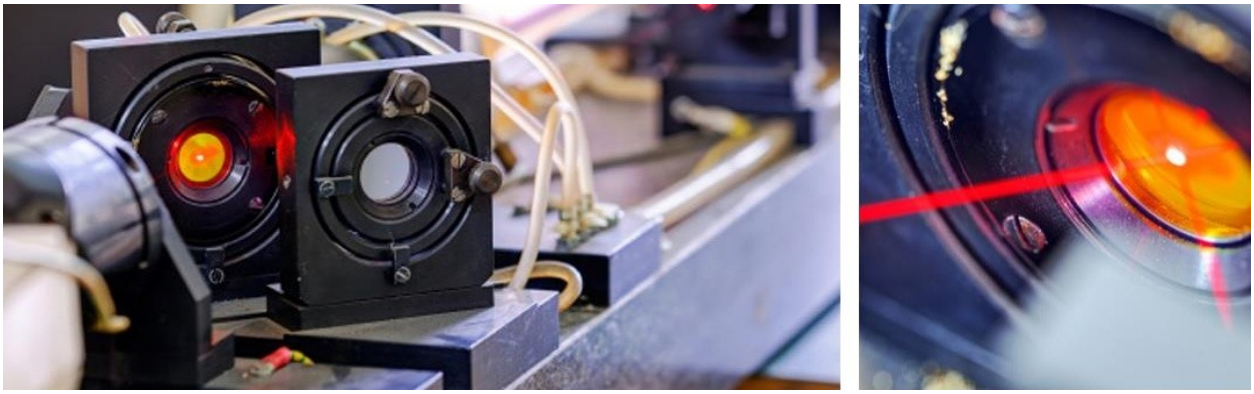
Fast edges and picosecond timing for laser and electro-optic benches

Edge time, interval jitter and drive amplitude, derived from the optical requirement

Pulse and delay generator white paper · BNC-AN-112 Rev A · October 2026 | dc-62029201



Cover photo. Optical mounts on a laser bench, and a red laser beam meeting an optic, the kind of setup this paper times.

Abstract

On a photonics bench every timing quantity is also a length: 10 ps is 3.0 mm of free-space path. This paper derives the electrical requirements a pulse source must meet when it drives a laser trigger, an electro-optic gate and a detector window that have to coincide. It relates the two rise-time conventions, shows how oscilloscope bandwidth inflates a measured edge, explains why the jitter that matters is the jitter of the interval between two edges, and derives how much of a programmed pulse is usable once its edges are counted. A worked example budgets a 1 ns modulator gate around a short optical pulse. The reader will be able to write a pulse-source requirement, score any instrument against it and set up the bench to verify the result.

Who this paper is for. Laser, LiDAR and electro-optic test engineers who build pulsed benches, and the research staff who specify their timing. Design and test engineers get a requirements table they can lift into a specification; researchers get the derivations behind it.

David Brown, President, Berkeley Nucleonics Corp.

Key results

- **3.0 mm**: of free-space path per 10 ps of timing error
- **30%**: slow reading of a 105 ps (10% to 90%) edge on a 4 GHz oscilloscope, k = 0.35
- **1/3 the specified interval jitter**: with both edges on one timebase, under 10 ps RMS versus under 30 ps RMS through a trigger link
- **895 ps**: above 90% amplitude in a 1 ns gate with 105 ps (10% to 90%) edges

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1. Timing on an optical bench is a length

In free space, light covers 3.0 mm in 10 ps or 30 cm in 1 ns. On a bench where a laser pulse, an electro-optic gate and a detector window must coincide, every timing quantity is therefore also a length. A 100 ps error in a detector gate is 3.0 cm of optical path, and in a time-of-flight measurement, where the light makes the trip twice, it is 1.5 cm of range. The conversion changes by no more than about a factor of 1.5 across the media on the bench, including the coaxial cable that carries the electrical pulse to the device.

Interval	Free space	Silica fiber, group index 1.468	Coax, velocity factor 0.66
10 ps	3.0 mm	2.0 mm	2.0 mm
100 ps	30 mm	20 mm	20 mm
1 ns	300 mm	204 mm	198 mm

Table 1. Ten picoseconds is 2 to 3 mm of path in every medium on the bench, so a picosecond timing budget is also a millimeter path budget.

Computed as path = c × interval / n, with c = 299.79 mm/ns. The group index is typical of standard single-mode fiber near 1550 nm; the velocity factor is typical of solid polyethylene dielectric.

Table 1 sets the scale for everything that follows. Three properties of the electrical pulse decide the optical result. The **edge time** sets how quickly a modulator, a gate or a laser-diode driver changes state, and so how much of a programmed width is usable. The **timing**, meaning where each edge is placed and how far it wanders from shot to shot, sets whether the optical events coincide. The **amplitude** decides whether the device switches at all: a few volts reach the half-wave voltage of a typical traveling-wave modulator, while many driver stages need tens of volts.

