

Visible Light LVP on Ultra-Thinned Substrates

**Joshua Beutler, J. Joseph Clement, Mary A. Miller,
Jeffery Stevens, and Edward I. Cole Jr.**

**Sandia National Laboratories
Albuquerque, NM USA**

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin company, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

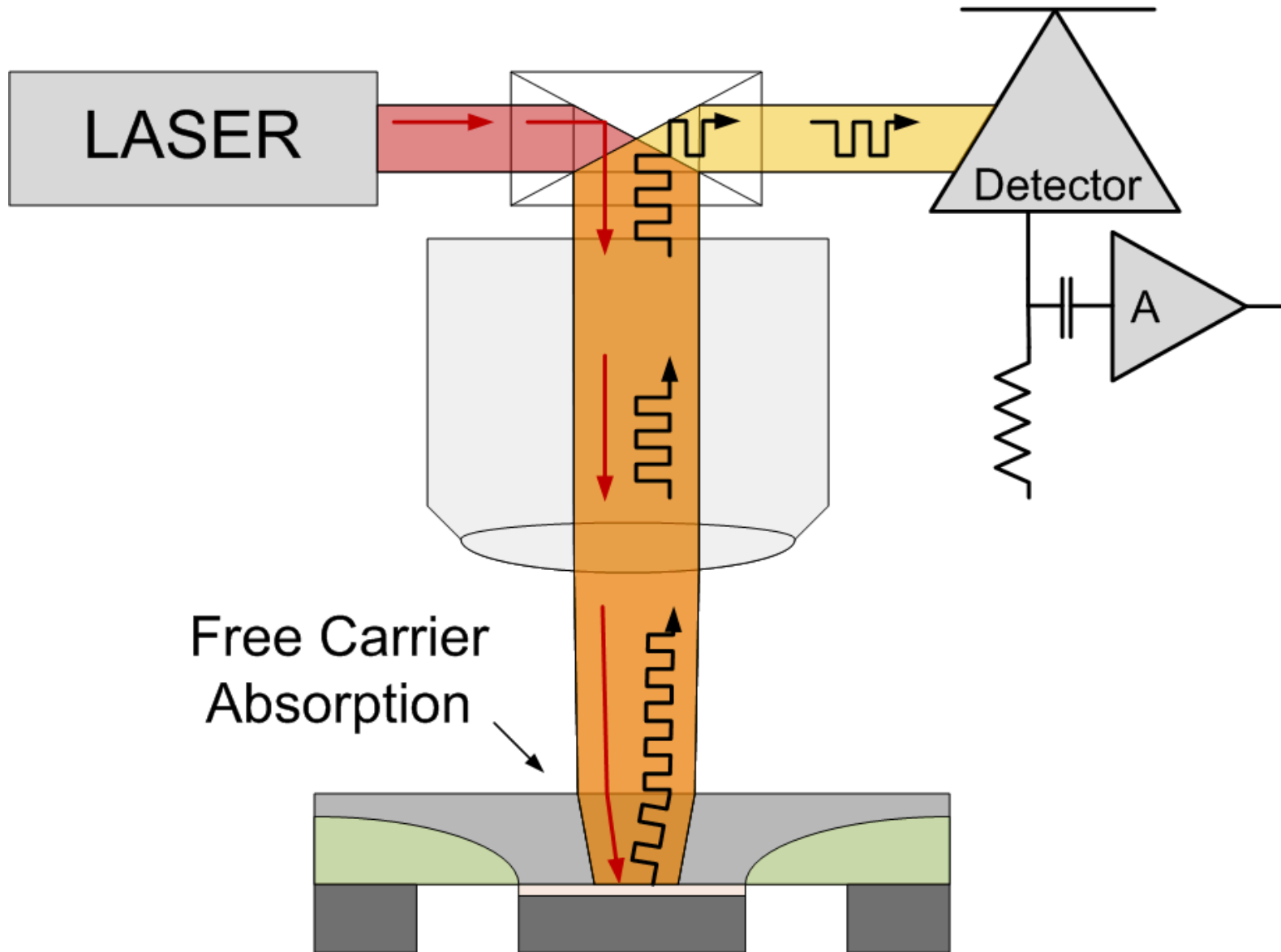
Purpose

- **Describe Ultra-Thin LVP (UTLVP) using visible light sources from the backside**
- **Discuss Ultra-Thinning of SOI substrates**
- **Discuss resolution improvements and signal enhancement**
- **Demonstrate UTLVP on multiple SOI technology nodes**

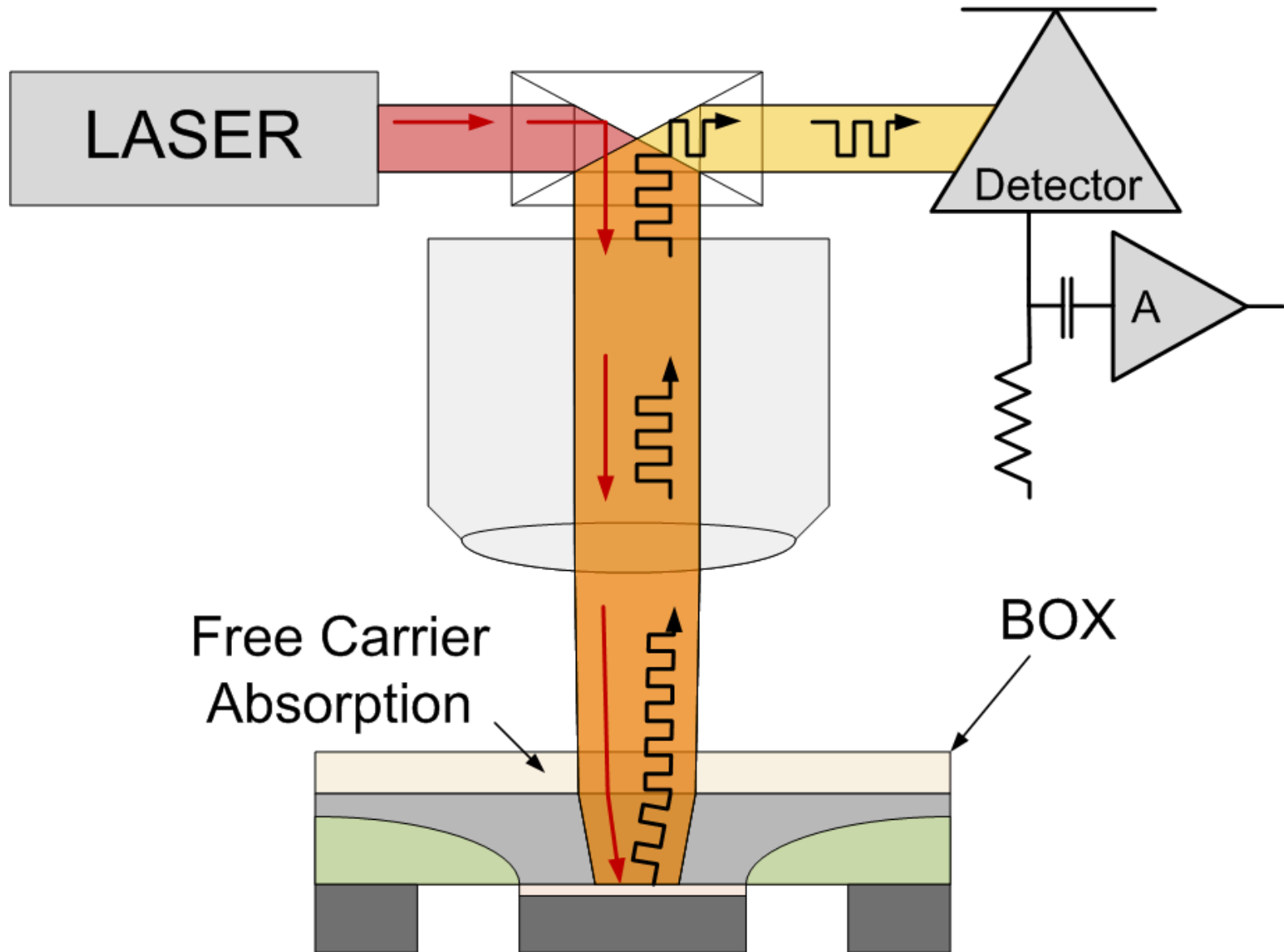
Outline

- **LVP Basics**
- **Ultra-Thinning**
- **Visible Light Resolution**
- **Visible Light Transmission**
- **UTLVP SOI Case Studies**
 - 350 nm
 - 45 nm
- **Conclusion**

