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Modelling of Picosecond Timing Signals from Fast Vacuum Photodiodes

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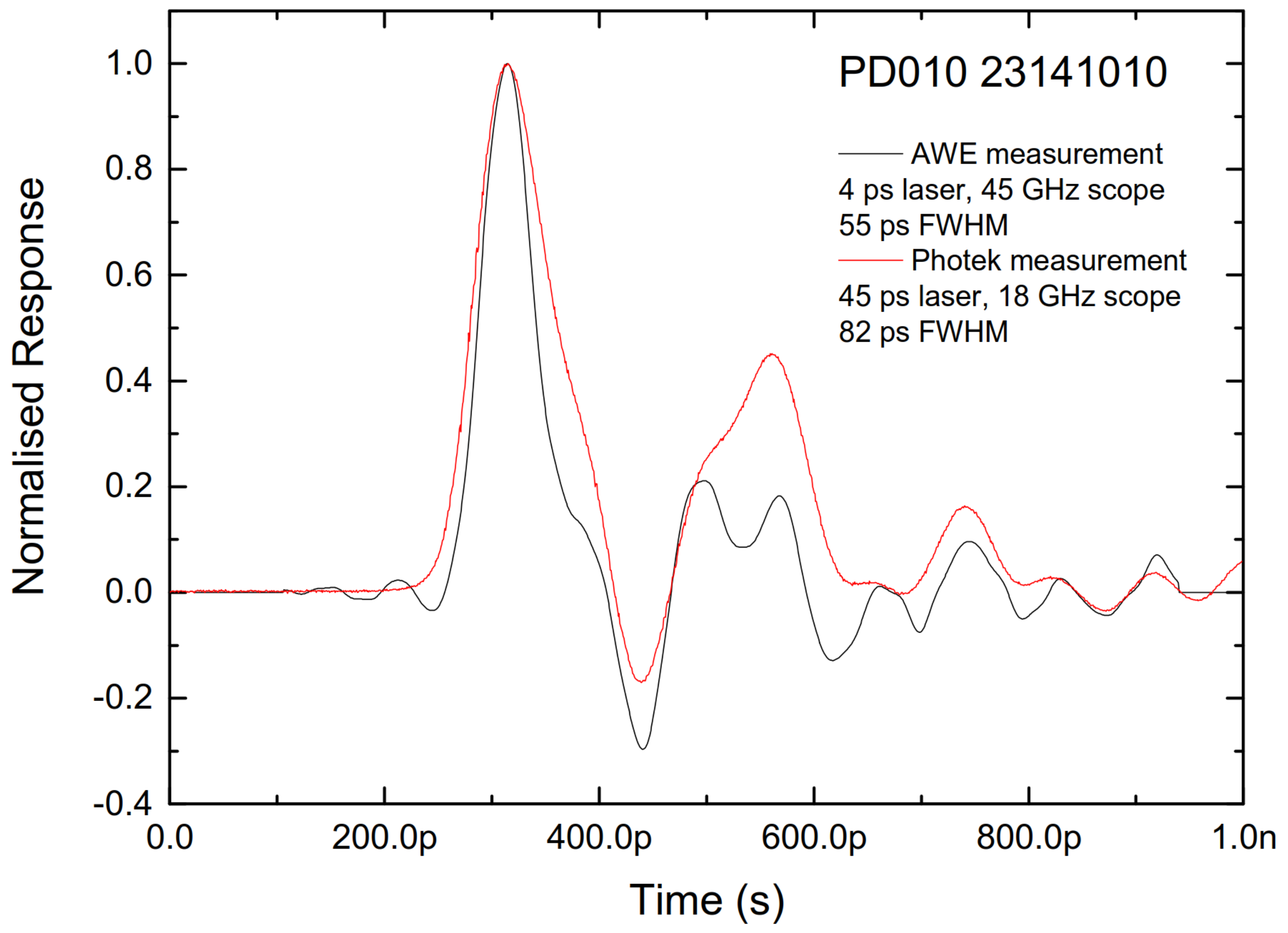


A plot of measured PD010 pulse response showing the effect of varying laser pulse width and oscilloscope bandwidth.

Introduction

Vacuum photodiodes should offer even faster time resolution and higher signal bandwidth than microchannel plate based photomultipliers, albeit with lower sensitivity due to their lack of electron gain. The absence of the microchannel plate removes the additional pulse broadening associated with the electron amplification, a cascade process along the length of the microchannel pore.

