Existing time-of-flight depth imaging and transient imaging systems are limited either in terms of spatial/temporal resolution or are prohibitively bulky/expensive.

By jointly designing optics, mechanics, electronics, and computation, we overcome the spatial resolution(4××32) limit of Single Photon Avalanche Diode(SPAD) arrays by compressive sensing(image resolution up to 800××400) and realize a temporal resolution of ~20 picoseconds via a physical temporal PSF model.

Our SPAD array is working in TCSPC mode and the measurements from each SPAD pixel could be reconstructed independently with tiling artifacts addressed.

\[ X = \arg \min_X \frac{1}{2} \| \Psi(X) - Y \|^2 + \sum \lambda_i D_i(X) \]

Where \( Y \in \mathbb{R}^{N \times T} \) is the 4D data sharpened in the temporal domain after modulation, \( X \in \mathbb{R}^{N \times T \times M} \) is the 3D signal under evaluation, \( \Psi \) is an operator that maps the random patterns to individual pixels at each layer, and \( D \) is 3D TV regularizer.

As the picosecond laser pulse is approximately Gaussian and has a FWHM ~80ps, the target Gaussian pulse is shown and denoted as \( G \) who has fixed \( \sigma \). Therefore, we can estimate the depth \( \mu \) through solving a least square problem.

\[ \min_{A} \| G(A; \mu) * \Pi(t) - \tilde{Y} \|^2 \]

Where \( \tilde{Y} \) is the raw sensor data We present the sharpened sensor data \( Y_i \) for each pixel i as a sequence of Gaussians \( G \).