LVP Basics



LVP Basics

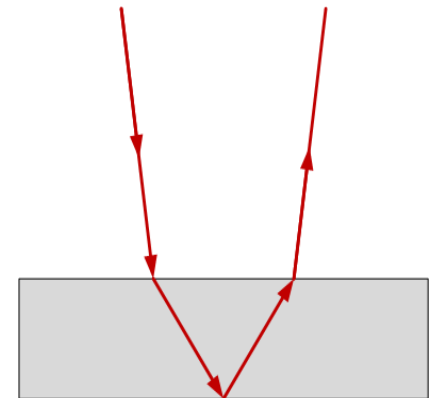
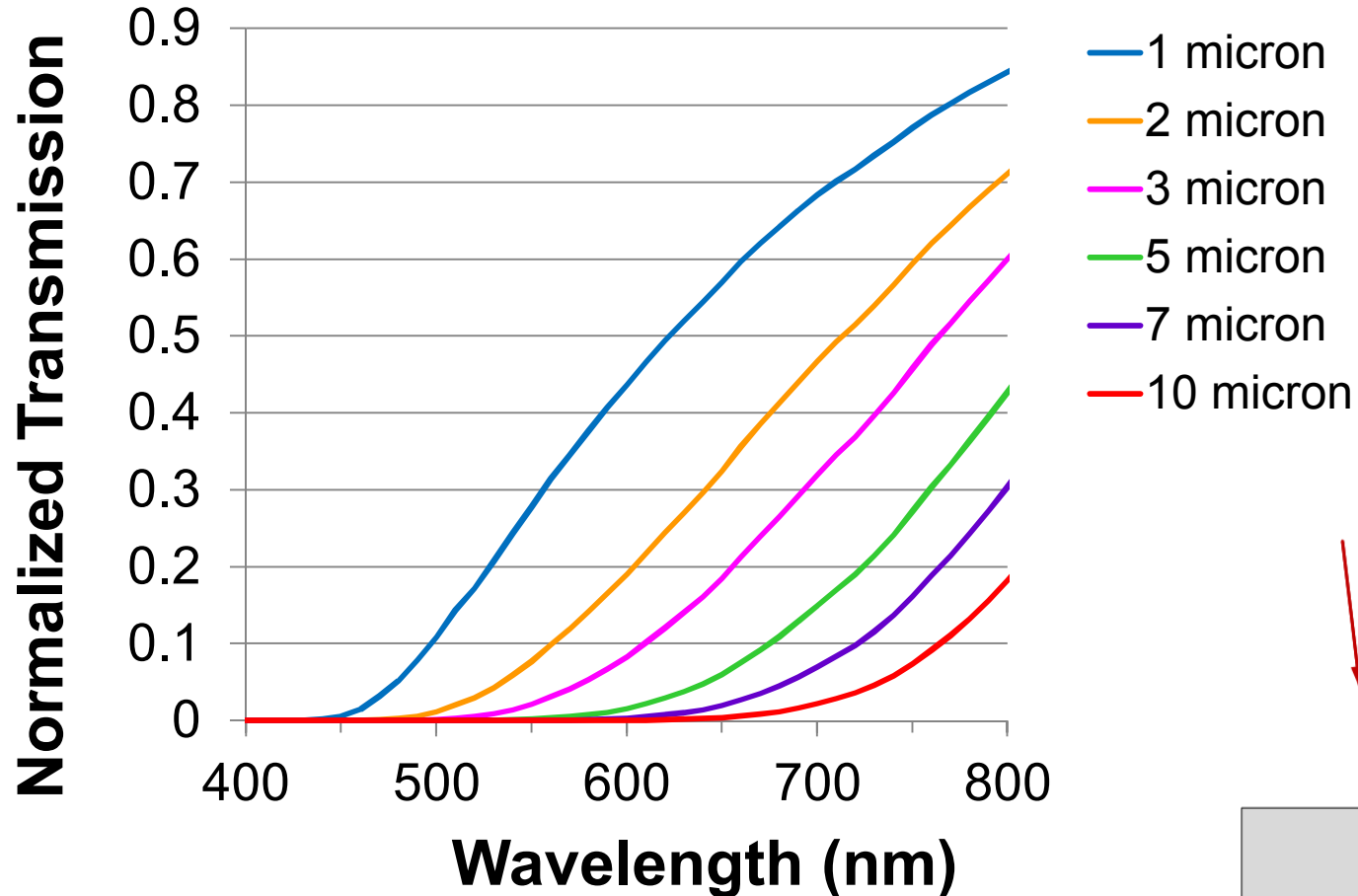


LVP Limitations

- **IR Light**
 - **Advantages**
 - **Silicon Transparency**
 - **Straightforward backside sample preparation**
 - **Limitations**
 - **Poor spatial resolution**
 - **Resolution enhancements becoming difficult**
- **Visible light addresses IR limitations**
 - **Advantages**
 - **Shorter wavelengths / Enhanced spatial resolution**
 - **Increased thinning is not difficult**
 - **New realm of possible resolution enhancements**

