LightTrans

Why VirtualLab Fusion?

The Digital Twin Platform for Light

Overview Paper | Version 1.3

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VirtualLab Fusion – Your Virtual Lab, Unified

To predict how an optical system will behave before you assemble it, you first need to create a virtual representation—and that is why we gave our software the name VirtualLab. And because we combine the diversity of simulation concepts known in optics literature into one unified simulation environment, we call it VirtualLab Fusion.

The Logic You Already Know

When you choose a software product, you choose a simulation concept—for example, ray tracing. That is how it works. For the simulation of many optical systems, that is perfectly fine.

But when your system includes assets that require different simulation concepts, you end up in tool-hopping. And you know how painful that is.

Or worse: sometimes no software product provides a simulation model for an asset at all.

We are not here to replace what works. We are here for the cases where your current approach reaches its limits.

The solution is logical: the software does not enforce a single simulation concept on all assets. It uses the best one for each asset. That is what we do.

A. The Demand: Simulation of Modern Optical Systems

Modern optical systems are built from diverse assets. Different assets demand different modeling approaches. A lens, a grating, a metalens, a waveguide, a detector—each has its own physics. Each requires its own balance of accuracy and speed. Traditional software, built around a single dominant method, cannot deliver this in a unified way. It forces all assets into one modeling box, regardless of whether it fits.

The consequence is painful **tool-hopping**: users must switch between different software products to simulate their full system. This is time-consuming, error-prone, and forces users to learn multiple products with different user interfaces. Moreover, connecting these products—each built around different modeling concepts—lacks a clear foundation in optical theory.

So the demand is clear: you need a platform that can use different modeling concepts for different assets, and connect them seamlessly.

B. The Solution: Optical Digital Twins

VirtualLab Fusion delivers exactly that.

We take inspiration from working in a real optical lab and transfer that concept into simulation. In VirtualLab Fusion, real lab assets—such as sources, components, objects in the light path, and detectors—are replaced by optical digital twins.

Each digital twin represents a parametric class of an optical asset. For example, a Gaussian beam source twin defines the class of Gaussian beams and allows you to adjust parameters like wavelength and beam radius and also the order of the beam, to define the exact source for your simulation. In the same way, you configure other twins to match your specific optical setup. Each twin provides an interface for this configuration and simulates the optical behavior using a tailored, built-in simulation model.

Key point: Each twin comes with its own simulation model, chosen to optimize the balance between accuracy and speed. These models may draw on any theoretical concept in optics—

including geometrical optics, scalar optics, paraxial optics, Fourier optics, physical optics, and electromagnetic optics, as well as their modifications and combinations.

You build your system from these twins. Running a simulation means propagating light non-sequentially from source twins through component twins to detector twins—connecting all the different simulation models in a unified environment.

This gives you the diversity of models needed to simulate the full range of optical sources, components, and detectors—while you enjoy a unified simulation experience. The platform maintains the speed of geometrical optics where appropriate, for example in traditional lenses, and seamlessly connects with other modeling concepts, such as electromagnetic simulation for gratings and metalenses, wherever needed.

To use the platform and its existing twins, you do not need to be an expert in each simulation model. The expertise is built into the twins. The user interface focuses on the parameters for asset and system configuration.

This approach makes high-end simulation technology accessible and flattens the learning curve. You can concentrate on building your system and running simulations, rather than studying different modeling concepts and user interfaces for each product and each concept.

Summary

To simulate modern optical systems, different modeling concepts are needed for different assets—and they must be connected. Software products that offer only one dominant modeling approach must be connected externally, which is technically challenging and conceptually weak.

VirtualLab Fusion solves this challenge at its core: suitable simulation models are built into the optical digital twins that represent the assets and are seamlessly connected in system simulation.

What You Get with VirtualLab Fusion

- A unified simulation environment based on a solid physical foundation
- Optical Digital Twins with built-in, tailored models
- Seamless connection of simulation concepts ranging from geometrical to electromagnetic optics

"Understand Scenario. Select Twins and Tools. Simulate and Design."

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How to Get Started with VirtualLab Fusion

From Your Scenario to Your Virtual Lab

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Your Scenario, Your Assets, Your Task

You have your scenario. You know what is in your system—sources, components, detectors. Your central question is: how can I simulate this system with all its assets? That is where working with VirtualLab Fusion starts.

1. Start with Your Asset List

Begin with a practical description of your optical scenario. What sources, components, objects in the light path, detectors, measurement tasks, target quantities, and critical parameters are involved?

This asset list is the foundation. It connects your real setup, device, product, or measurement task to the virtual setup in VirtualLab Fusion.

2. Check the Twin Hub

With your asset list in hand, check the Optical Digital Twin Hub to see which Optical Digital Twins already exist for your assets. Use Cases and the Document Center can also inspire you and show what is possible.

We are always available to support you in solving your modeling and design tasks. You can explore on your own—but you are welcome to ask us. In fact, we encourage it.