In a photodiode the fundamental signal bandwidth depends only the following factors:

1. The variation in the delay of the photoelectron emission from the photocathode. This is an insignificant effect.
2. The variation of the photoelectron flight time due to variations in emission angle and energy, also insignificant due to the magnitude of the accelerating voltage.
3. Further pulse broadening can be caused elastically or inelastically scattered primary electrons, or secondary electron emission from the anode.

The motion of primary and secondary electrons induces the fast signal on the anode. Geometry modifications between photocathode and anode can improve rise time and pulse width.

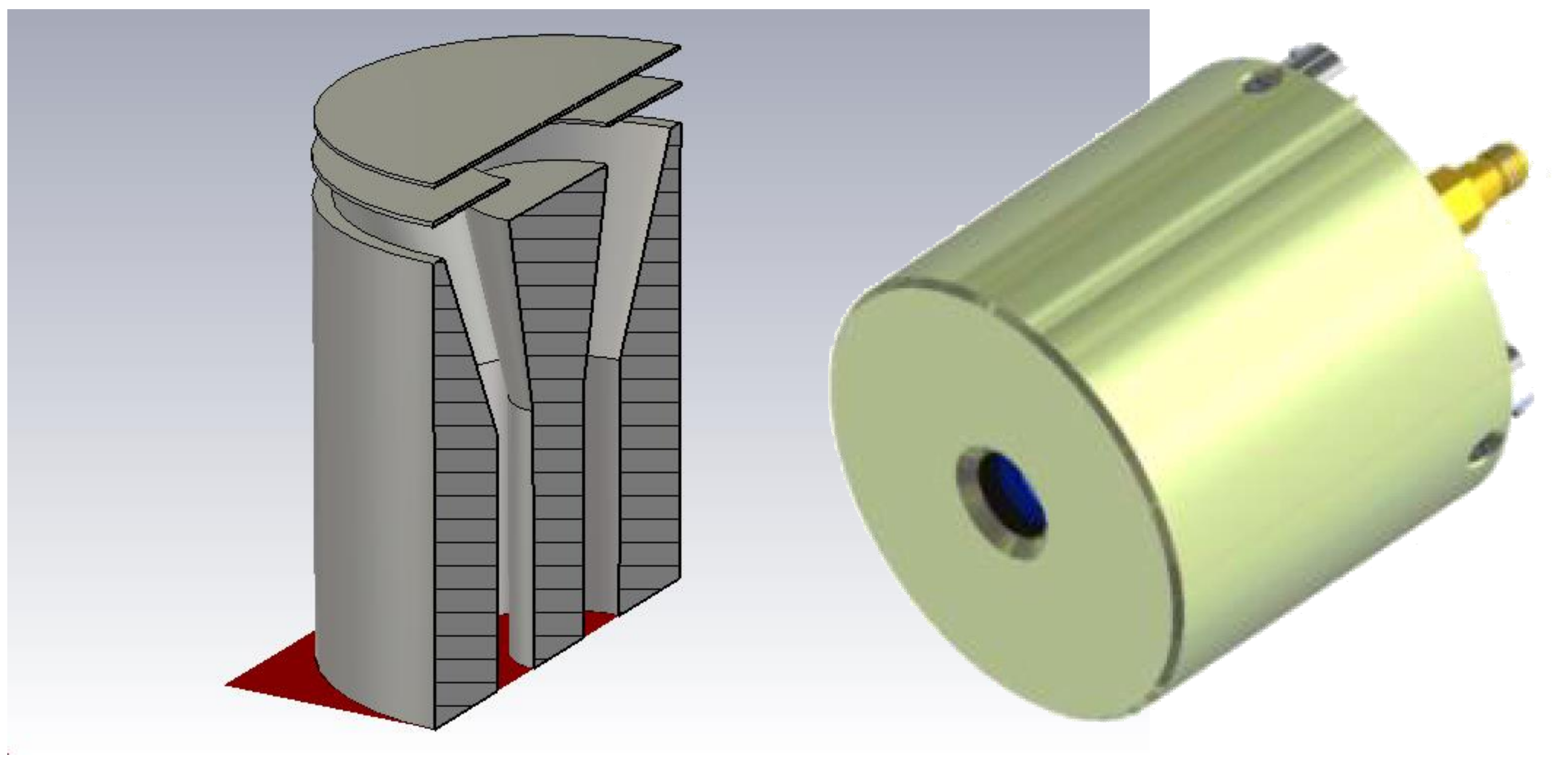
In practice, impedance matching of the output is a crucial factor in minimising pulse rise time, width and ringing.