Visible Light Transmission

Transmission for a Double Through Si Transit



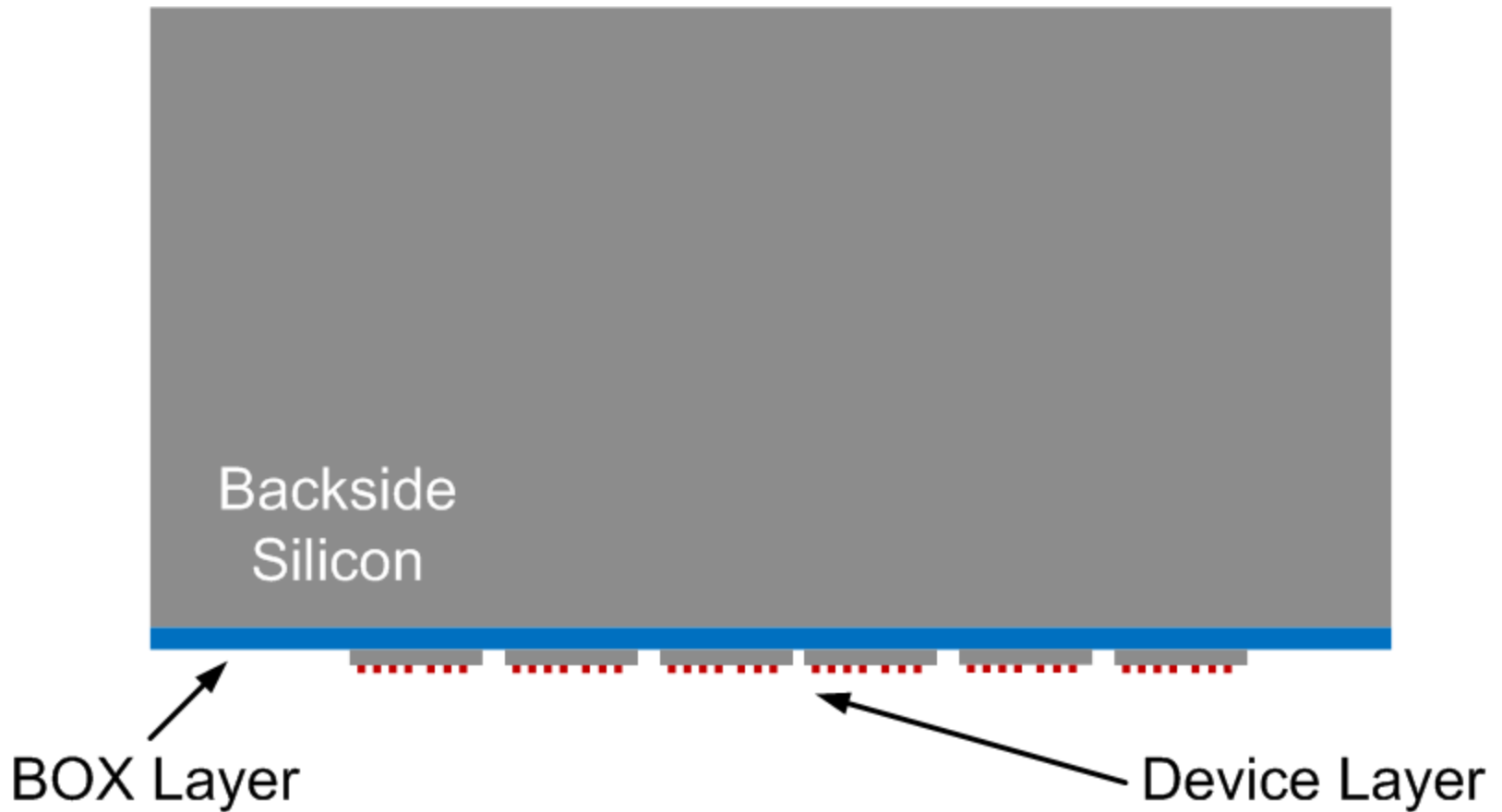
Visible Light Resolution

- Rayleigh Criteria

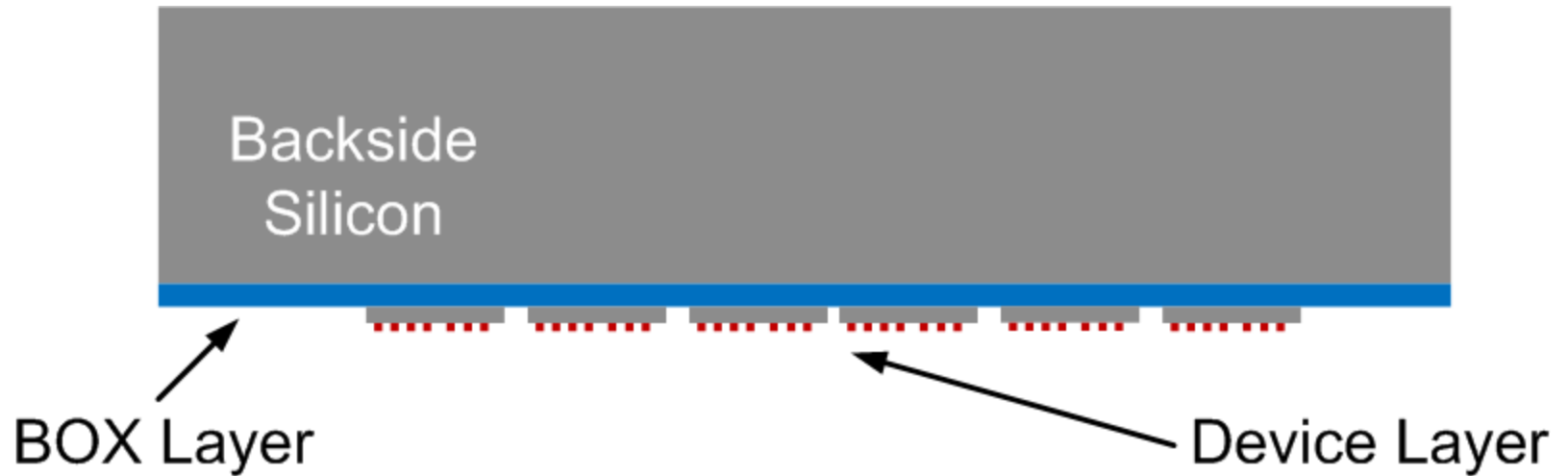
$$D = \frac{0.61\lambda}{NA}$$

Lens Type	λ (nm)	NA	D (nm)
Air Gap	633	0.9	429
	532	0.9	361
1.4 Oil	633	1.4	276
	532	1.4	232
3.0 SIL	1320	3.0	270
	1064	3.0	216