3. Get Expert Support – We Are Here to Help

We are not just a software provider—we are your technical partner.

When you contact us, you reach colleagues who discuss optics and physics with you at eye level. We take the time to understand your scenario, add our expertise, and together we map it to the right twins and tools.

After a technical discussion and the clarification of the technical path to a solution, our sales experts take over and handle the business side.

Contact us at support@lighttrans.com. People who have contacted us know: we provide real technical expertise—not just sales talk.

Save time. Get clarity. Let us find the best technical path forward for your project.

4. If a Twin Is Missing

Sometimes a required twin or tool does not yet exist. That is not a dead end.

Because of our twin concept, we can embrace the full diversity of ideas and simulation technologies—from modern literature, from our own developments, or from your ideas—to tailor a simulation model that fits the asset perfectly and works seamlessly with all other optical twins.

The VirtualLab Fusion concept makes this possible. The platform is designed to grow—with new expertise, new models, and new capabilities, from us or from you.

You have several options to add new twin technology:

- **Use our SDK** to bring your own models and expertise into the platform.
- **Trigger development through our roadmap.** We learn from you about your needs. Often, your request aligns with a broader market trend. In that case, we add the devel-

opment of the missing twin or tool to our roadmap and inform you about the expected timeline.

- **Agree on a prioritized development path.** If you need the solution faster and cannot wait for the roadmap, we can define a clear timeline, scope, deliverables, and commercial commitment together.

Summary

Getting started with VirtualLab Fusion follows a clear, practical path:

1. **Start with your asset list.** What sources, components, and detectors are in your system?
2. **Check the Twin Hub.** See which Optical Digital Twins already exist for your assets.
3. **Get expert support.** We are here to help—like colleagues, not salespeople.
4. **If a twin is missing,** you have several options: roadmap integration, SDK development, or a commercial path.

We are here to support you at every step.

Where to Go Next

- Contact us at support@lighttrans.com – we encourage you to reach out. We are happy to help you find the best path for your project.
- Once we have clarified your scenario and your technical path to a solution, we also provide a full evaluation version where you can test the solution path yourself—while one of our support engineers helps you to get things done quickly.
- Explore the Optical Digital Twin Hub – browse available twins
- Read Use Cases – learn from application examples
- Browse the Document Center – find white papers and technical documentation
- Try the Trial Version – work with twins yourself

"Understand Scenario. Select Twins and Tools. Simulate and Design."

LightTrans

The Physical Foundation of VirtualLab Fusion

Optical Digital Twins and Connecting the Diversity of Simulation Models

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One Method Cannot Do It All

Optical systems are diverse. A lens behaves differently from a grating. A metalens is different from a waveguide. Each optical asset has its own physics and requires its own approach to simulation.

VirtualLab Fusion was built around this simple observation.

1. The Core Idea: Optical Digital Twins

In VirtualLab Fusion, every optical asset in your system is represented by an Optical Digital Twin.

- A **Source Twin** represents your light source.
- A **Component Twin** represents a lens, grating, metalens, waveguide, or other optical element.
- A **Detector Twin** represents your measurement or analysis.

Each Optical Digital Twin is a digital representation of a real lab asset. It provides a user interface with parameters—such as focal length, period, material, or geometry—and contains a tailored simulation model for its optical behavior.

Key point: Each twin uses a simulation model tailored for that specific asset. We put no restrictions on the type of simulation model used per twin. Instead, we can utilize the wealth of simulation concepts from different optics disciplines, add new ideas from in-house research and literature, and by that ensure that the twin receives a simulation model which enables the appropriate accuracy-speed balance. This can also mean that one asset comes in more than one twin, with different built-in models.

2. Three Enablers and One Orchestrator

For the twin concept to work, we need three enablers and one orchestrator.

Enabler 1: Each twin has its own simulation model

The simulation model inside each twin can be selected from any optics discipline or newly developed. This is how we achieve the diversity of modeling approaches needed for different assets.

Enabler 2: A common light representation for all twins

All twins must be able to communicate. Some of them require full electromagnetic field information—full information about light that any built-in method may need access to. Thus, there is no way around it: the universal light representation for all twins must be electromagnetic fields. That is the only way to obtain a unified platform on which all twins can communicate with each other.

Conclusion: VirtualLab Fusion uses electromagnetic fields as the common input/output language for all twins.

A twin does not have to use all information carried by the field. If its built-in method only needs part of it, the rest can simply be bypassed inside the twin. But the common representation must not limit what other twins and modeling techniques can access.

Enabler 3: Electromagnetic light representation demanded — approximations of light propagation welcome

This is the enabler that can be a source of confusion—and therefore the most important one to state clearly.

Enabler 2 demands that the light representation is never reduced to a subset—for example, only one component, only intensity, only phase, only local directions represented by rays.