A common way to build such a bench uses the instruments already on it: a function or arbitrary waveform generator to trigger the laser, a digital delay generator to place gates, and the digitizer’s own trigger. The arrangement is flexible, every instrument in it is well understood, and for optical features of tens of nanoseconds it is adequate. Its limits appear as the features shrink toward a nanosecond. Each instrument contributes its own edge time, and each trigger link between instruments adds an insertion delay, which can be calibrated out, and a random jitter, which cannot. Section 4 converts these effects into numbers a requirements document can carry.

2. Edges, bandwidth and timing

Two conventions for one edge

An edge is specified by the time it takes to cross between two fractions of its amplitude. Two pairs of reference levels are in common use, 10% to 90% and 20% to 80%, and IEEE Std 181 defines the

reference levels and the terms used for them. For an edge whose shape is close to Gaussian, the two readings are related by a fixed ratio:

$$t_{10–90} \approx 1.52 \cdot t_{20–80} \quad (1)$$

where:

- $t_{20–80}$ is time between the 20% and 80% levels, 70 ps to 400 ps for the edges in this paper
- $t_{10–90}$ is time between the 10% and 90% levels

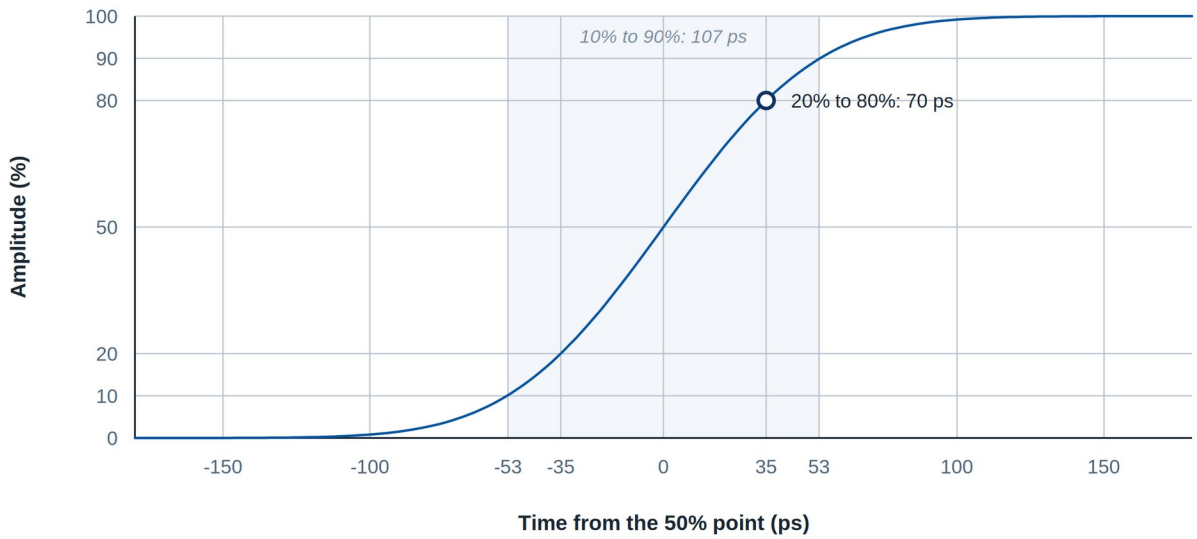


Figure 1. An idealized Gaussian edge with a 70 ps (20% to 80%) rise time reads about 1.5 times slower in the 10% to 90% convention, so a rise-time figure is incomplete without its reference levels. *[Derived]*

The ratio follows from the error-function shape of a Gaussian edge: the 10% and 90% points lie 1.28 standard deviations from the midpoint and the 20% and 80% points lie 0.84, and 1.28 / 0.84 = 1.52. Figure 1 draws an idealized 70 ps (20% to 80%) edge, which reads 107 ps between 10% and 90%. Published captures agree closely: an edge measured at 390 ps (20% to 80%) and 577 ps (10% to 90%) gives a ratio of 1.48. Real edges with overshoot depart from the Gaussian shape, which is why datasheets specify the two conventions separately; equation (1) is a conversion for comparison, not a substitute for measuring in the convention a specification uses.

Bandwidth, and what the oscilloscope adds

Rise time and bandwidth describe one property from two sides:

$$t_{10–90} \approx k / B \quad (2)$$

where:

- k is 0.35 for a single-pole response, about 0.34 for a Gaussian response, and 0.4 to 0.45 for the flatter responses typical of high-bandwidth oscilloscopes
- B is the −3 dB bandwidth, for example 4 GHz

Equation (2) works in both directions. A source with 100 MHz of analog bandwidth cannot produce an edge much faster than 3.5 ns, and an edge of 105 ps (10% to 90%) carries significant spectrum out to about 3.3 GHz. When that edge passes through a cable, a probe and an oscilloscope, each stage adds its own rise time, and for near-Gaussian responses the stages add as a root sum of squares:

$$t_{meas} = \sqrt{(t_{sig}^2 + t_{sys}^2)} \quad (3)$$

where:

