

Instantaneous Irradiance Detector

Digital Twin Specification

Twin Code:	DF-IIRR01
Twin Name:	Instantaneous Irradiance Detector
Category:	Detector
Type:	Function-Based
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Package:	Platform
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Description

The Instantaneous Irradiance Detector evaluates the time-dependent electromagnetic field to calculate the instantaneous irradiance—the power per unit area at each moment in time. Similiar to the Pulse Detector [Temporal], it provides time-resolved analysis of pulsed optical fields at spatial evaluation regions of your choice: points, lines, or rectangles.

This twin reveals the temporal dynamics of optical pulses, showing either the rapid oscillations at the optical carrier frequency or the smoothed intensity envelope, depending on your analysis needs.

Simulation Model

The instantaneous irradiance is calculated from the time-dependent electric and magnetic fields. For a propagating field, the instantaneous irradiance along the propagation direction \mathbf{u} is given by the magnitude of the Poynting vector component in that direction:

$$I(t) = |\mathbf{S}(t) \cdot \mathbf{u}| = |(\mathbf{E}(t) \times \mathbf{H}(t)) \cdot \mathbf{u}| \quad (1)$$

For fields normally incident on a detector plane, this simplifies to the magnitude of the Poynting vector perpendicular to that plane.

Key Physical Principle: Field Oscillations vs. Envelope

The detector can output either:

- **Full irradiance including carrier:** Shows rapid oscillations at the optical frequency, resolving individual cycles of the electromagnetic wave.
- **Temporal intensity envelope only:** Shows the pulse shape without carrier oscillations, representing the averaged power flow.

The choice depends on whether your application requires resolution of optical cycles (e.g., for nonlinear optics, pulse shaping) or only the pulse envelope (e.g., for energy delivery calculations).

Model Parameters

The instantaneous irradiance add-on evaluates the field internally and calculates irradiance based on the following parameters that control the field evaluation:

- **Show Pulse With Carrier Frequency:** Boolean switch (default: `false`).
 - `false`: Output only the temporal intensity envelope (smoothed, carrier-free).

- **true**: Output the full instantaneous irradiance including high-frequency carrier oscillations.
- **Oversampling Factor**: Numeric value ≥ 1 (default: 1).
 - Interpolates the frequency-domain data onto a finer grid before inverse Fourier transform to time domain.
 - Higher values produce smoother time-domain signals and a longer effective time window without aliasing.
 - Essential when resolving carrier oscillations (factor 10–100 typically needed).
- **Evaluation Region**: Selection of spatial evaluation mode.
 - **Point**: Evaluate at a single (x, y) coordinate. Output is 1D (irradiance vs. time).
 - **Line**: Evaluate along a line defined by start and end points with specified number of samples. Output is 2D (time vs. position along line).
 - **Rectangle**: Evaluate over a rectangular region with specified sampling in x and y . Output is 3D (time vs. x vs. y).

Typical Application Scenarios

1. **Ultrafast pulse characterization**: Analyze the temporal shape and peak irradiance of femtosecond and picosecond laser pulses at specific points in an optical system.
2. **Pulse propagation dynamics**: Track how pulses broaden, compress, or distort as they propagate through dispersive media by evaluating irradiance along a line in the propagation direction.
3. **High-NA focusing of ultrashort pulses**: Investigate how tight focusing modifies the temporal structure of pulsed beams in the focal region.
4. **Laser-material interaction studies**: Determine peak irradiance levels at material surfaces for damage threshold analysis or processing optimization.

Software Usage

After adding the Pulse Detector (Temporal) to your system:

1. **Activate the detector add-ons**: Double-click the detector icon to open its properties. Navigate to the **Add-ons** tab. You will find three available add-ons: *Pulse Evaluation (Point)*, *Pulse Evaluation (Line)*, and *Pulse Evaluation (Rectangle)*. Activate the desired one by clicking the eye symbol next to it.
2. **Configure the evaluation region**:
 - For a *Point*, enter the (x, y) coordinates in the detector’s local coordinate system.
 - For a *Line*, define the start and end points and the number of sampling points along the line.
 - For a *Rectangle*, set the corner coordinates and the number of sampling points in x and y .
3. **Set time-domain parameters**: In the same add-on dialog, specify:
 - **Oversampling Factor**: Start with 1 for envelope-only analysis; increase to 10–100 when resolving carrier oscillations.

- **Show Pulse With Carrier Frequency:** Enable only when you need to resolve optical cycles (requires sufficient oversampling).
4. **Run the simulation:** Execute the field tracing. The detector internally evaluates $\mathbf{E}(t)$ and $\mathbf{H}(t)$ at each spatial sample point via inverse Fourier transform of the frequency-domain data and calculates the instantaneous irradiance.
 5. **Visualize results:** After simulation, open the detector's result window to display the instantaneous irradiance. For line and rectangle evaluations, you can also create animations showing temporal evolution across the spatial region.

Important notes:

- The choice between envelope and carrier-resolved output dramatically affects memory usage and computation time—carrier resolution requires much finer temporal sampling.
- When evaluating along lines or rectangles, consider the spatial Nyquist criterion: ensure adequate sampling to resolve spatial irradiance variations.
- The instantaneous irradiance is calculated internally from both electric and magnetic fields—no additional user configuration is required.

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Related Twins:	DF-IFLX01, DF-PDTE01, DF-PDUR01, DF-PENG01, DF-PDFR01