However, this does **not** mean that the propagation of light, in free space or when interacting with matter, cannot be approximated. Often in textbooks and literature, the approximation of light propagation is linked to a specific representation. The most prominent example is the geometrical optics approximation—the neglecting of diffraction—which is commonly linked to a ray representation of light.

Here we cite from *Principles of Optics*, the famous book by Born and Wolf:

> *"It is, however, possible, and from our point of view quite natural, to extend the meaning of geometrical optics to embrace also certain geometrical laws relating to the propagation of the 'amplitude vectors'* $\mathbf{E}$ *and* $\mathbf{H}$*."* [1]

We follow exactly this advice and extend it to all simulation concepts, enabling them to work with fields.

Here is what this means in practice, with a brief description of what each approximation implies for fields for important cases:

- **Rigorous Maxwell solver:** When we solve Maxwell's equations, we naturally work with electromagnetic fields and no further consideration is needed.
- **Approximated Maxwell solver:** We still work with vectorial fields, but with some simplifying assumptions—for example, specific material models, reduced structural complexity, or simplified boundary conditions.
- **Scalar optics:** When we assume that the transversal field components experience the same effect and that we have no crosstalk, at least in a paraxial approximation we have no vectorial effects. That leads in literature often to the conclusion to work with a placeholder U for the field components and call it scalar. But that is not needed. We can work with fields by applying the same model on the transversal components. Then, the full field information is maintained.
- **Paraxial optics:** The propagation model uses the paraxial approximation. In terms of the field, this means the longitudinal (z) components of the field are approximately zero. The propagation itself can also be approximated within this regime.
- **Geometrical optics:** From a field point of view, this means propagation without diffraction. The fields have local directions—often associated with ray directions. These directions are associated with the wavefront phase, which is common to all field components. The extraction of this phase is not an approximation. But its use to define local directions is what makes geometrical optics for fields possible, including the high speed of simulating light propagation. This applies when fields are in their geometrical zone, which mainly means not in focal regions.

[1] Principles of Optics, p. 125, 7th edition, 1999.

- **Fourier optics:** We work with models in different domains—frequency and time, real space (x) and spatial frequency (k)—and connect them via Fourier transforms. This is a general framework, not an approximation level. It can be combined with any of the above approximations as needed.

Other approximations: Many more approximations exist in the literature. Many are already formulated for fields; others can be reformulated if needed. In either case, they can be used inside a twin. LightTrans has also invented and implemented specialized modeling approaches for specific assets.

The key distinction is between the light representation and the modeling of light propagation.

- **The light representation** = electromagnetic fields (the complete, un-approximated language).
- **The modeling of light propagation** = the simulation model inside each twin, with its chosen level of approximation.

This separation is the foundation of the entire approach. It allows us to keep the light representation consistent and complete across the whole system, while still using approximations for propagation and interaction wherever they are useful for a specific asset and the propagation between them. The light representation and the simulation model approximation are decoupled.

The Orchestrator: Field tracing

Fields are traced non-sequentially from source twins through the relevant component twins and finally to detector twins. This is what LightTrans refers to as field tracing.

Field tracing is the orchestrator of the Optical Digital Twin approach. It allows twins with different built-in methods to work together in one optical simulation and design workflow on a platform with a unified optical foundation.

It does not replace the tailored method inside each twin; it enables the twins to work together. Field tracing propagates the light between twins, including diffraction where needed.

3. The Virtual Lab – Built from Twins

In VirtualLab Fusion, you build your system by arranging twins in a virtual setup—just like you would arrange real assets on an optical table.

- You select the twins that represent your assets.
- You arrange them in the order that matches your system.
- You run the simulation. Field tracing connects the twins. Each twin applies its own method. The result is a unified simulation of your entire system.

This is your virtual lab. It grows with your needs. Add new twins when you need new assets. Add new tools when you need new capabilities.

4. Built-In Expertise

The built-in methods inside the twins are selected and tailored by LightTrans from a wide pool of optical modeling techniques. As a user, you do not need to be an expert in all these models. You use the twin; the appropriate model is already built in.

For users interested in the theory behind a twin, LightTrans provides white papers and further technical documentation.

Summary

The concept behind VirtualLab Fusion rests on three core principles:

- **Optical Digital Twins** represent your assets. Each twin uses a simulation model tailored to that asset, selected from any optics discipline.
- **All twins share a common light representation:** electromagnetic fields. This is the input/output language for communication between twins. It ensures that full information about light is available to any twin that needs it.
- **Approximations can be applied to the modeling of light propagation — not to the light representation itself.** The light representation by electromagnetic fields and the level of approximation of the simulation model are decoupled.

This is the concept behind VirtualLab Fusion: a unified platform for optical simulation and design, built from digital twins with tailored simulation models inside, connected by field tracing, and based on a clear separation between light representation and approximation of light propagation.

"Understand Scenario. Select Twins and Tools. Simulate and Design."