- t_{meas} is the rise time displayed
- t_{sig} is the rise time of the signal itself, 105 ps in the example below
- t_{sys} is the combined rise time of oscilloscope, probe and cable, from equation (2)

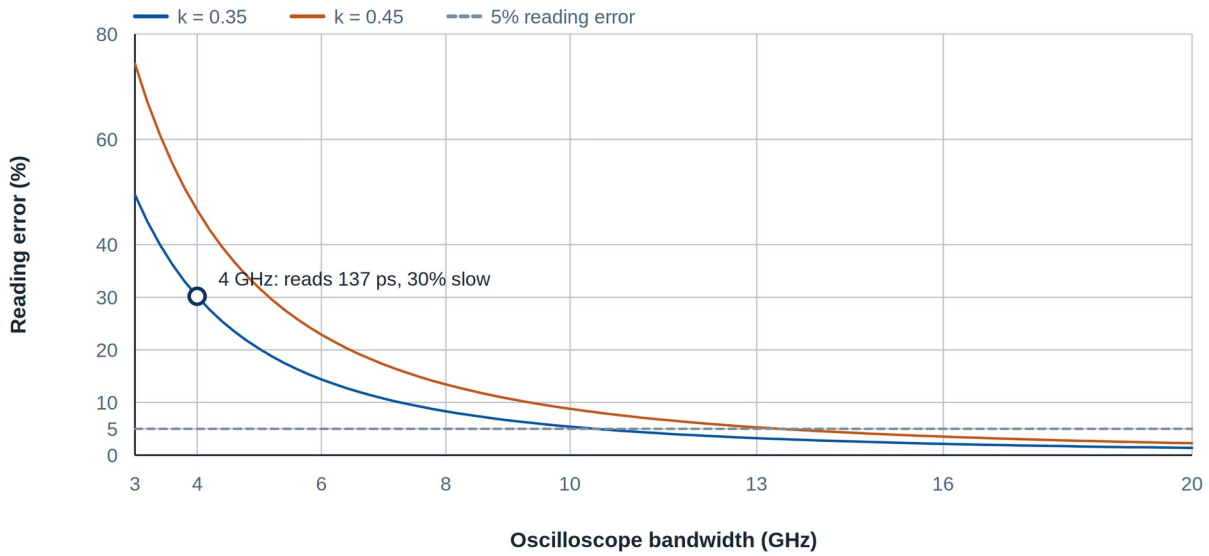


Figure 2. A 105 ps edge reads 30% slow on a 4 GHz oscilloscope; reading it within 5% takes about 10 GHz for k = 0.35 and 13 GHz for k = 0.45. *[Derived]*

The idealization in equation (3) is generous: responses with overshoot or a sharp roll-off do not add exactly in quadrature, so the result is an estimate good to a few percent. It is still the right tool for choosing an oscilloscope. A 105 ps edge viewed on a 4 GHz oscilloscope with k = 0.35 (t_{sys} = 87.5 ps) reads $\sqrt{(105^2 + 87.5^2)}$ = 137 ps, 30% slow. Reading it within 5% requires $t_{sys} \le 0.32 \times 105$ ps = 34 ps, which is a bandwidth of about 10 GHz for k = 0.35 and about 13 GHz for k = 0.45. Figure 2 plots the error across the range.

Slew rate: amplitude and edge together

A driver stage or a modulator responds to how fast the voltage changes, not to the edge time alone. Between the 20% and 80% points an edge crosses 60% of its amplitude, so:

$$SR = 0.6 \cdot V / t_{20–80} \quad (4)$$

where:

- SR is slew rate through the middle of the edge, in V/ns
- V is pulse amplitude, 5 V to 50 V in this paper

A 5 V pulse with a 70 ps edge slews at 0.6 × 5 / 0.070 = 43 V/ns. A 50 V pulse with a 400 ps edge slews at 0.6 × 50 / 0.400 = 75 V/ns. The second edge takes almost six times longer and still changes voltage faster, which is why edge time and amplitude are specified together and traded against each other.

Placement and jitter

Two timing properties matter. **Placement** is how finely an edge can be programmed and how closely it lands where programmed. **Jitter** is the shot-to-shot spread around that place, usually given as an RMS value. Both convert to path length:

$$\Delta x = c \cdot \Delta t / n \quad (5)$$

where:

- c = 299.79 mm/ns
- n is group index of the medium: 1 in free space, about 1.468 in silica fiber
- Δt is a timing error or jitter; for round-trip ranging, divide Δx by 2

Independent jitter sources add in quadrature:

$$\sigma_{int} = \sqrt{(\Sigma\, \sigma_i^2)} \quad (6)$$

where:

- σ_{int} is RMS jitter of the interval between two edges
- σ_i is RMS jitter of each independent contributor in the path between those edges

The quantity an optical bench depends on is the jitter of the **interval** between two edges, not the jitter of either edge alone. When both edges come from one timebase, the timebase's own wander is common to both and largely drops out of the interval. When the edges come from two instruments joined by a trigger link, the link's jitter adds to everything upstream of it.