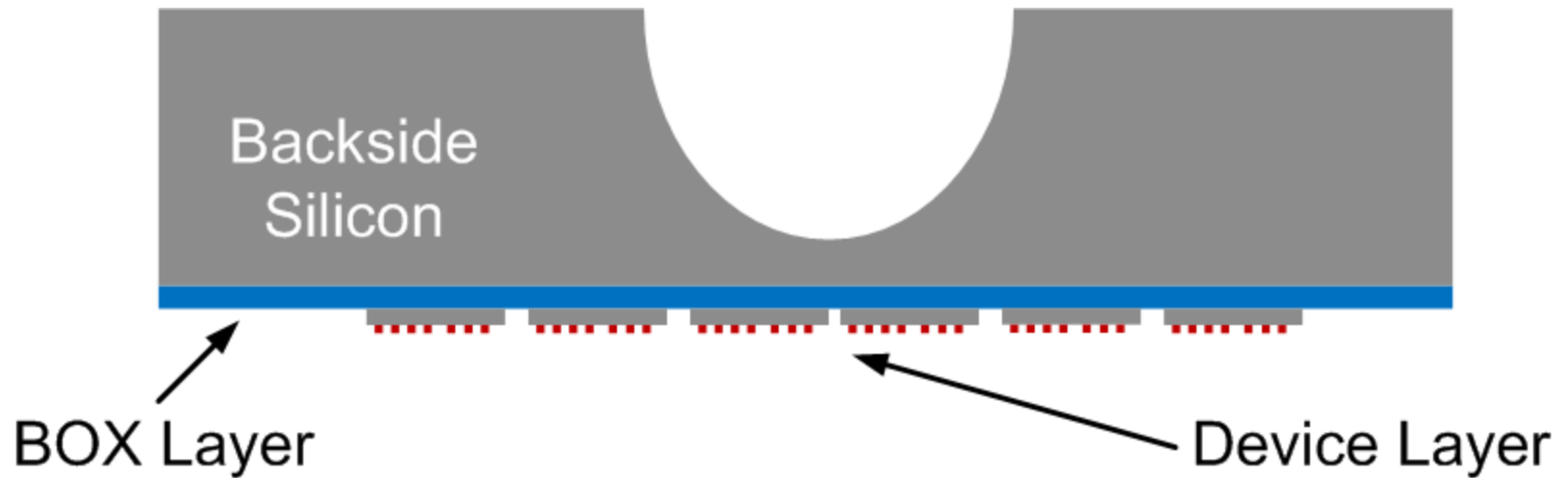
Ultra-Thinning



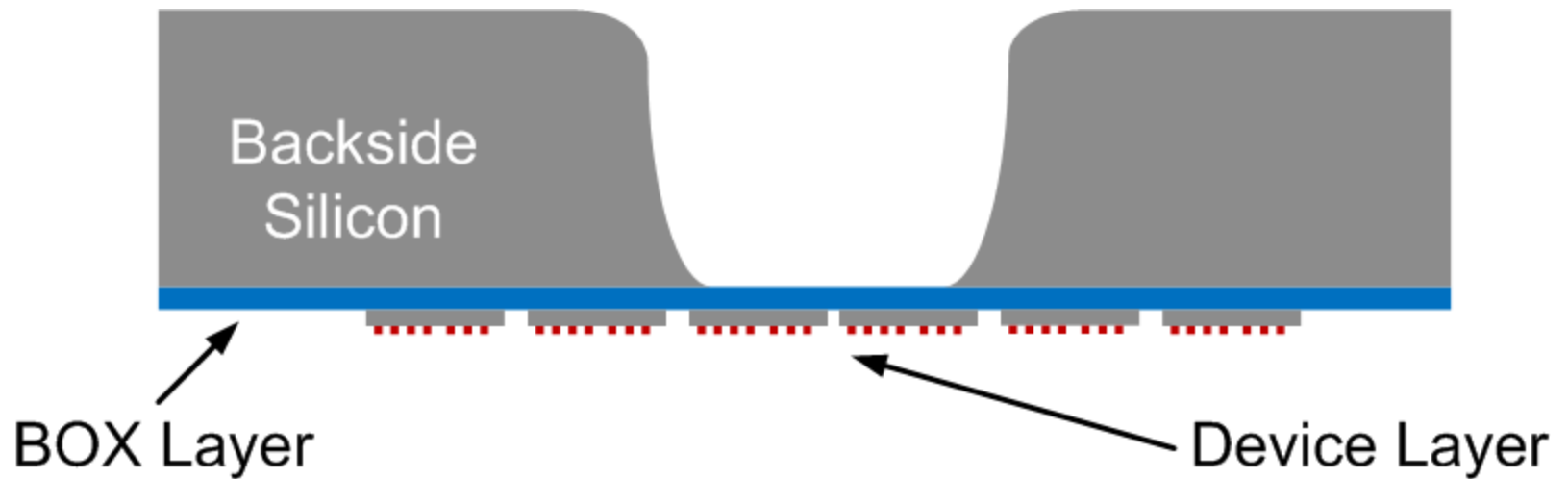
Ultra-Thinning



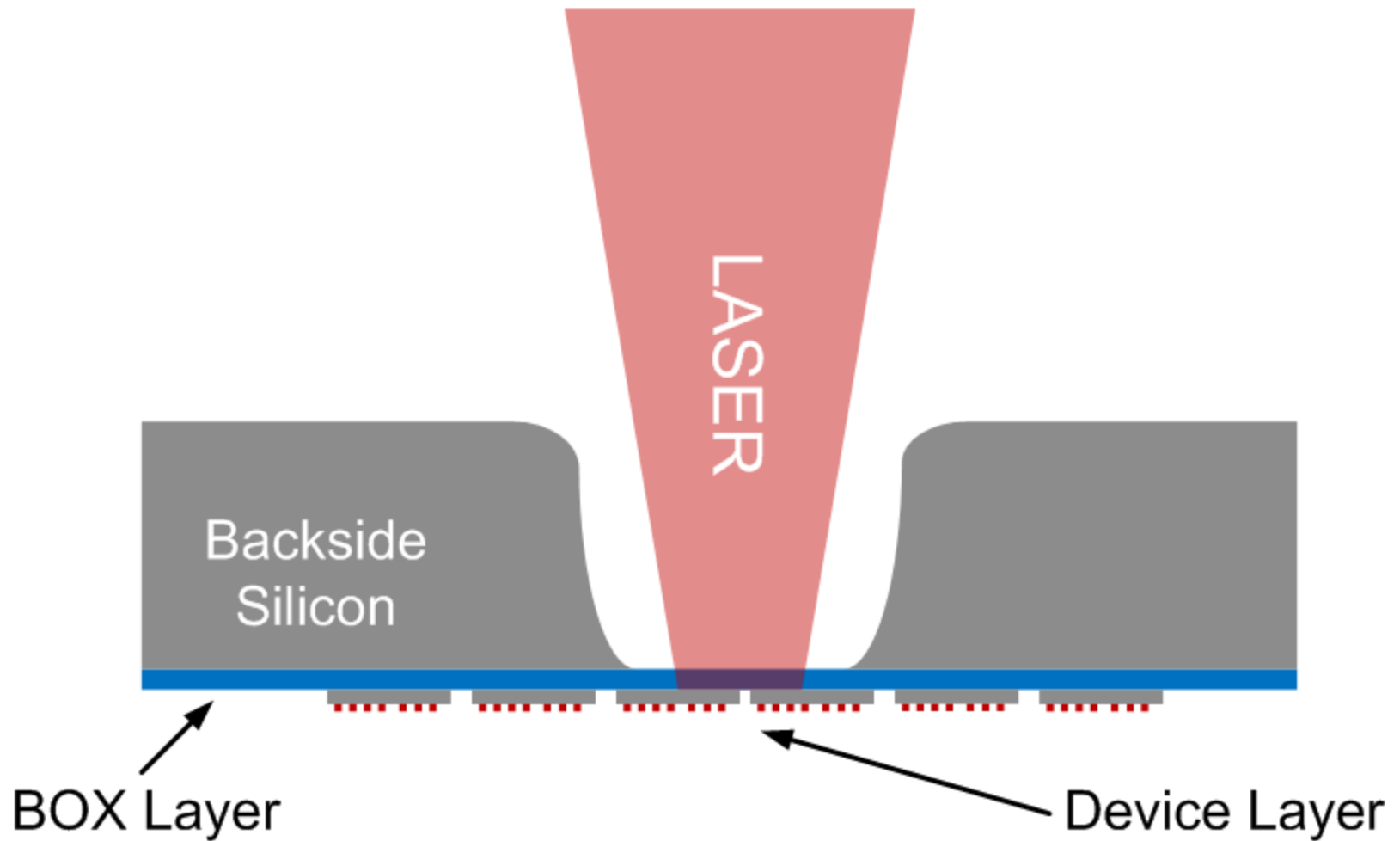
