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Spatiotemporal characterization of nanosecond pulses using an ultrafast diode array

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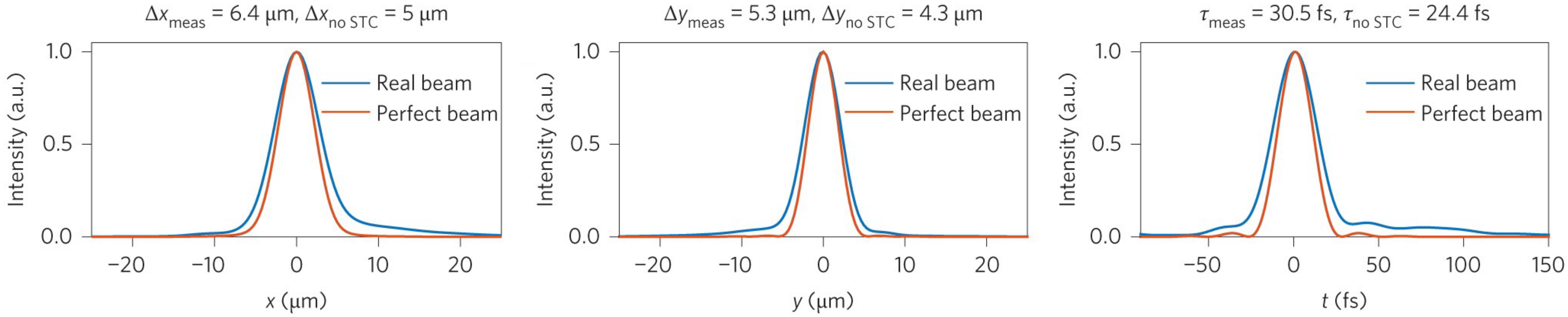
Outline

- Importance of spatiotemporal pulse characterization
- Previous approaches to spatiotemporal characterization of nanosecond pulses
- Overview of the Ultrafast Pixel Array Camera (UPAC)
- UPAC as a diagnostic of nanosecond laser pulses
- Additional capabilities and future development

Spatiotemporal measurements can reveal features obscured by integration and improve overall laser system performance

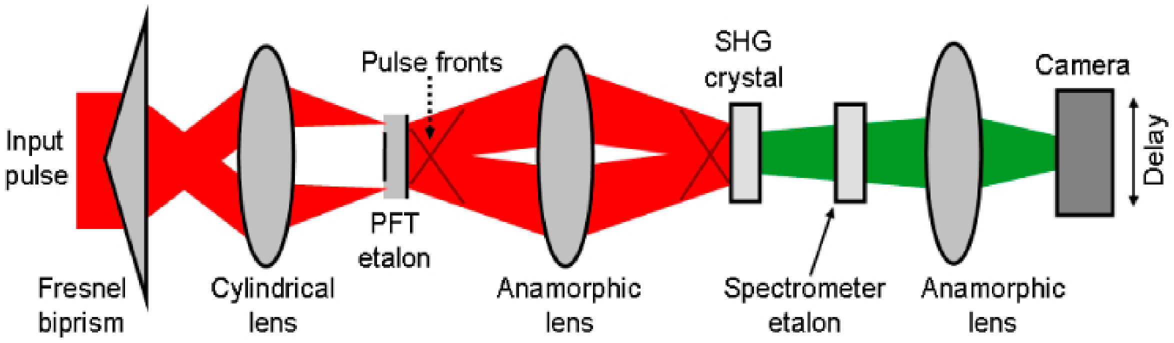
- Laser pulses are susceptible to a wide variety of spatiotemporal distortions
  - $E(r,t) \neq f(r)g(t)$
- These effects can substantially reduce peak intensities at focus
- Femtosecond spatiotemporal distortions can be introduced by inhomogeneities in nanosecond pump beams in the chirped domain of the OPCPA process