3. Where general-purpose sources reach their limit

A function or arbitrary waveform generator is built to reproduce many waveshapes from one sampled memory. That architecture gives it its flexibility, and it also sets its edge: the output edge is shaped by the reconstruction filter and the analog bandwidth, and from equation (2) a 100 MHz analog bandwidth corresponds to an edge of about 3.5 ns. For a 1 µs pulse that edge is negligible. For a 1 ns gate it is not, as a short construction shows. For a pulse with linear edges, the time between the 50% and 90% points on each edge is half of $t_{10–90}$, so the time a pulse spends above 90% of its amplitude is:

$$t_{90} = w - t_{10–90} \quad (7)$$

where:

- t_{90} is time above 90% of amplitude, the usable flat top; zero or negative means the pulse never reaches 90%
- w is pulse width at the 50% points, for example 1 ns

A 1 ns gate built from 105 ps edges keeps 1,000 − 105 = 895 ps above 90%. Built from 3.5 ns edges it never reaches 90%: the edges are longer than the pulse. Equation (7) assumes equal rise and fall times; where they differ, use their average.

The second limit is the trigger link. Consider the interval between a laser trigger from one instrument and a detector gate from another. From equation (6), the interval jitter is at least the jitter of the link, plus everything upstream. The fast pulse generator described in section 5 specifies the jitter from its trigger input to its trigger output, the event its output pulses are timed from, at under 30 ps RMS, and the jitter between two of its own channels at under 10 ps RMS. An interval routed through the trigger path is therefore specified to within 30 ps RMS, 9.0 mm of free-space path; with both edges on one timebase the specified limit is 10 ps RMS, or 3.0 mm.

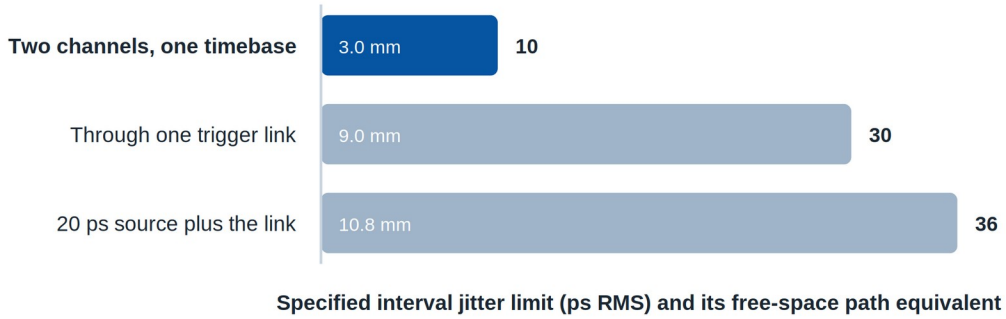


Figure 3. Putting both edges of a critical interval on one timebase gives a specified jitter limit three times lower than routing it through a trigger link, before any upstream source is counted. *[Derived]*

Figure 3 adds a third case, a 20 ps RMS upstream source feeding the link, which raises the interval to $\sqrt{(20^2 + 30^2)} = 36$ ps RMS. This is the buying criterion the rest of the paper uses: **specify the jitter of the interval between the edges that matter, in the operating mode that will be used**, rather than the jitter of a single output. A reader can compute it with equation (6) for any instrument whose datasheet gives channel-to-channel and trigger jitter.

4. Derived requirements

Table 2 converts the physics into a specification for a bench whose shortest optical feature is a 1 ns gate, with the stricter values for a 300 ps feature beside them. The edge requirement takes $t_{90} \geq 2w/3$ in equation (7), so the flat top is at least two-thirds of the pulse. The jitter requirement keeps the ±3σ spread of the interval within one-fifth of the width. These are working rules chosen for this paper; a bench with different tolerances can put its own fractions into the same equations.

Requirement	1 ns feature	300 ps feature	Basis
Edge time, 10% to 90%	≤ 333 ps	≤ 100 ps	Equation (7) with a flat top of at least two-thirds
Interval jitter, RMS	≤ 33 ps	≤ 10 ps	$6\sigma \leq w/5$, from equation (6)
Placement resolution	≤ 10 ps	≤ 10 ps	10 ps is 2 mm of coax (Table 1), so cable mismatch can be trimmed electrically
Amplitude into 50 Ω	Device switching voltage plus margin	Same	A few volts for a modulator; tens of volts for many driver stages
Channels	3 to 4	3 to 4	One per timed element: laser, gate, detector, digitizer
Pulses per channel	2 or more	2 or more	Double pulses and pump-probe pairs from one output with independent delays
Reference clock	Lockable at 10 MHz	Same	Shares a timebase with the laser and the digitizer over long acquisitions

Table 2. Requirements for a pulse source driving a bench whose shortest optical feature is 1 ns or 300 ps; every row can be scored against any instrument's datasheet.

