Knife-Edge

Digital Twin Specification Sheet | Version 1.0 | CF-KNED01

Specification identity

Twin Code:	`CF-KNED01`
Twin Name:	Knife-Edge
Twin Family:	Apertures, Stops, and Arrays
Family Role:	Models a movable optical edge for beam truncation, diffraction studies, and knife-edge beam-size measurement
Category:	Component
Type:	Function-Based
Package:	Platform

1 Purpose

The **Knife-Edge** twin represents an opaque screen boundary that can be positioned across an optical beam.

Its central application is virtual knife-edge beam metrology: the edge is scanned laterally through the beam and the transmitted radiant flux is recorded as a function of edge position. From this transmission curve, the beam size can be reconstructed.

The current LightTrans feature demo *Knife-Edge Beam Size Measurement* demonstrates this workflow and shows agreement between the beam size reconstructed from transmitted radiant flux and the direct field evaluation.

2 Geometric Support

For an ideal edge aligned with the y-axis, one half-plane transmits the field and the opposite half-plane blocks it. The edge can be shifted laterally to scan across the beam and rotated to change its orientation in the component plane.

A finite **Edge Width** can be used to represent a smooth transition instead of an infinitely sharp boundary.

3 Supported Field Operation

For an ideal edge at $x = 0$, the transmission is

$$t(x, y) = \begin{cases} 1, & x \geq 0, \\ 0, & x < 0. \end{cases} \tag{1}$$

The outgoing field is

$$\mathbf{E}_{\text{out}}(x, y) = t(x, y)\, \mathbf{E}_{\text{in}}(x, y). \tag{2}$$

The edge position and orientation determine which part of the field is transmitted.

4 Simulation Model

A physically finite edge can be represented by a smooth transition region of width Δw_e:

$$t(x,y) = \begin{cases} 1, & x \geq \Delta w_e/2, \\ 0, & x < -\Delta w_e/2, \\ \text{smooth transition}, & \text{otherwise.} \end{cases} \tag{3}$$

The finite transition width controls how sharply the field is truncated and therefore how strongly the edge contributes diffraction effects.

VirtualLab Fusion handles the numerical sampling required by a sharp edge internally. The user specifies the physical edge behavior; the implementation details used to keep the calculation efficient are intentionally not part of the user-facing model.

5 Parameters Where This Sheet Adds Guidance

Edge Position

Role: Lateral position of the knife edge in the component plane.

Spec-sheet insight: This is the parameter to scan for a classical knife-edge measurement. Evaluate transmitted radiant flux for successive edge positions.

Edge Orientation

Role: Rotation of the blocking boundary in the component plane.

Spec-sheet insight: Align the edge with the direction in which the beam profile should be measured. Repeating the measurement with another orientation allows different transverse directions to be investigated.

Edge Width Δw_e

Role: Width of the smooth transition between blocked and transmitted regions.

Spec-sheet insight: Smaller values represent a sharper physical edge and can strengthen diffraction effects. Start with a physically reasonable finite width and reduce it only when the influence of sharper edges is relevant.

Edge Samples N_e

Role: Number of samples across the finite edge transition.

Spec-sheet insight: The internal Knife-Edge specification recommends $N_e \geq 4$, with $N_e = 4$ normally sufficient. Increase it only when a convergence check indicates that the transition is not adequately resolved.

6 Recommended Usage

Knife-Edge Beam Size Measurement

1. Place **CF-KNED01 - Knife-Edge** in the plane where the beam profile should be measured.
2. Position the edge so that the beam is initially largely transmitted.
3. Scan the edge laterally across the beam using a parameter variation.

4. Evaluate the **transmitted radiant flux** for each edge position.
5. Build the cumulative transmission curve from the scan.
6. Reconstruct the beam size from the measured flux curve.
7. Compare the reconstructed result with a direct field-based beam-size evaluation when a reference is desired.

This reproduces the principle of a real laboratory knife-edge measurement while keeping the complete measurement chain inside the optical simulation.

Diffraction-Aware Edge Studies

The same twin can be used whenever the influence of a finite blocking edge on a propagated field is relevant. Choose an appropriate physical Edge Width and verify convergence if very sharp edges are used.

Usage note

The Knife-Edge twin models the optical interaction with the edge. Beam-size reconstruction requires a scan of the edge position together with evaluation of transmitted radiant flux, as demonstrated in the dedicated LightTrans feature demo.

7 Related Twins

Related twin	Main distinction
Aperture [Elliptical, Rectangular]	Finite transmitting aperture instead of one blocking half-plane.
Aperture [General Shape]	Arbitrary aperture geometry instead of a single straight edge.
Stop / Stop [Truncation]	General blocking or truncation elements.
Beam Size Detectors	Direct field-based beam-size evaluation instead of scan reconstruction.

8 Possible Replacement Twins

Possible replacement twin	When it replaces this twin
Stop / Stop [Truncation]	Use for general blocking or truncation without a dedicated edge scan.
Aperture variants	Use when the relevant geometry is a transmitting opening.
Beam Size Detector	Use for direct field-based beam-size evaluation.

9 Further Reading

- LightTrans Feature Demo – *Knife-Edge Beam Size Measurement*, published September 18, 2026.
- VirtualLab Fusion 2026.1 release notes – CF-KNED01, Knife-Edge.
- Internal Knife-Edge twin specification – simulation model, edge width, edge sampling, positioning, and orientation behavior.