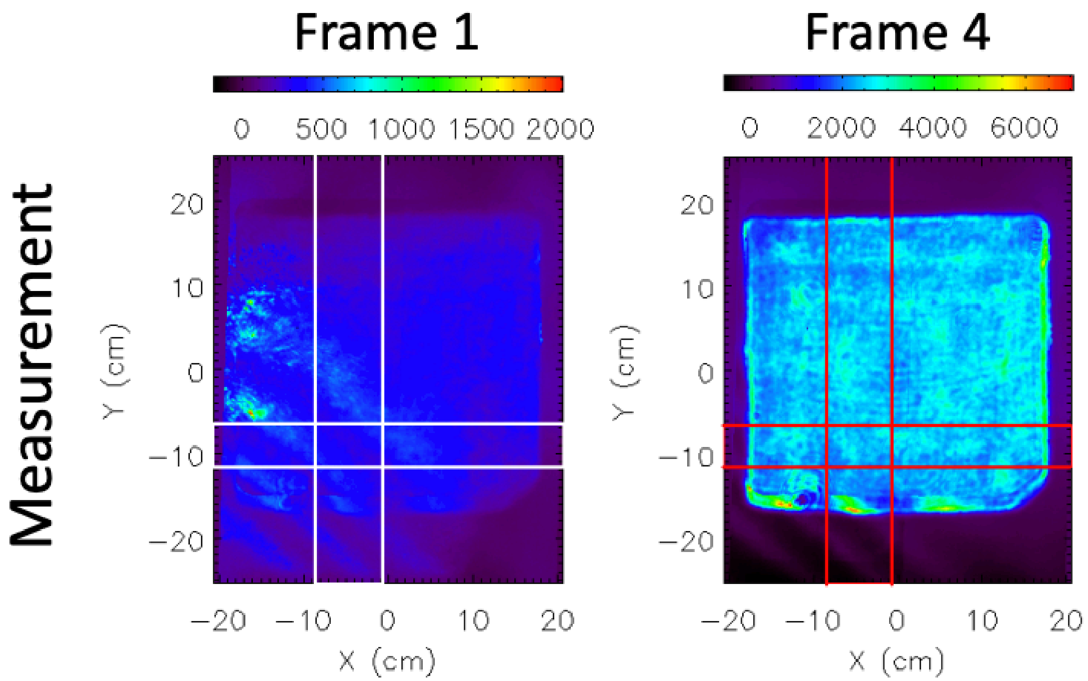
G. Pariente et al., *Nat. Photon.* 2016

Spatiotemporal characterization of nanosecond-duration pulses remains challenging

- Techniques developed for femtosecond pulse characterization are often not suitable for nanosecond pulses
- Nanosecond FROG
  - Maximum pulse duration limited
- Temporal self-referencing
  - Not spatially-resolved
- Direct $I(r,t)$ measurements using hCMOS
  - Coarse temporal resolution



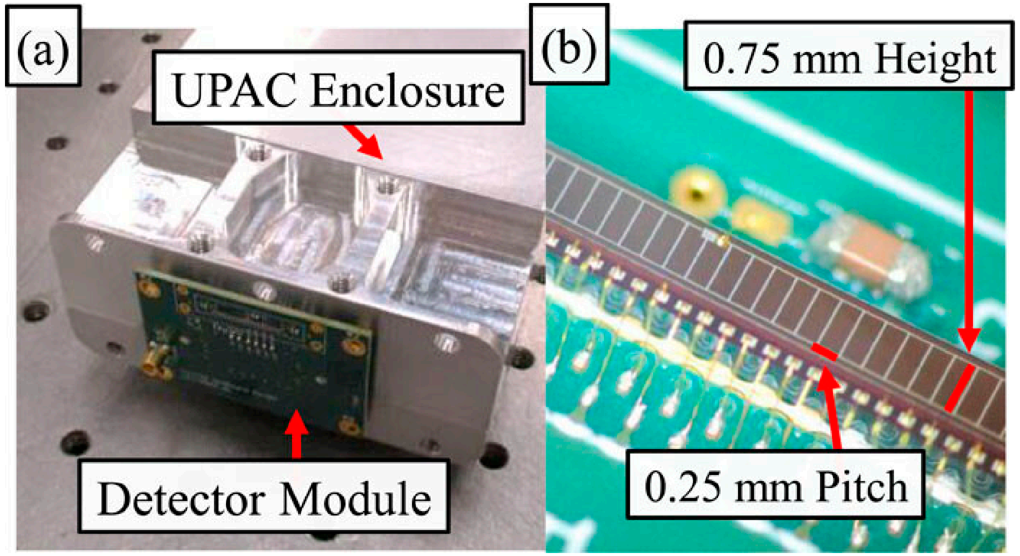
Bowlan and Trebino, *Opt. Express* 2011



T. Lanier et al., Photonics West 2020

The Ultrafast Pixel Array Camera (UPAC) was developed at Sandia to measure single-shot events evolving on nanosecond timescales