Ultra-Thinning



Ultra-Thinning



Ultra-Thinning



LVP Framework

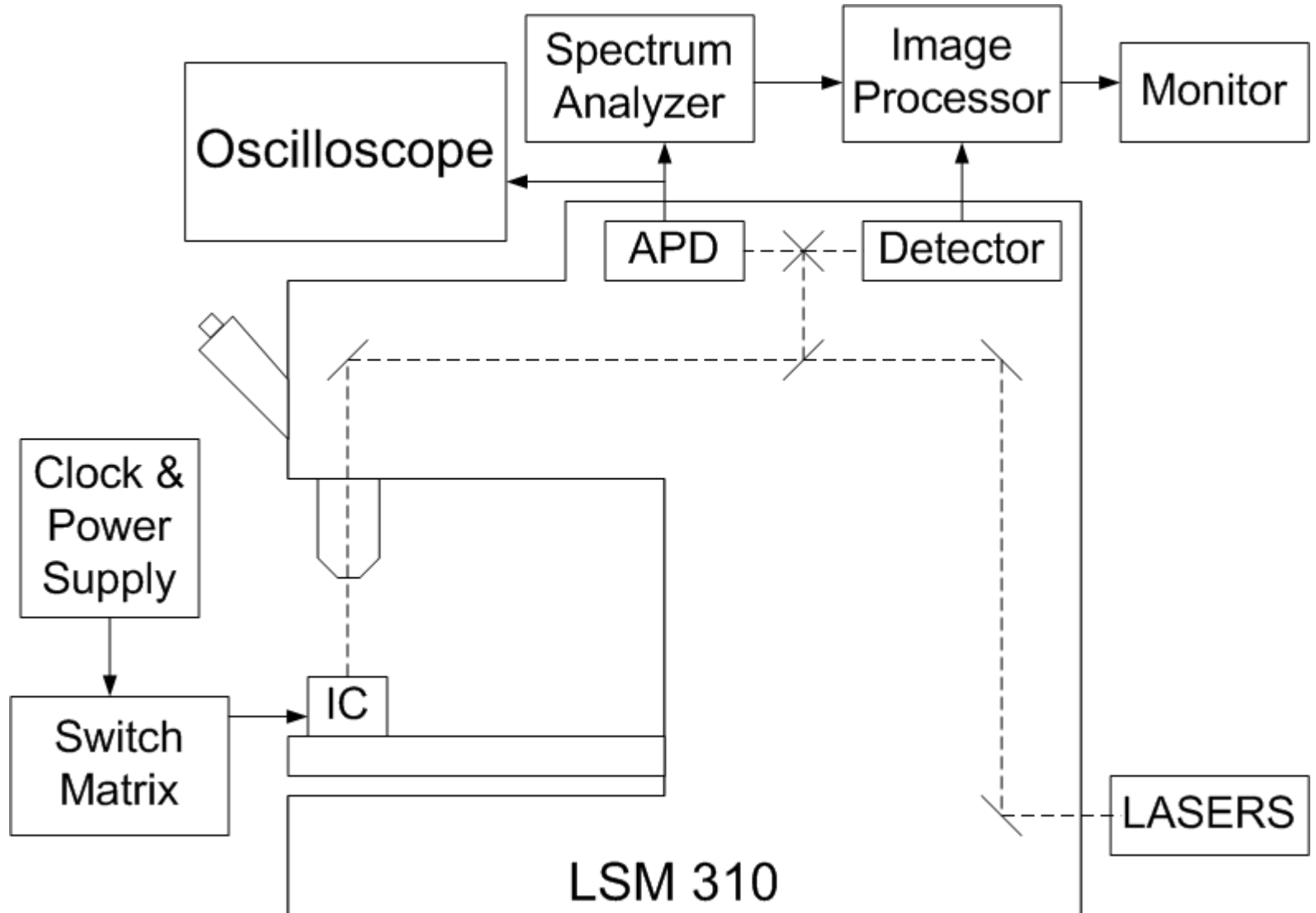
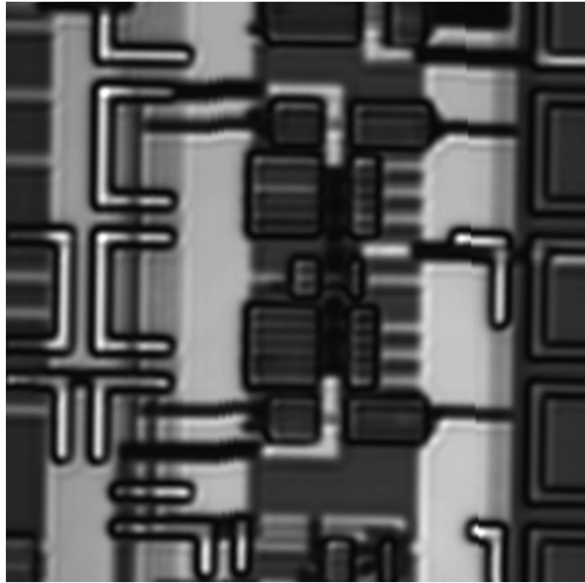