Everything before this table is physics; everything after it is instrumentation. The table is written so that it can be checked against any vendor's published specifications.

5. Meeting the requirements

A fast pulse and delay generator built for this class of work is the Berkeley Nucleonics **Model 765**, with the **Model 765-HV** as its high-amplitude counterpart. Both program period, width and delay in 10 ps steps from one internal timebase, and both accept an external 10 MHz to 100 MHz reference. Table 3 lists the published values that map to the requirements, each with its condition.

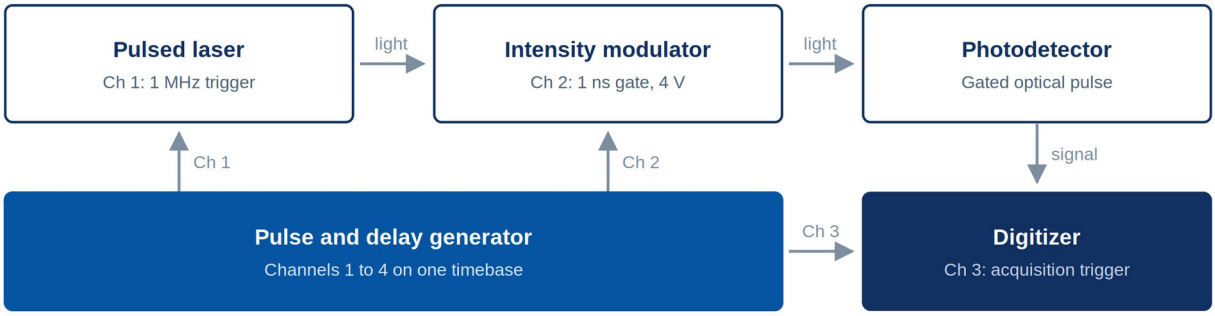
Parameter	Model 765	Model 765-HV
Channels	2 or 4, independent	1 or 2, independent
Rise and fall, 20% to 80%	< 70 ps, up to 5 Vpp into 50 Ω	Rise < 400 ps up to 50 Vpp; fall < 430 ps to 25 Vpp, < 530 ps to 50 Vpp; 0 V offset
Rise, 10% to 90%	< 95 ps at 1 Vpp; < 105 ps at 5 Vpp (rise and fall)	< 570 ps to 25 Vpp; < 630 ps to 50 Vpp; 0 V offset
Fall, 10% to 90%	As rise	< 640 ps to 25 Vpp; < 840 ps to 50 Vpp
Amplitude	10 mVpp to 5 Vpp, within −5 V to +5 V	100 mVpp to 50 Vpp, within −25 V to +25 V
Pulse width	300 ps to period − 300 ps	1 ns to period − 1 ns
Width, delay, period resolution	10 ps	10 ps
Channel-to-channel jitter	< 10 ps RMS, all channels at one frequency, single-pulse continuous mode	< 15 ps RMS
Period jitter	4 ps RMS, 100 Hz to 10 MHz integration, 200 MHz output	< 15 ps RMS
RMS jitter, trigger in to trigger out	< 30 ps (Trigger IN frequency ≤ 15 MHz)	< 30 ps (Trigger IN frequency ≤ 15 MHz)
Repetition rate	200 MHz single pulse; 800 MHz in quadruple-pulse mode	200 MHz single pulse; 400 MHz in double, triple or quadruple mode
Overshoot	< 5%	< 8% to 25 Vpp; < 5% from 25 to 50 Vpp

Table 3. The Model 765 meets the edge and jitter requirements of a 1 ns optical feature with margin; the Model 765-HV trades edge time for ten times the amplitude on the same timing platform.

Published values from the Model 765 datasheet (V1.22) and the Model 765-HV datasheet at berkeleynucleonics.com. Edge times are maxima, so slew rates computed from them are minima.

Read against Table 2, the Model 765 meets the 1 ns column with margin: its 10% to 90% edge of under 105 ps at 5 Vpp is about a third of the 333 ps allowed, and its channel-to-channel jitter of under 10 ps RMS is under a third of the 33 ps allowed. The 300 ps column is met at its boundary: the edge requirement of 100 ps is met at 1 Vpp (under 95 ps), while the specified maximum at the full 5 Vpp is 5% over it, and the jitter requirement of 10 ps is met at the specification limit. Multi-pulse mode places up to four independently timed pulses on each output, which covers double pulses and pump-probe pairs without a second instrument.

Worked example: a 1 ns modulator gate



The generator and the digitizer share one 10 MHz reference.

Figure 4. One generator provides the timing for the laser, the gate signal for the modulator and the trigger for the digitizer, and serves as the common timebase for all critical timing intervals on the bench. *[Schematic]*

Figure 4 shows the bench. Channel 1 triggers a pulsed laser at 1 MHz. Channel 2 drives a 50 Ω traveling-wave intensity modulator with a half-wave voltage of 4 V, a typical value for a lithium niobate device, opening a 1 ns window that passes each optical pulse and blocks the background between pulses. Channel 3 triggers the digitizer, and channel 4 is free for a second gate. The optical pulse is taken as 100 ps wide for illustration. Table 4 works the budget.