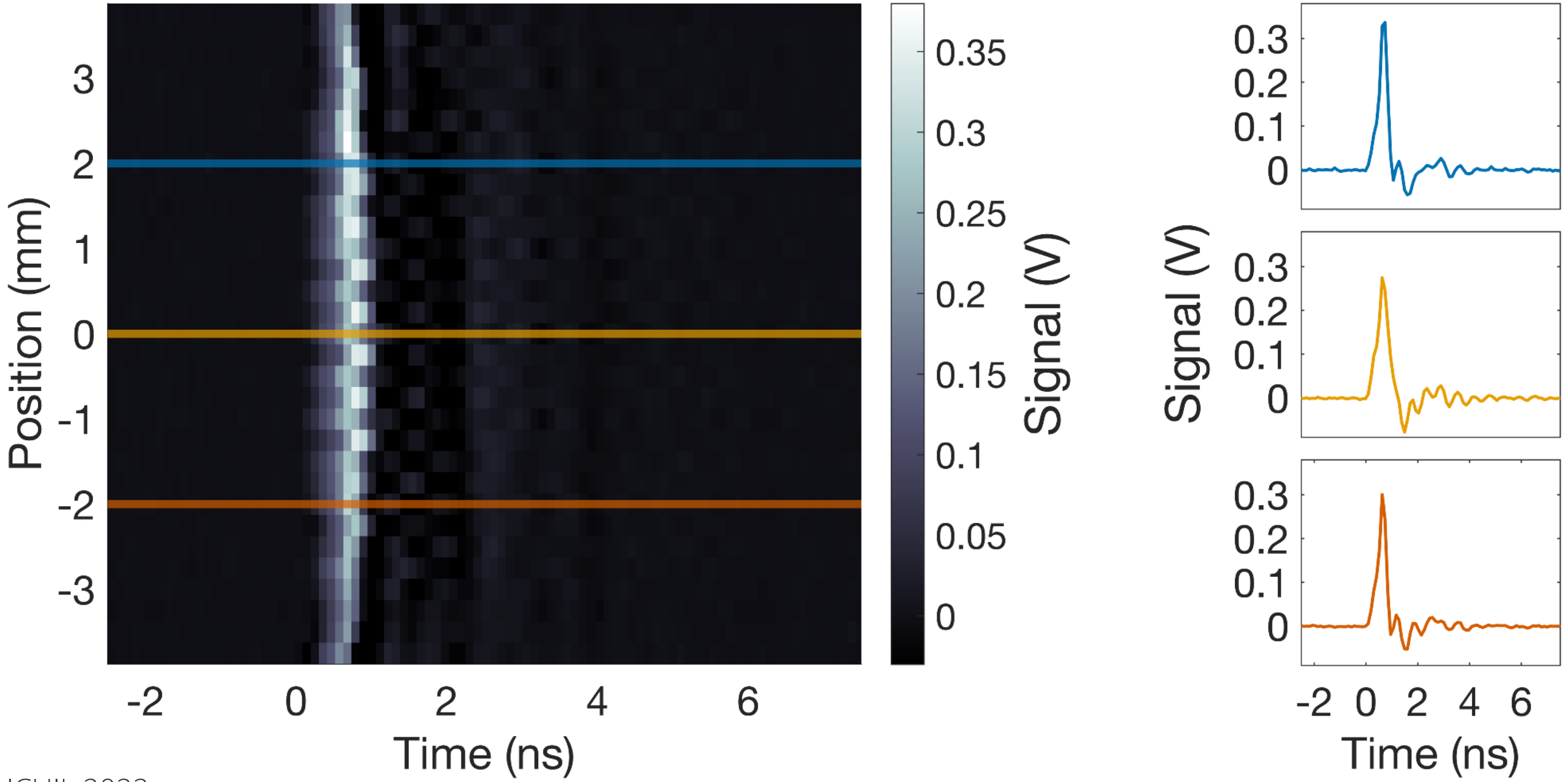
- Compact 32-channel digitizer for detector readout
- Each channel demonstrates 10 Gsample/s, 1.8 GHz analog bandwidth
- Preliminary detector modules: 1D photodiode array, 2D photodiode array, neutron spectrometer
- 1D linear diode array (8 mm total length) provides 1D spatial, 1D temporal information
  - "Solid state streak camera"