Image Contrast vs. Wavelength

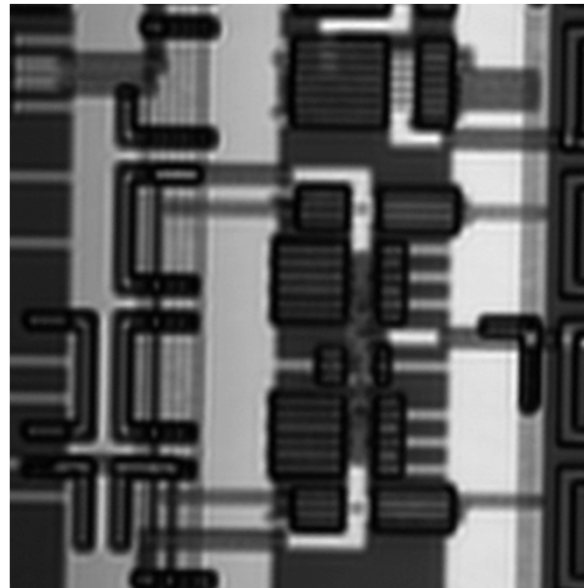


1320 nm

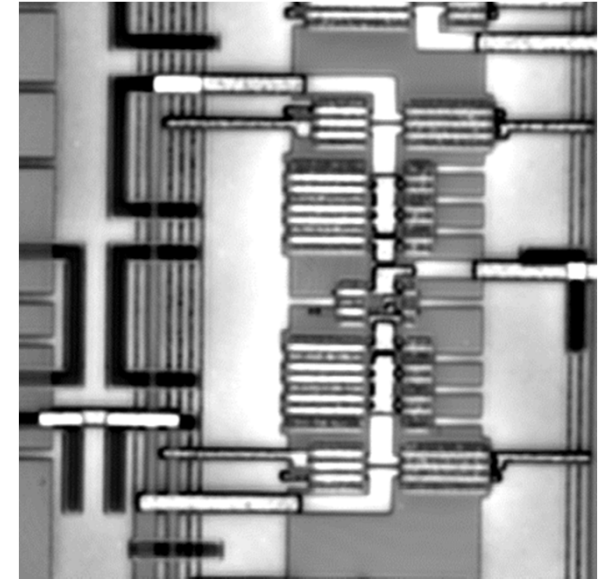
Improved Contrast

**Decreased Spatial
Resolution**

**Reflected light
images with 50x
objective
350 nm SOI**



1064nm

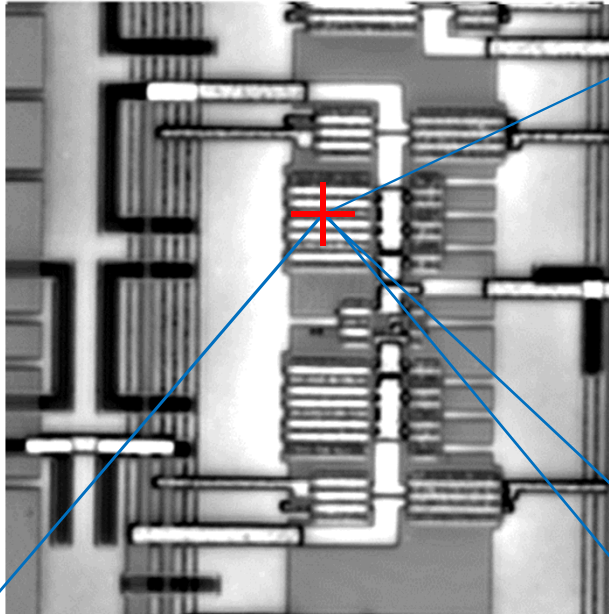


633 nm

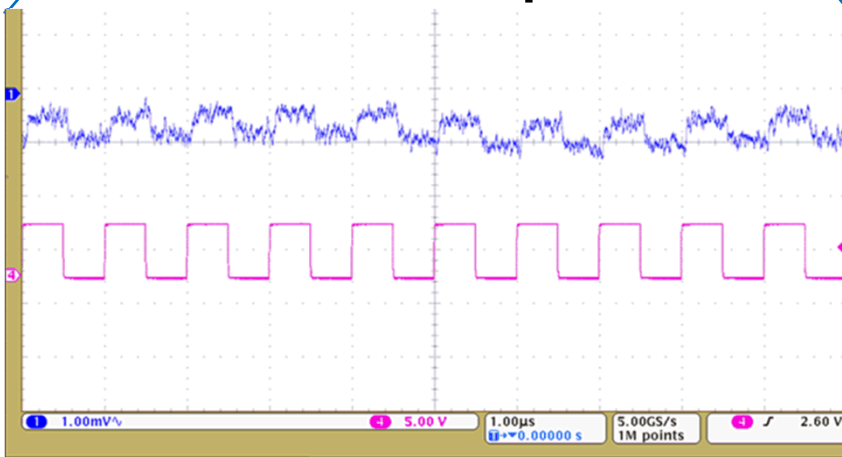
Decreased Contrast

**Improved Spatial
Resolution**

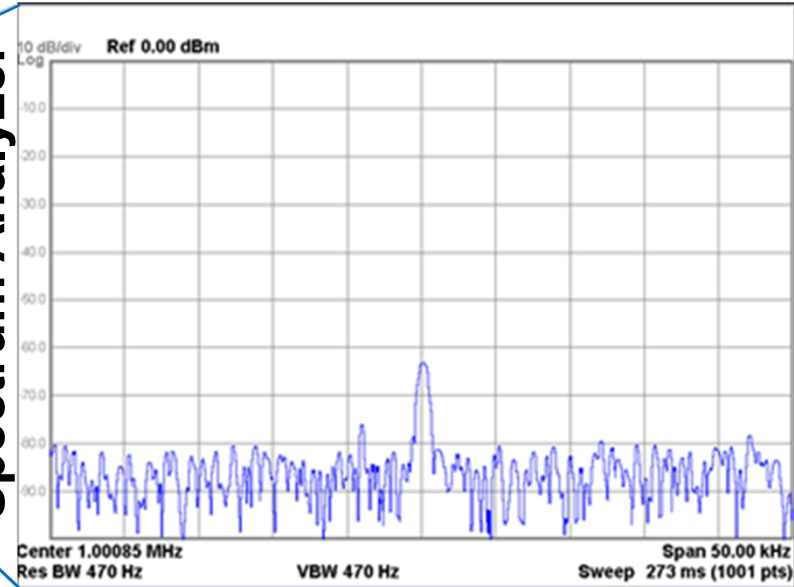
350 nm UTLVP



Oscilloscope



Spectrum Analyzer



Presence of LVP Signal

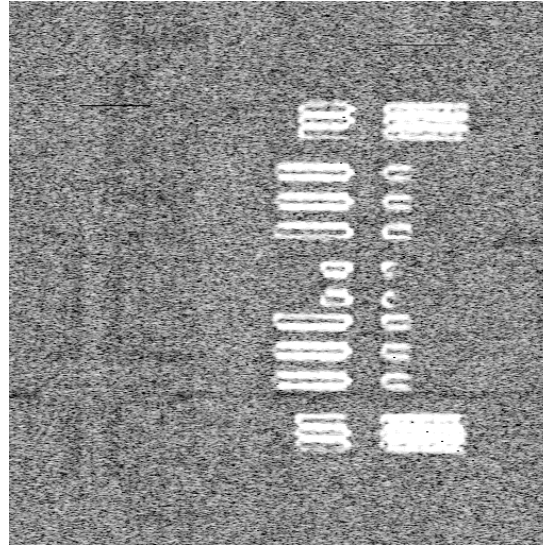
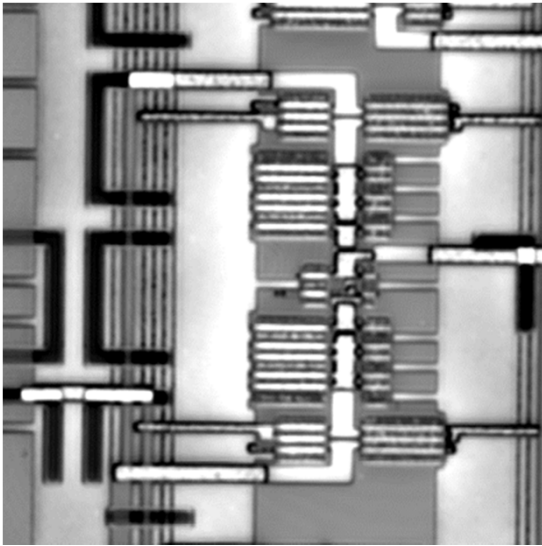
Scope
Averaging to
capture LVP
Signal

633 nm 50x
Obj.

Signal Directly
from APD
Module

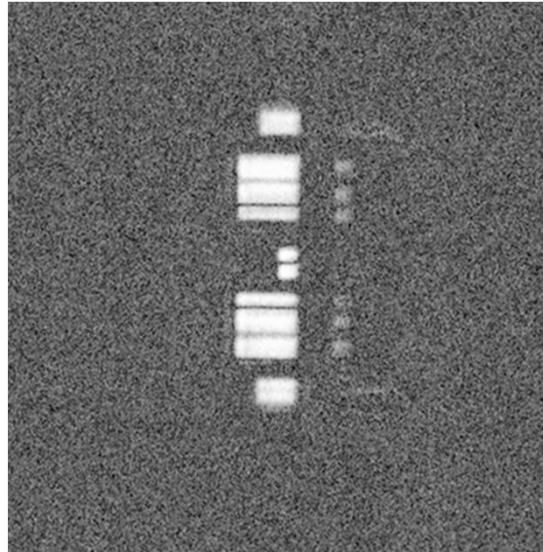
350 nm UTLVI

633 nm



**Signal from APD
fed into zero
spanned
Spectrum
Analyzer**

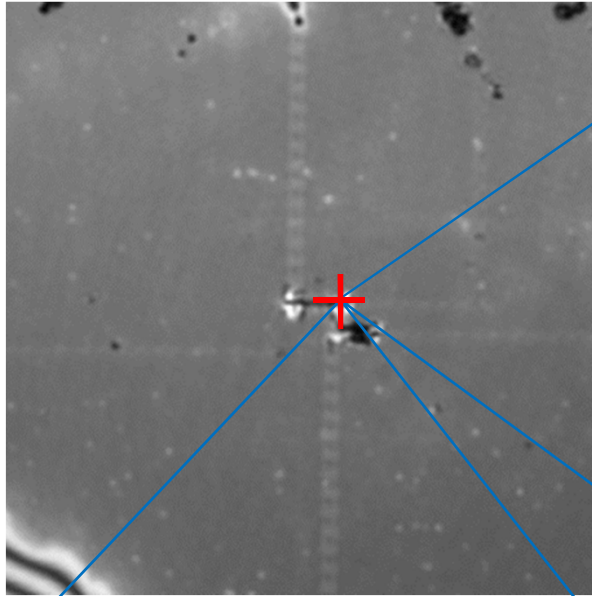
1320 nm



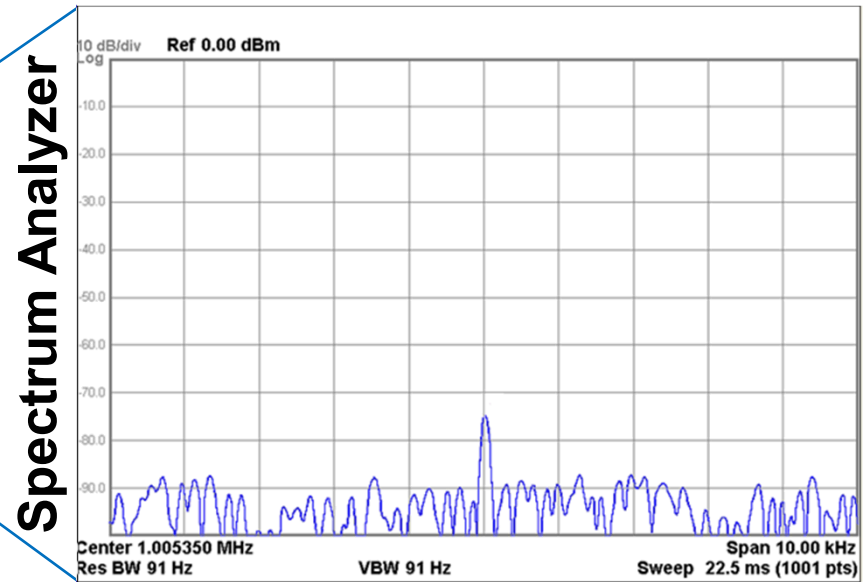
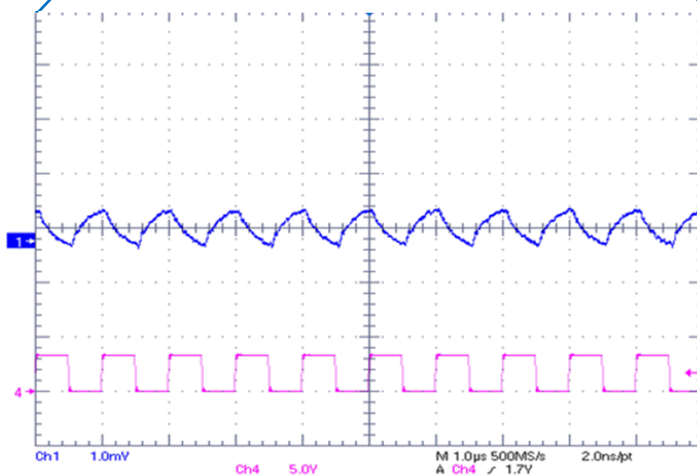
**Video Out from
Spectrum
Analyzer fed
into frame buffer**