Step	Quantity	Value	Arithmetic
1	Gate width at 50%	1,000 ps	Programmed
2	Gate edge, 10% to 90%	< 105 ps	Table 3, 5 Vpp
3	Flat top above 90%	895 ps	1,000 − 105, equation (7)
4	Margin each side of the optical pulse	397 ps	(895 − 100) / 2
5	Interval jitter, channel 1 to channel 2	±30 ps at 3σ	3 × 10 ps RMS
6	Margin after jitter	367 ps	397 − 30; 110 mm of free-space path
7	Amplitude accuracy at 4 V, 0 V offset	±60 mV	1% of 4 V + 20 mV, or 1.5%

Table 4. With both edges on one timebase, electrical jitter uses under a tenth of the timing margin; the laser's own trigger-to-light jitter is the term left to measure.

Two terms are outside the generator. The laser's trigger-to-light latency is fixed and is removed by programming channel 2's delay, which also absorbs cable differences at about 2 mm of coax per 10 ps step. The laser's trigger-to-light jitter is random, varies by source, and can be the largest term in the budget. It is measured with the method in section 6 and added to step 5 with equation (6).

When the load needs tens of volts

The Model 765-HV carries the same timing platform to 50 Vpp into 50 Ω, within a −25 V to +25 V window, with a rise time under 400 ps (20% to 80%) at 0 V offset and selectable baselines at −25 V, −12.5 V, 0 V,

+12.5 V and +25 V. It is the choice when a laser-diode driver stage, a gated detector input or a high-voltage modulator needs more than the 5 Vpp of the Model 765.

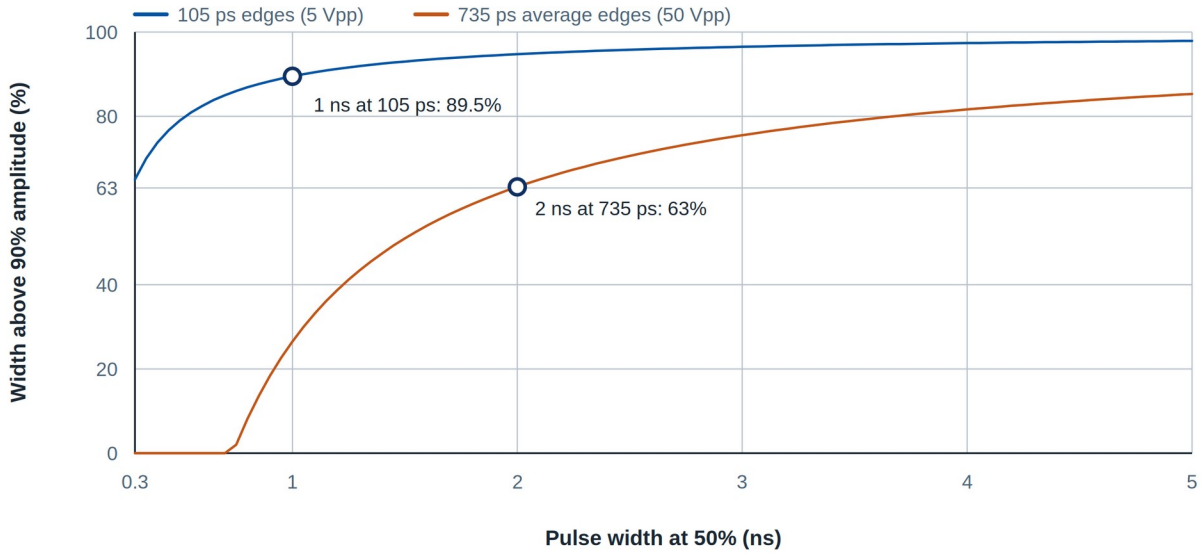


Figure 5. At full 50 Vpp output the usable flat top grows slowly with width: a 1 ns pulse keeps 27% of its width above 90%, and a 2 ns pulse keeps 63%. *[Derived]*

Its edge is the trade. At 50 Vpp the 10% to 90% edges are under 630 ps rising and under 840 ps falling. Equation (7) takes their average, 735 ps, so a 1 ns pulse keeps only 1,000 − 735 = 265 ps above 90%, while a 2 ns pulse keeps 1,265 ps (Figure 5). For full-amplitude work where the flat top matters, plan widths of 2 ns and longer. At 25 Vpp the edges are under 570 ps and 640 ps, an average of 605 ps, and the same 2 ns pulse keeps 1,395 ps.