Q. Looker et al., *Rev. Sci. Inst.* 2022

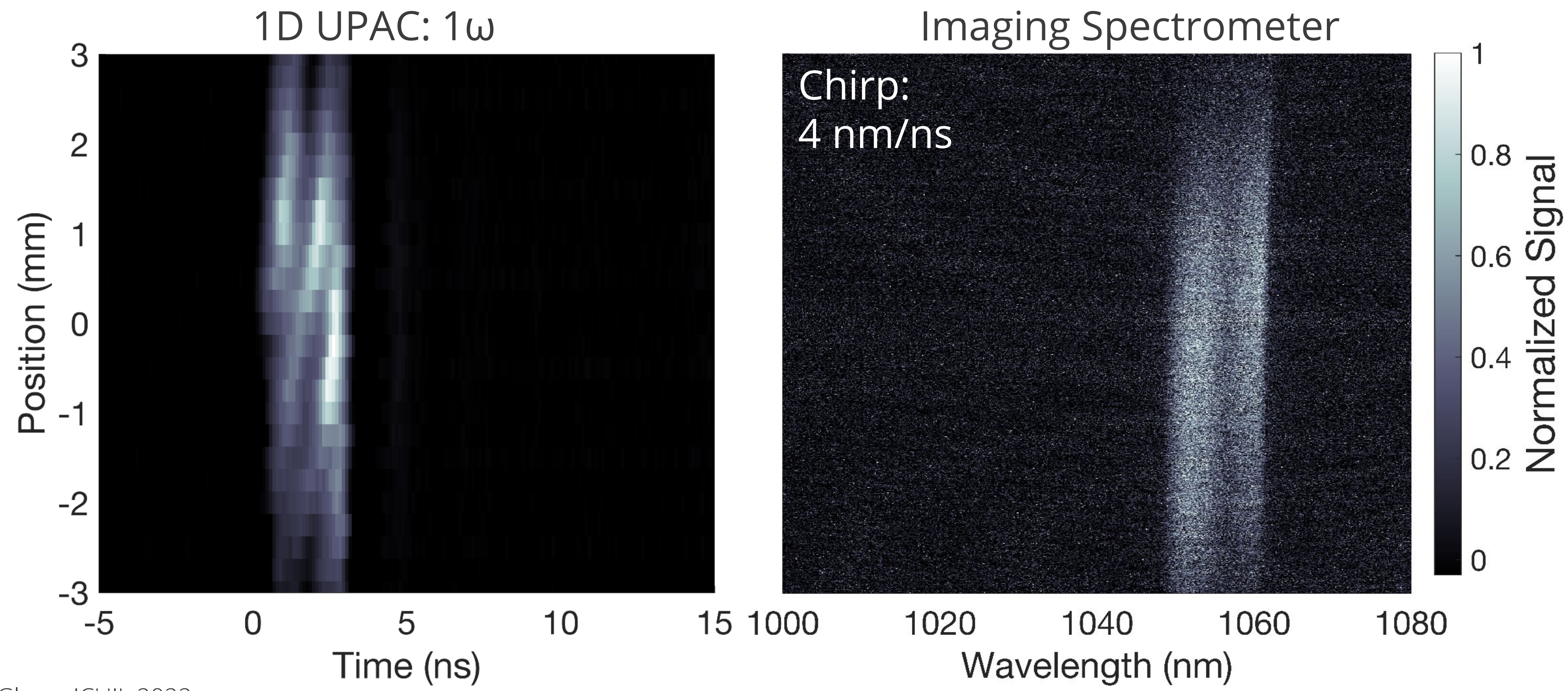
We extended the initial demonstration of the UPAC to illustrate its utility in characterizing multi-nanosecond laser pulses

- Tested δ-function response using compressed (~500 fs) pulse
  - Minimum pulse energy required: 500 pJ
  - Pulse FWHM: 200 ps



1D UPAC measurements of chirped pulses are consistent with imaging spectrometer measurements

- Etalon effects visible in center of pulse due to Si detector thickness and near-IR laser wavelength



