sections) violated;
- Motion capture (video) of process to see actual choices made (with links to metadata should operator note specific actions);
- Aggregated data to advance continued development of Expert Systems (ES) and Artificial Intelligence (AI) for safety systems

Continued Evolution

The baseline model discussed demonstrates that basic Photonics processes can be shown within current CAD environments. The process of manipulating those models is time consuming and still requires a skilled operator to exercise the system so a user can evaluate the hazards of a system before it is built.

The next goal is to convert this to an operational Virtual and Augmented environment with the necessary physical controls and computer processing power to display this in real time.

Our performance goal will be that the beam line rendering controls must be achieved in less than 0.1 seconds and the analysis for every sensor point must be resolved in less than 0.01 seconds.

Citations / References:

LaserSafe PC, ScientificPhotonics, GL Services, ©1995-2019

SolidWorks, Dassault Systemes, ©1995-2019

Photopia, LTI Optics, © 2018