**50x
Objective**

45 nm UTLVP



Oscilloscope



Presence of LVP Signal

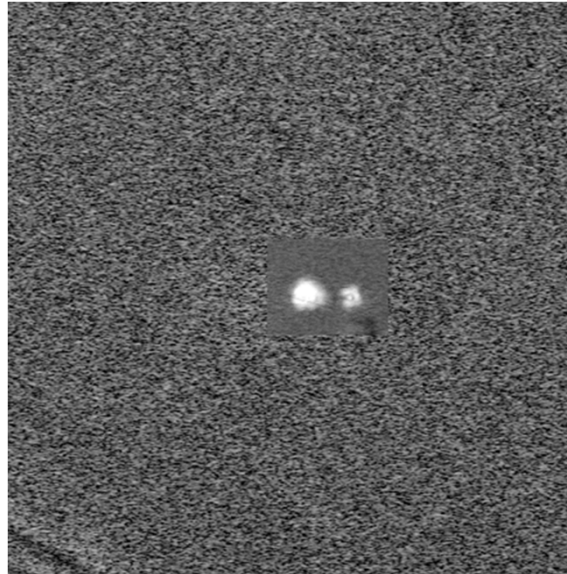
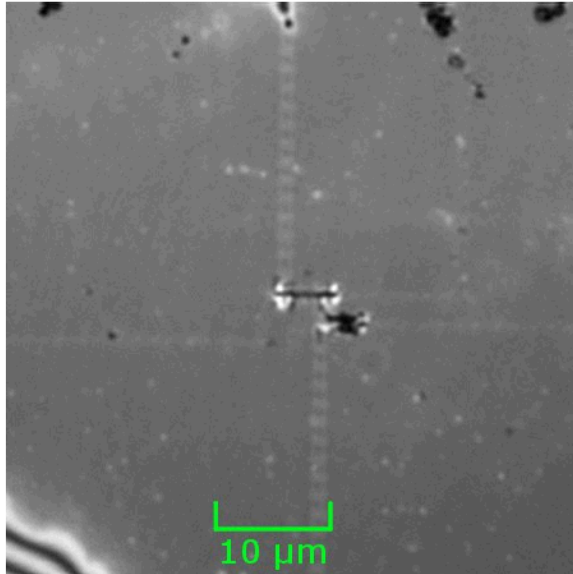
Scope Averaging to capture LVP Signal

**633 nm 50x
Obj.**

Signal Directly from APD Module

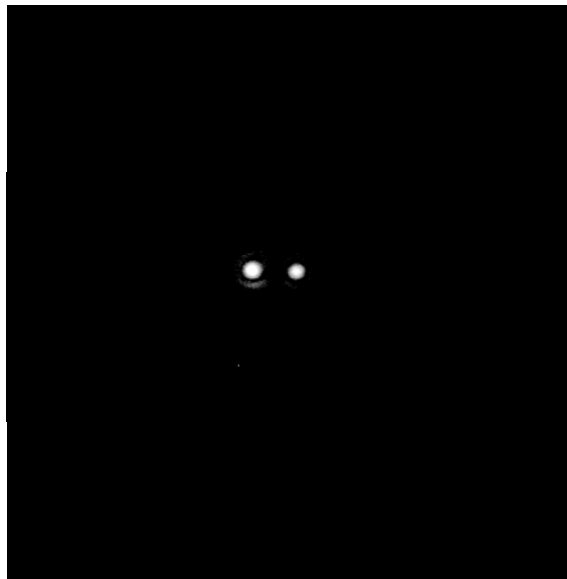
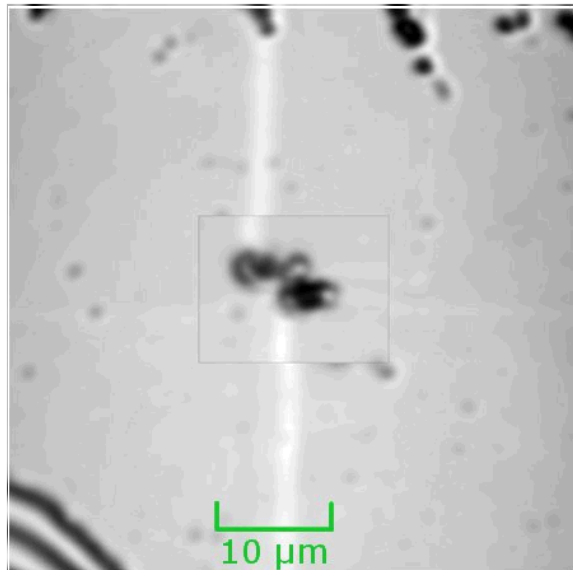
45 nm UTLVI

633 nm



**Signal from APD
fed into zero
spanned
Spectrum
Analyzer.**

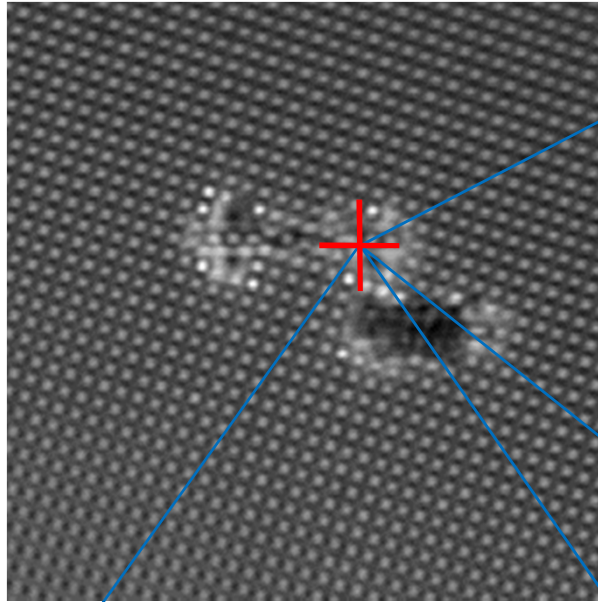
1320 nm



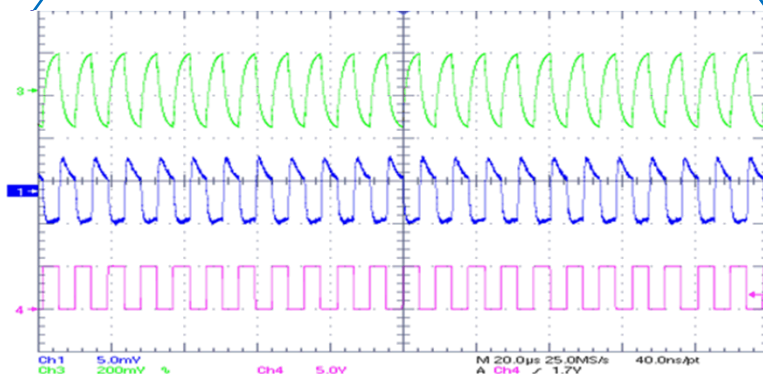
**Video Out from
Spectrum
Analyzer fed
into frame buffer**

50x Obj.