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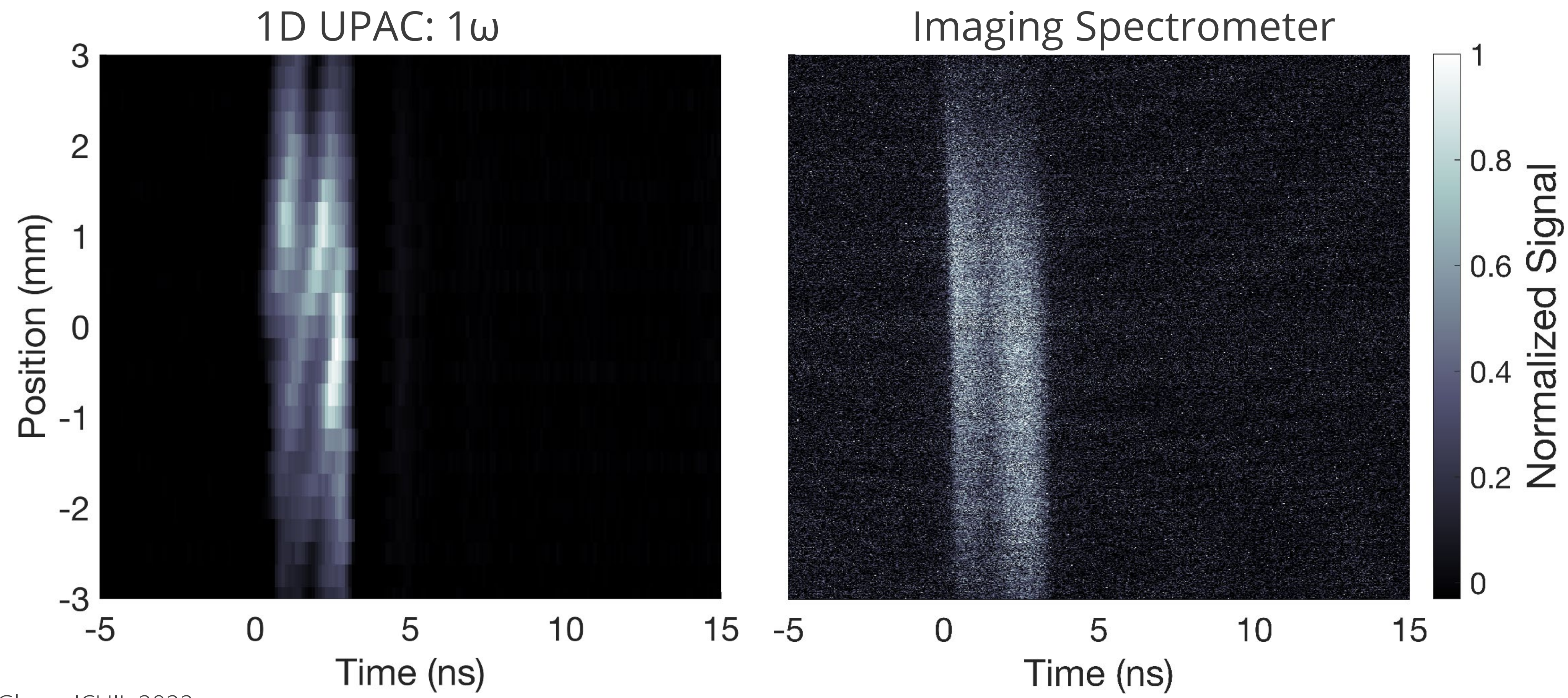
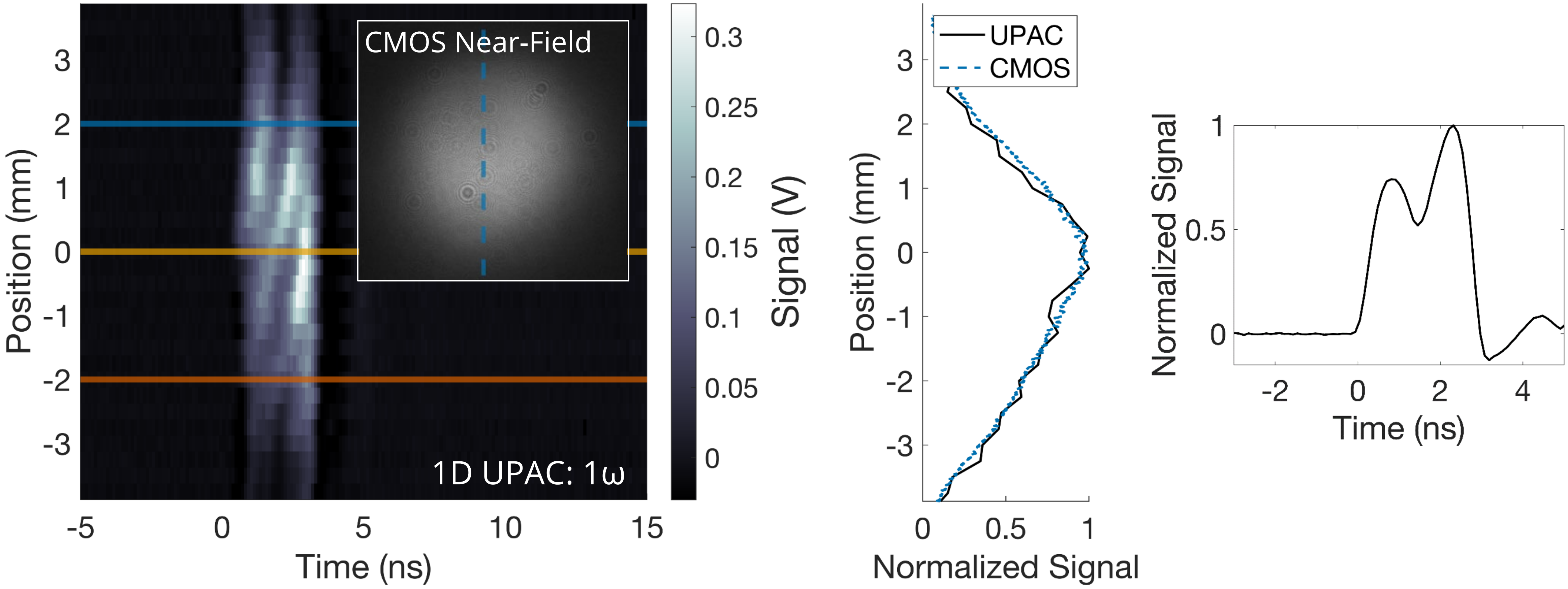