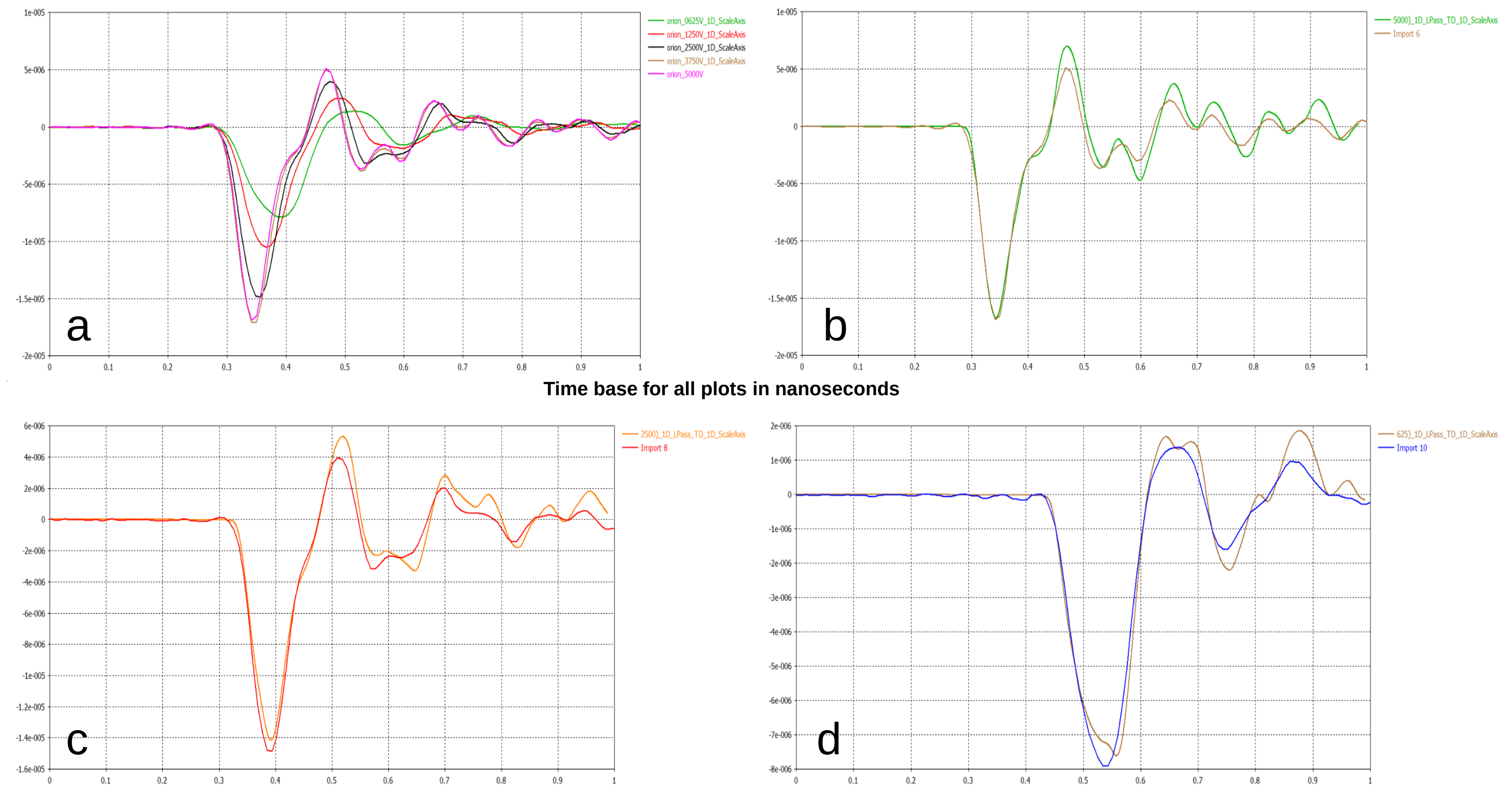
Modelling using CST Studio Suite

The Photek PD010 photodiode was modelled with CST Studio Suite software using particle tracking. A cut-away drawing of a simplified photodiode detector is shown on the right, together with a photograph of the device in its housing.