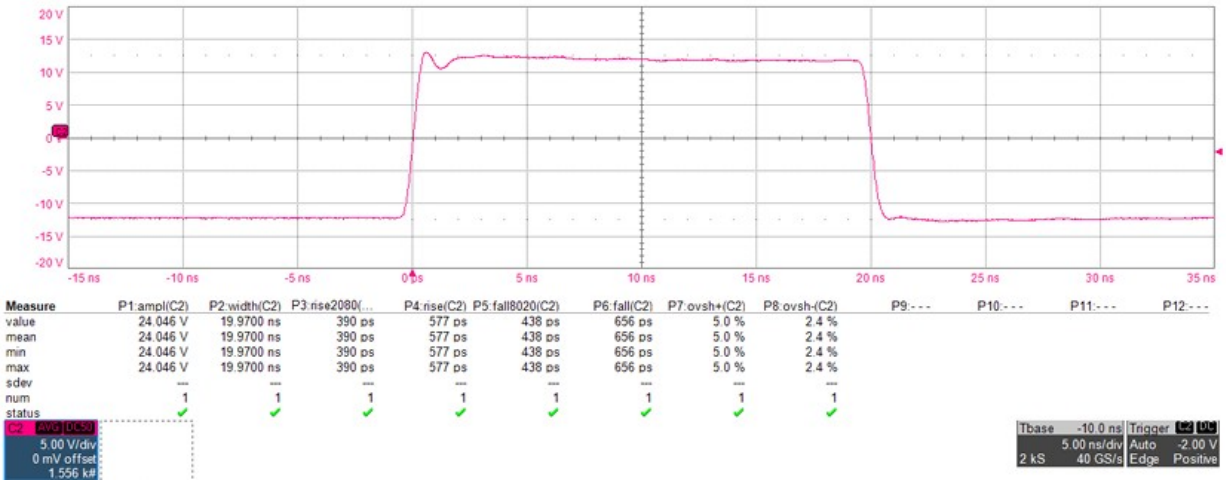


Figure 6. Model 765-HV output at 24 Vpp into 50 Ω, from the published datasheet: the rising edge measures 390 ps (20% to 80%) and 577 ps (10% to 90%), a ratio of 1.48 against the 1.52 of the Gaussian model in equation (1). Displayed edge times include the measurement cabling and fixture. *[Measured]*

Where a bench needs both, a Model 765-HV can drive the high-voltage stage while a Model 765 places the gates, with both locked to one 10 MHz reference. A trigger passed between the two instruments adds the link jitter of section 3, so the most critical interval should be kept between two channels of the same instrument.

Limitations

- The sub-70 ps edge applies up to 5 Vpp. Above that, edges are in the 400 ps class of the Model 765-HV, whose fall time at 50 Vpp (under 840 ps, 10% to 90%) is slower than its rise.
- On the Model 765, a baseline offset other than 0 V can move the pulse width away from its specification, depending on the offset and other settings. The 765-HV edge times are specified at 0 V offset.
- The channel-to-channel jitter of the Model 765 is specified with all channels at one frequency in single-pulse continuous mode. Other modes should be measured on the bench.
- The trigger input accepts up to 40 MHz. A bench timed from a faster external clock, up to 100 MHz, can lock the generator timebase to it through the reference input instead of triggering on each cycle.
- Neither instrument drives bulk Pockels cells at kilovolts or laser diodes at tens of amperes. Berkeley Nucleonics builds high-voltage pulsers and laser-diode drivers for those loads.

This instrument may not be needed at all. A bench whose shortest optical feature is 10 ns or longer, with timing tolerances of a nanosecond, is served by a conventional digital delay generator such as the Berkeley Nucleonics Model 577, with 250 ps resolution and under 50 ps RMS channel-to-channel jitter.

6. Measurement practice

These steps apply to any fast pulse source, and to benches that never use the instruments described here.

1. **Record the reference levels with every edge measurement.** Convert between conventions with equation (1) only for near-Gaussian edges, and say when a number has been converted.
2. **Choose the oscilloscope from equation (3).** Reading a 105 ps edge within 5% takes about 10 GHz to 13 GHz depending on the response. Correct a slower reading with equation (3) only when the oscilloscope's own rise time is known.
3. **Size the attenuator for the baseline, not only the duty cycle.** A 50 Vpp pulse from −25 V to +25 V puts 25 V across the load in both states: $25^2 / 50 = 12.5$ W continuously into 50 Ω, at any duty cycle. Use an attenuator rated for that power ahead of the oscilloscope input, and include its rise time in equation (3).
4. **Tell the instrument what it is driving.** Displayed levels assume a 50 Ω load. The Model 765 and Model 765-HV both accept the load impedance as a setting, or apply Auto Load Compensation to correct the displayed levels for the load; on the Model 765 this covers any load from 50 Ω to 100 MΩ. Left set for 50 Ω, a 50 Ω source driving a high-impedance load delivers up to twice the displayed voltage, and the unmatched edge reflects back to the source.
5. **Measure cable delays at the device, then trim them electrically.** One 10 ps delay step equals about 2 mm of polyethylene-dielectric coax.
6. **Measure interval jitter where it matters.** Trigger the oscilloscope on one channel and histogram the other edge at the device. The oscilloscope's own trigger jitter adds by equation (6), and can be removed in quadrature only when it is known.
7. **Measure the laser's trigger-to-light jitter the same way**, with a fast photodiode in place of the second channel, and add it to the electrical budget.
8. **Lock every timebase on the bench to one 10 MHz reference**, so drift over a long acquisition is common to the laser, the pulse source and the digitizer.
9. **Allow the 30-minute warm-up** the user manual specifies before running self calibration, and before taking timing data meant for a record.