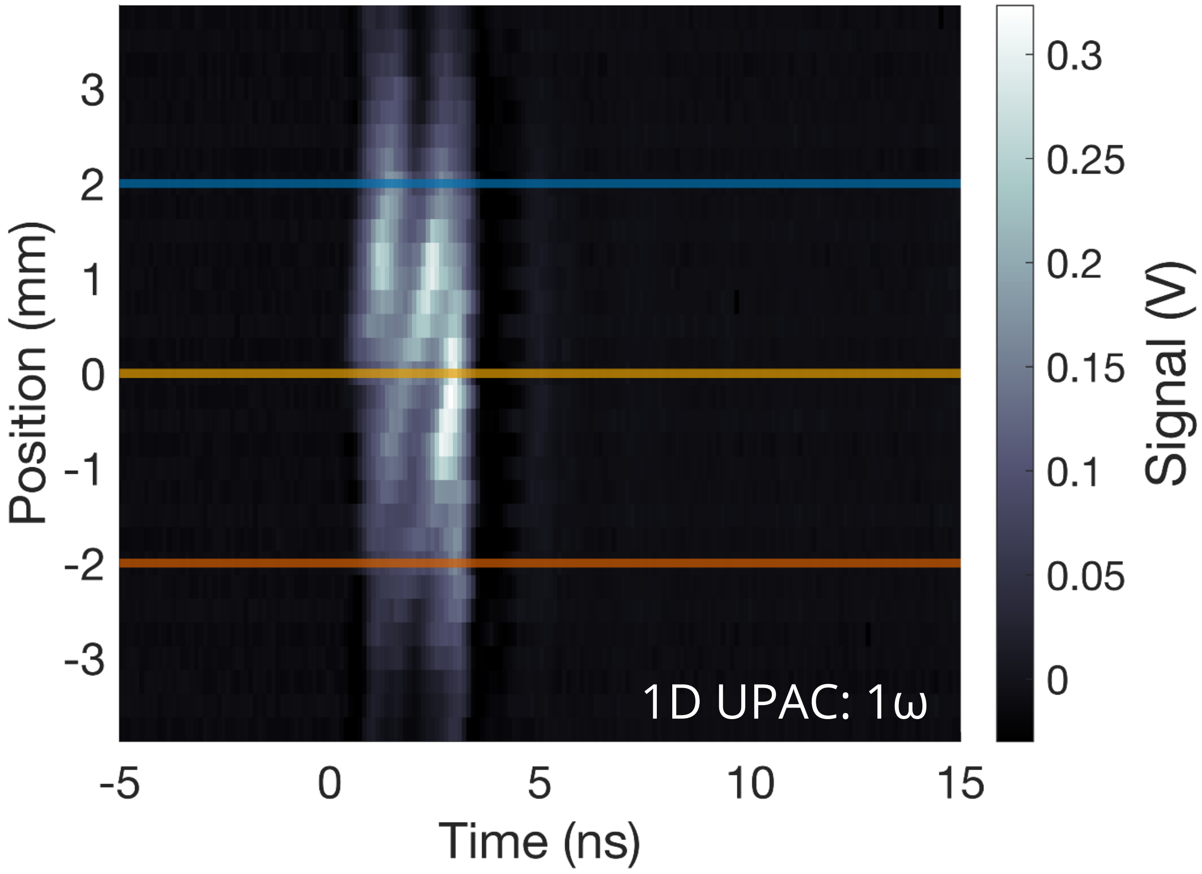
1D UPAC measurements reveal pulse features obscured by integrating measurements

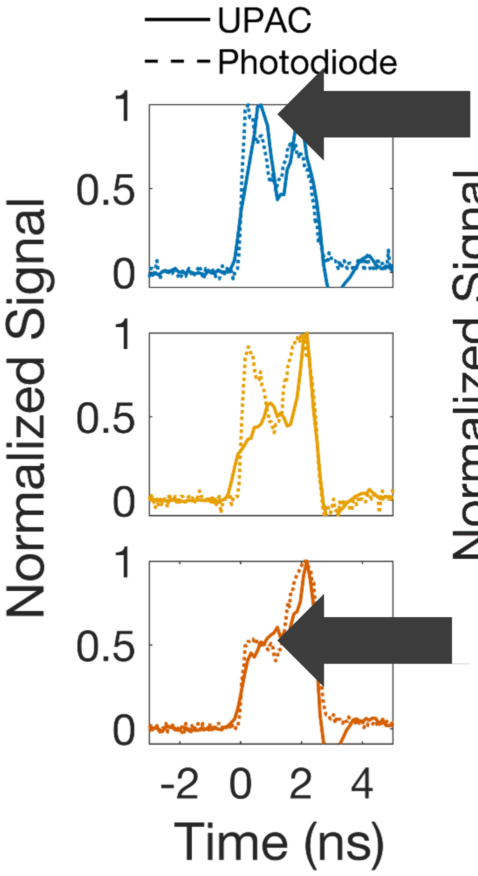
- 1D UPAC spatial measurements are consistent with CMOS camera near-field image