The model used for simulation results below was significantly more detailed and was developed using the 3D CAD STEP file used for actual device manufacture. It was straightforwardly imported into the CST Studio Suite software to create an accurate geometrical model.

The results below show that the simulation can accurately predict photodiode performance even at very high bandwidths.





Time base for all plots in nanoseconds

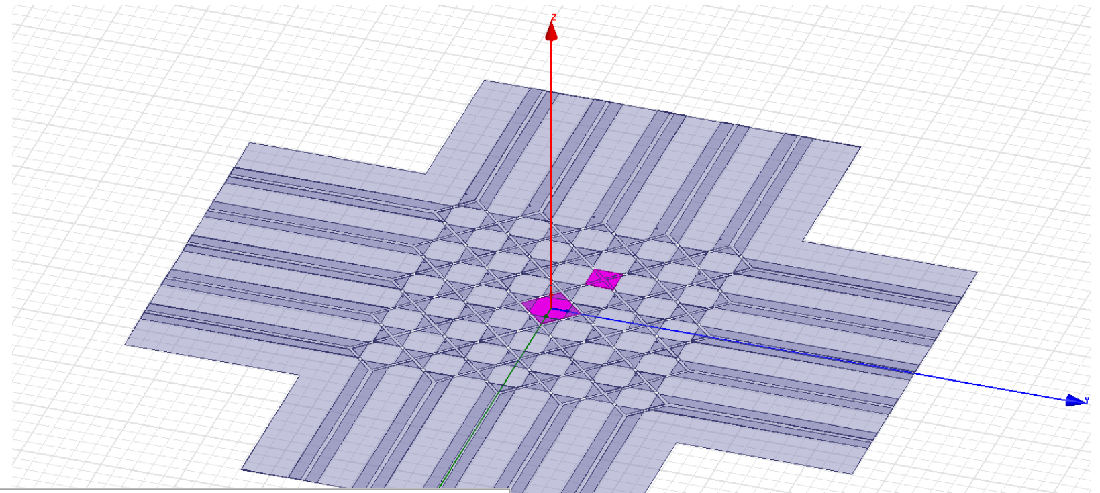
Experimental measurements (a) of the Photek PD010 at varying operating voltages (see legend a) were undertaken in February 2015 during detector testing using a fast laser at the AWE ORION laser facility. Comparisons between experimental data and simulation are shown left. These used a 50 GHz simulation bandwidth at three tube operating voltages: 5 kV (b), 2.5 kV (c) and 0.625 kV (d). Each plot shows the experimental data obtained using a fast oscilloscope (17 GHz bandwidth) in comparison with simulated results. The simulation results were filtered using a 2nd Order Butterworth low pass filter to emulate the oscilloscope response.