7. Summary and selection

The governing relations, each with the condition it depends on:

- Path per timing error: $\Delta x = c\Delta t/n$; 10 ps is 3.0 mm in free space, 2.0 mm in silica fiber at group index 1.468.
- Convention ratio: $t_{10–90} \approx 1.52\ t_{20–80}$, for near-Gaussian edges.
- Measured edge: $t_{meas} = \sqrt{(t_{sig}^2 + t_{sys}^2)}$, with $t_{sys} \approx k/B$ and k from 0.35 to 0.45.
- Usable flat top: $t_{90} = w - t_{10–90}$, for linear and equal edges.
- Interval jitter: $\sigma_{int} = \sqrt{(\Sigma\sigma_i^2)}$; specify it between the edges that matter, in the mode that will be used.

If the bench needs	Choose
Edges under 70 ps (20% to 80%), up to 5 Vpp, 2 or 4 channels	Model 765-2C or Model 765-4C
Up to 50 Vpp into 50 Ω with sub-400 ps edges, 1 or 2 channels	Model 765-HV-1C or Model 765-HV-2C
Fast gates and a high-voltage stage together	Model 765 and Model 765-HV on one 10 MHz reference
Features of 10 ns and longer, nanosecond tolerances	A digital delay generator such as the Model 577
Kilovolt Pockels cells or high-current laser diodes	Berkeley Nucleonics high-voltage pulsers and laser-diode drivers

Table 5. Selection follows the amplitude first and the edge second, because the amplitude decides whether the device switches at all.

8. Definitions, symbols and acronyms

Channel-to-channel jitter. The RMS variation of the interval between edges on two outputs of one instrument.

Edge time. The time an edge takes to cross between two reference levels, stated with those levels: 10% to 90% or 20% to 80%.

Group index. The ratio of the speed of light in vacuum to the speed of a pulse envelope in a medium; it sets the path per unit time in fiber.

Half-wave voltage. The voltage that changes the optical phase in an electro-optic modulator by half a cycle, taking an intensity modulator from minimum to maximum transmission.

Interval jitter. The RMS variation of the time between two edges, which is the timing quantity an optical bench depends on.

Slew rate. The rate of change of voltage through the middle of an edge, in V/ns.

Velocity factor. The speed of a signal in a cable as a fraction of the speed of light in vacuum.

Symbols used in this document:

Symbol	Meaning	Units
B	−3 dB bandwidth	GHz
c	speed of light in vacuum, 299.79	mm/ns
k	rise-time bandwidth constant, 0.34 to 0.45	none
n	group index	none
SR	slew rate	V/ns

Symbol	Meaning	Units
$t_{10–90}$, $t_{20–80}$	edge time between the stated levels	ps
t_{90}	time above 90% of amplitude	ps
t_{meas}, t_{sig}, t_{sys}	measured, signal and measurement-system rise times	ps
V	pulse amplitude	V
w	pulse width at 50%	ns
Δt, Δx	timing error and its path equivalent	ps, mm
σ_{int}, σ_i	interval jitter and contributor jitter	ps RMS

Acronyms:

LiDAR = Light Detection and Ranging
RMS = Root Mean Square
Vpp = Volts peak to peak
MHz = Megahertz
GHz = Gigahertz
ns = nanosecond
ps = picosecond
mm = millimeter
nm = nanometer

9. Further reading

- Berkeley Nucleonics, *Digital Delay Generator Handbook*, BNC-HB-003 Rev C, with full reviews of the Model 765 and Model 765-HV and bench recipes for laser-diode, LiDAR and detector work: berkeleynucleonics.com/docs/handbook-pdg-digital-delay.html
- Model 765 datasheet: berkeleynucleonics.com/docs/bnc-model-765-datasheet.html
- Model 765-HV datasheet: berkeleynucleonics.com/docs/bnc-model-765hv-datasheet.html
- Berkeley Nucleonics, *Jitter, resolution and timing accuracy*: berkeleynucleonics.com/docs/article-pdg-jitter-timing-accuracy.html
- IEEE Std 181, *IEEE Standard for Transitions, Pulses, and Related Waveforms*, which defines the reference levels used for edge time.
- H. W. Johnson and M. Graham, *High-Speed Digital Design: A Handbook of Black Magic*, Prentice Hall, 1993, for the rise-time and bandwidth relations.

If your bench has a timing or amplitude budget you would like to talk through, the Berkeley Nucleonics applications team is glad to work it with you at info@berkeleynucleonics.com or 800-234-7858.

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