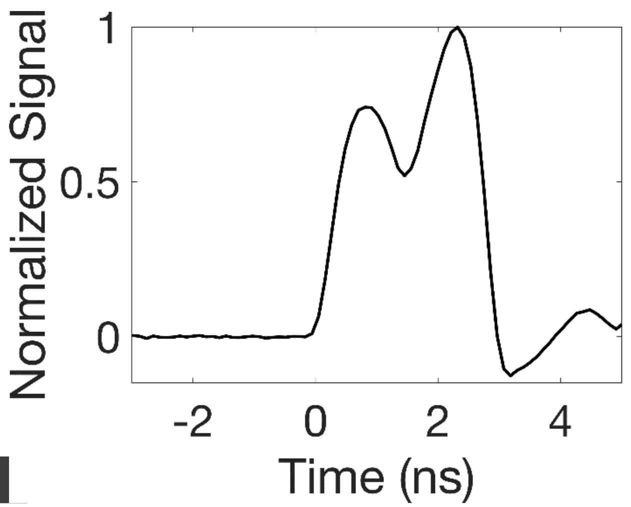


1D UPAC measurements reveal pulse features obscured by integrating measurements

- 1D UPAC temporal measurements show that the pulse temporal profile changes as a function of spatial position

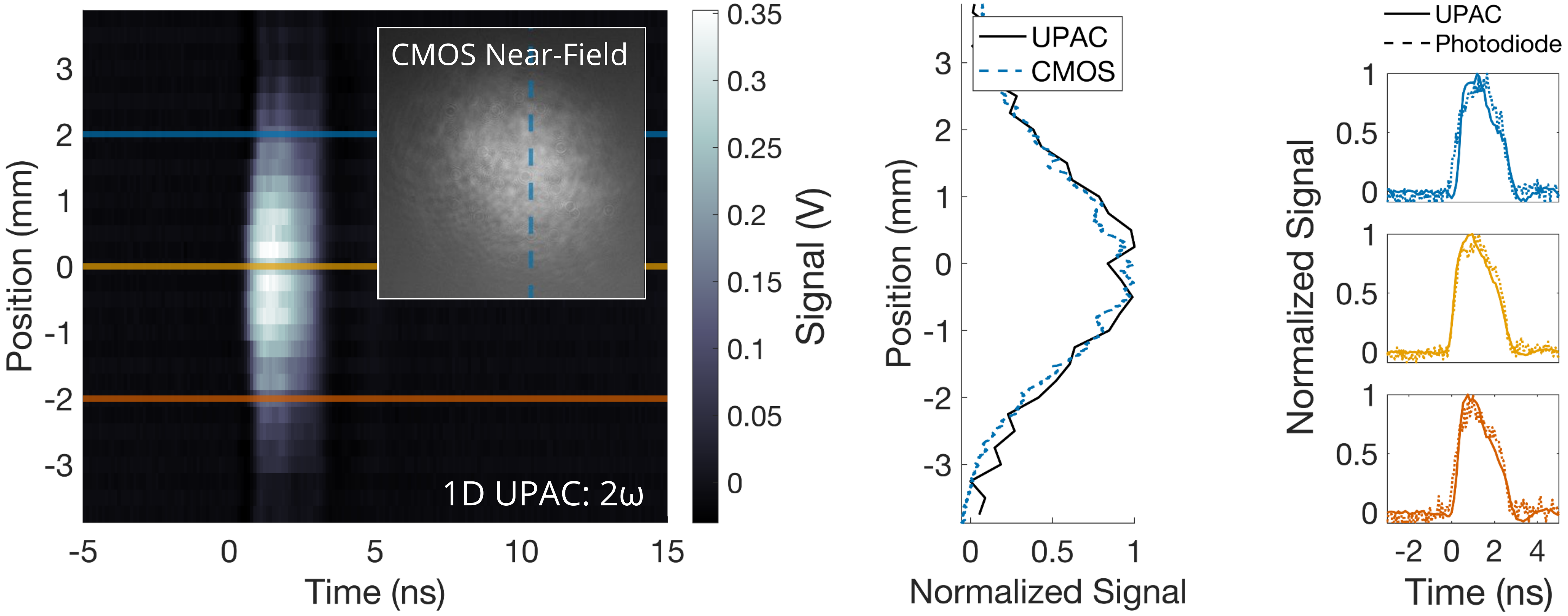






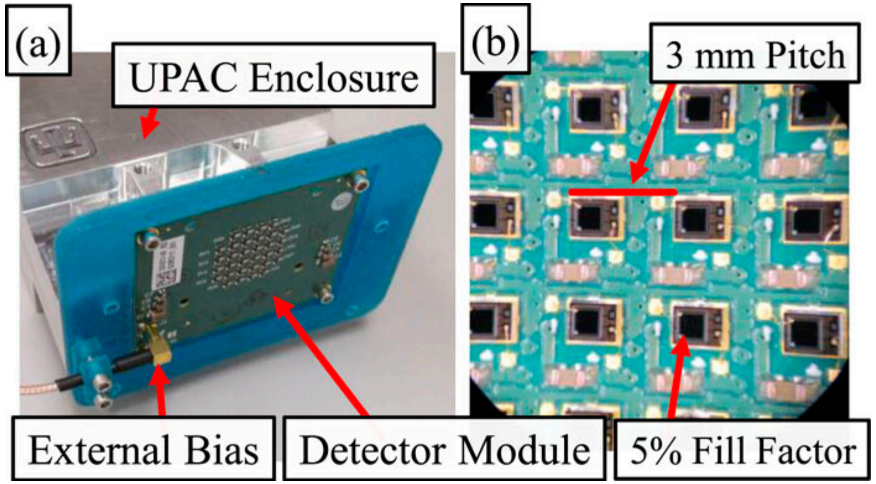
1D UPAC measurements of 2ω pulses are confirmed by conventional diagnostics

- CMOS measurements reproduce time-integrated spatial structure; photodiode measurements reproduce spatially-resolved temporal structure