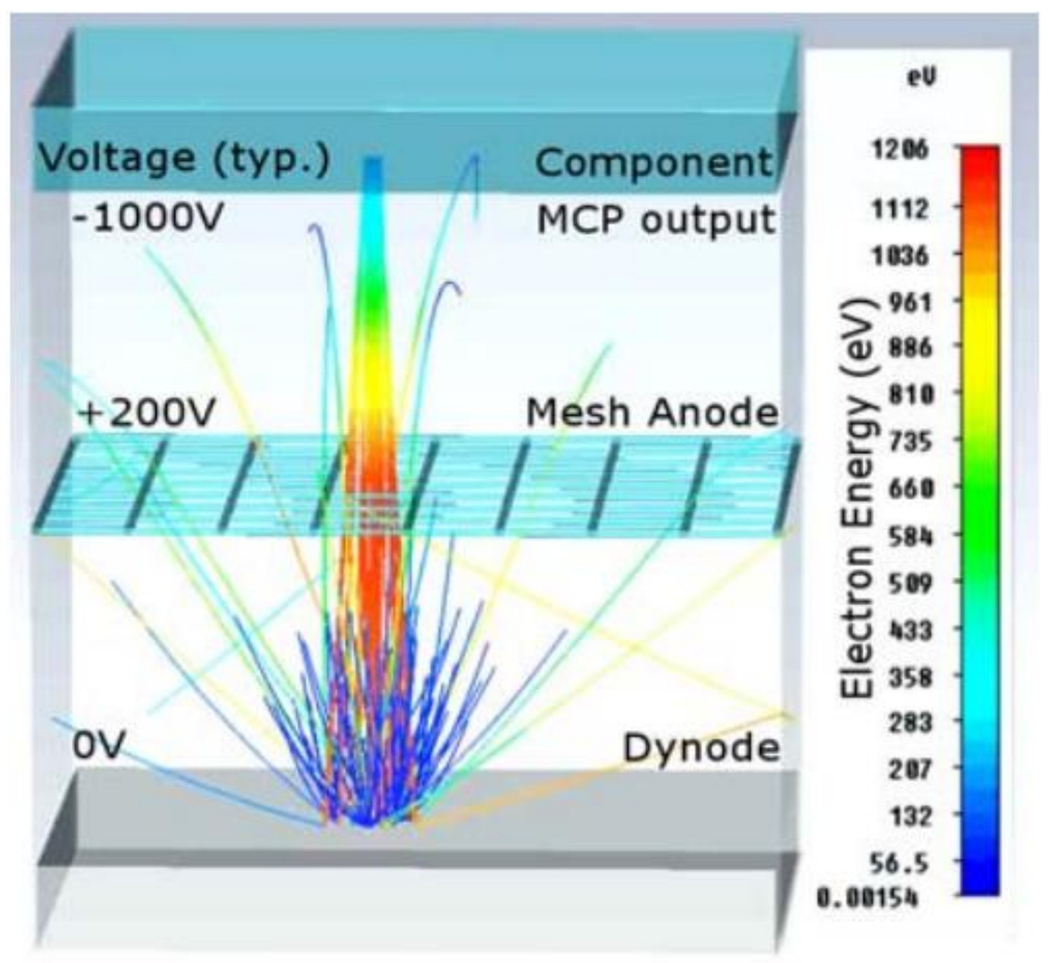
Findings

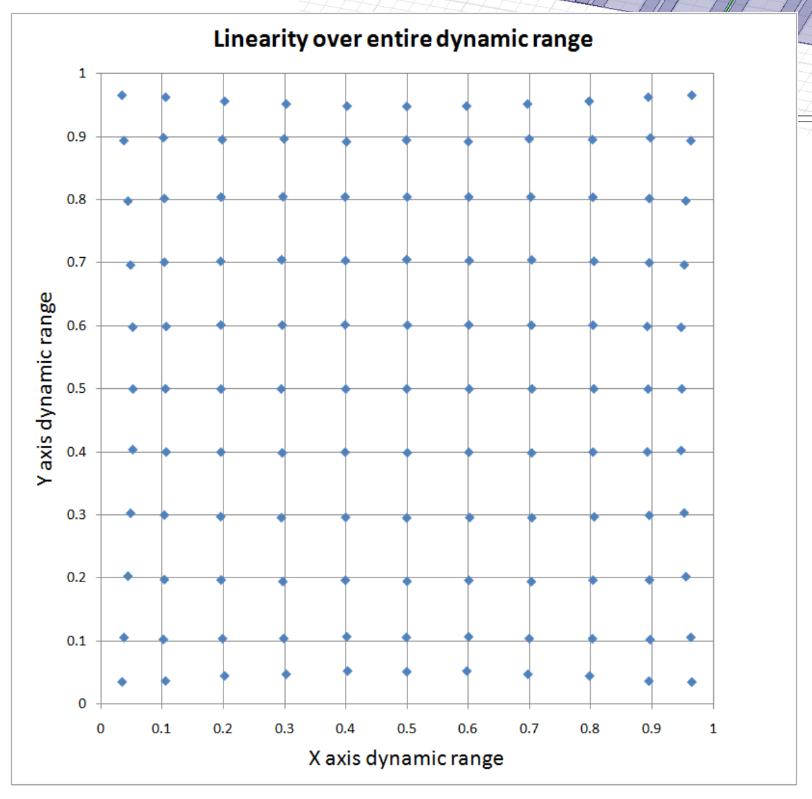
The fit of simulation data to experimental results is remarkably good, especially given that the full design with SMA connector coupled to a 600 mm coaxial cable was not included in the model. This suggests that the major effects resulting from impedance mismatch occur in the large scale end of the waveguide where non-ideal geometrical features represent larger phase errors (the simulation bandwidth is 50 GHz ≡ 6 mm wavelength).

CST Studio Suite has multiple uses in detector simulations, and here we show it can replicate experimental results at high accuracy in the picosecond regime.

Other CST Detector Simulations







CST has also been used to model an active anode electron gain structure employing secondary electron emission (left) and modelling of a charge division image readout (top right) showing linearity achieved (bottom right)

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