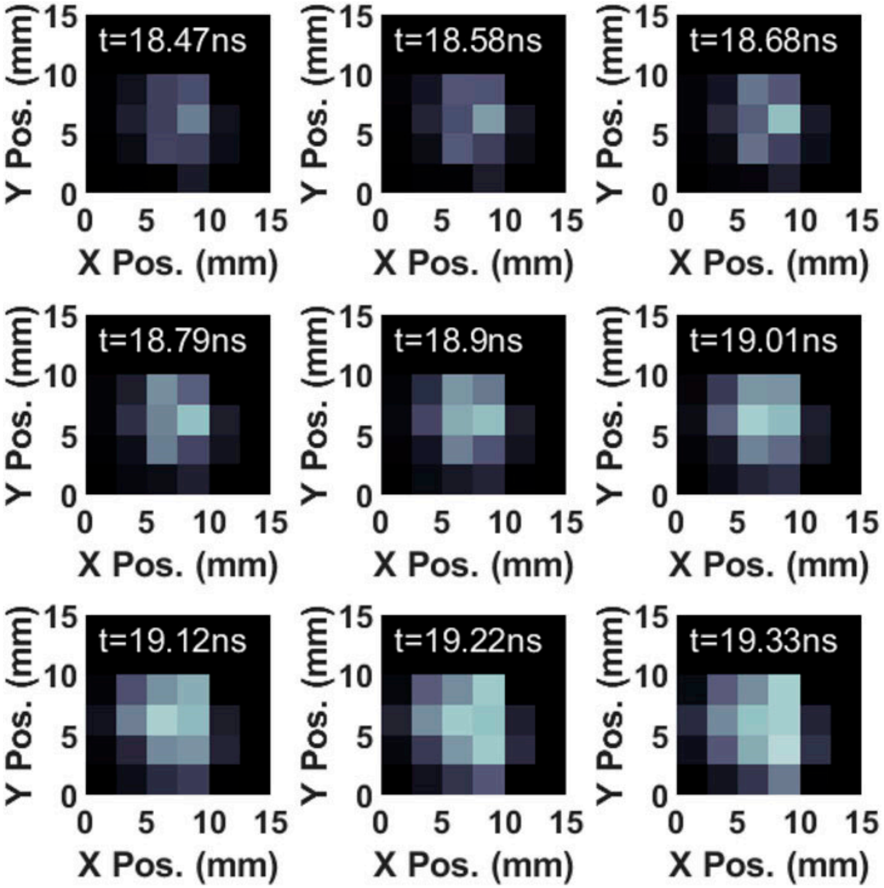


Future development of the UPAC will continue to advance the capabilities presented here

- 2D photodiode detector provides 2D spatial, 1D temporal data
- UPAC is compatible with alternative diode architectures for IR applications
- Subsequent UPAC versions are planned to scale 32 input channels up to 96



Q. Looker et al., *Rev. Sci. Inst.* 2022



Q. Looker et al., *Rev. Sci. Inst.* 2022

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