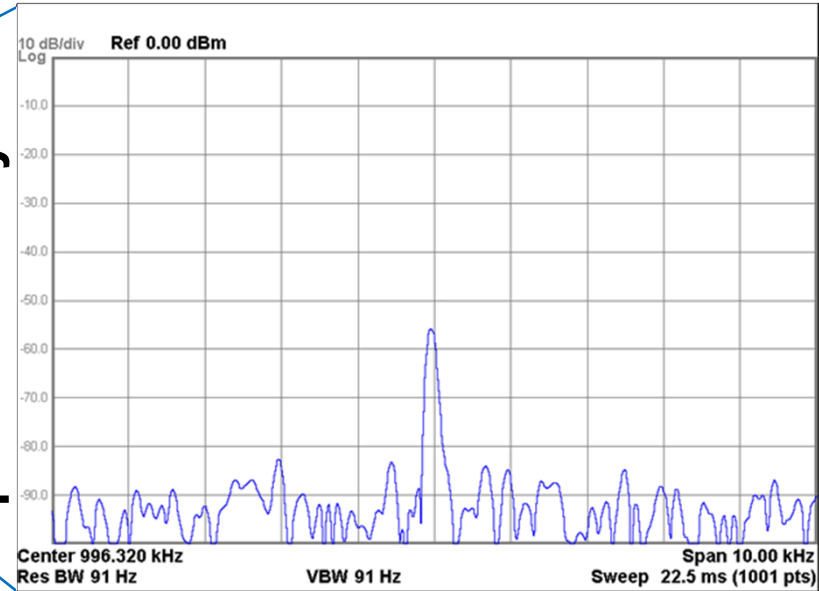
45 nm UTLVP with Oil Immersion



Oscilloscope



Spectrum Analyzer



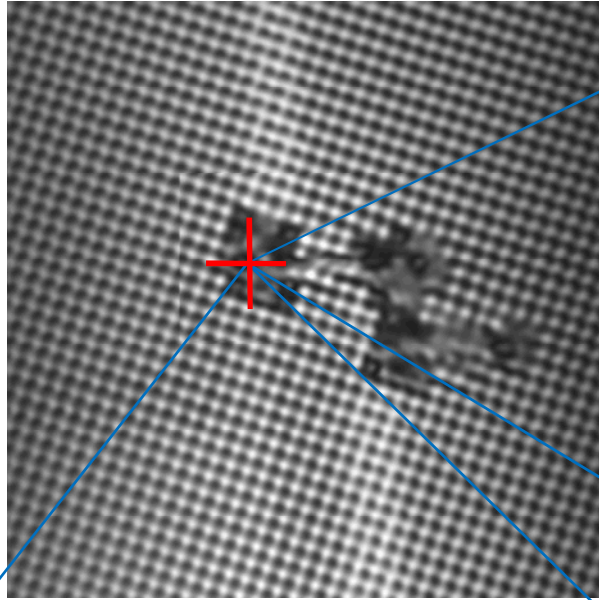
Presence of LVP Signal

Scope
Averaging to
capture LVP
Signal

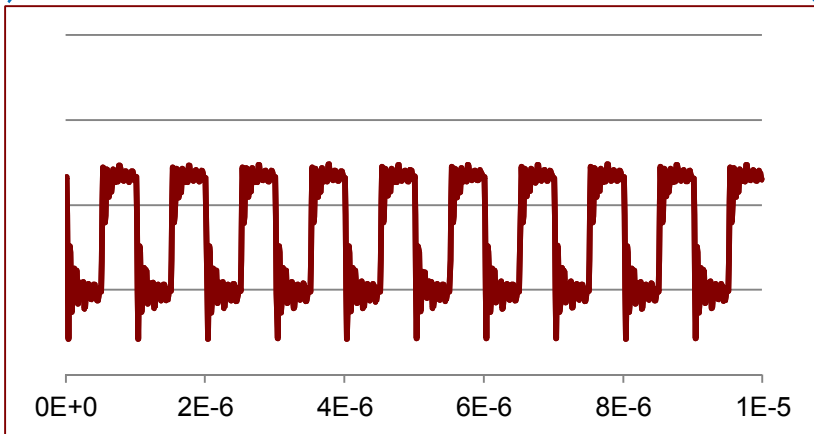
633 nm 63x
1.4 NA Obj.

Signal Directly
from APD
Module

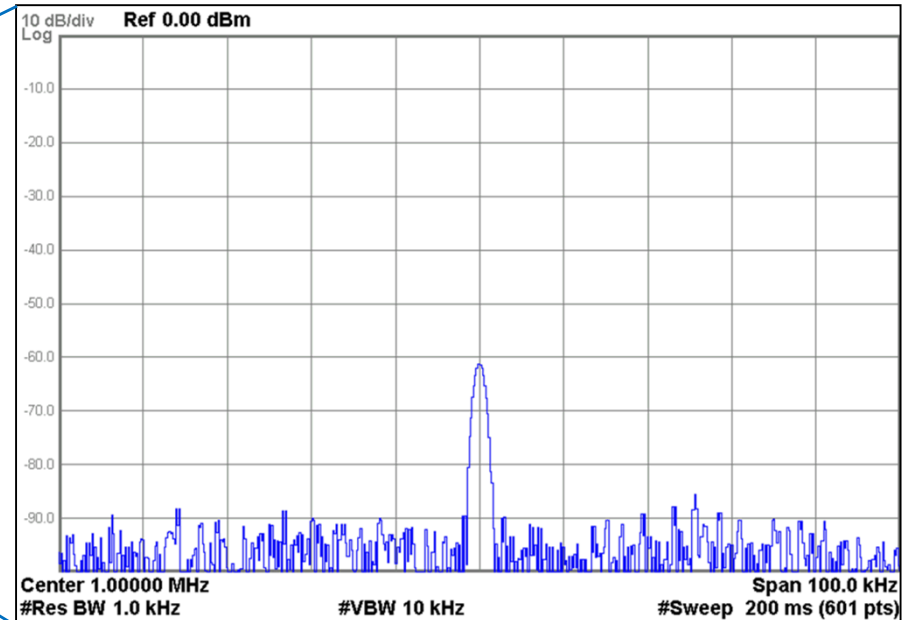
45 nm Conventional LVP with SIL



Oscilloscope



Spectrum Analyzer



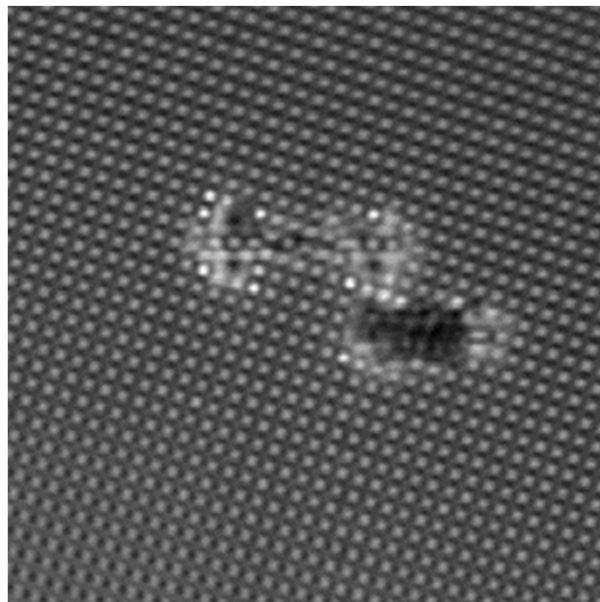
Presence of LVP Signal

Scope
Averaging to
capture LVP
Signal

1320 nm 300x
2.6 NA Obj.

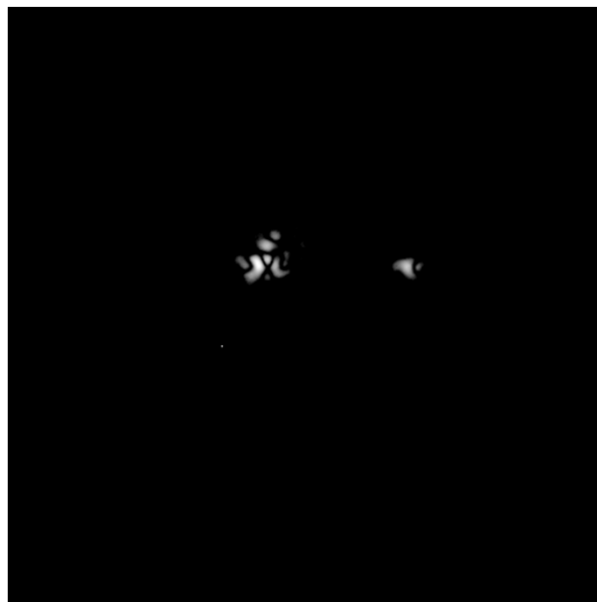
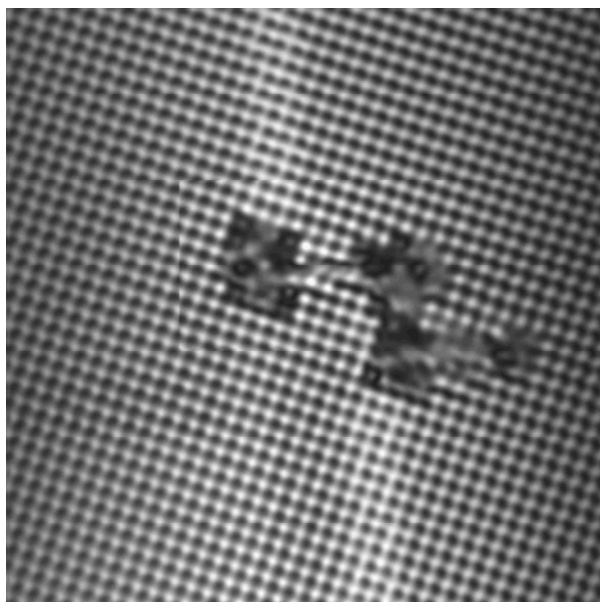
45 nm Oil UTLVI vs. SIL LVI

633 nm



UTLVP
1.4 NA OIL

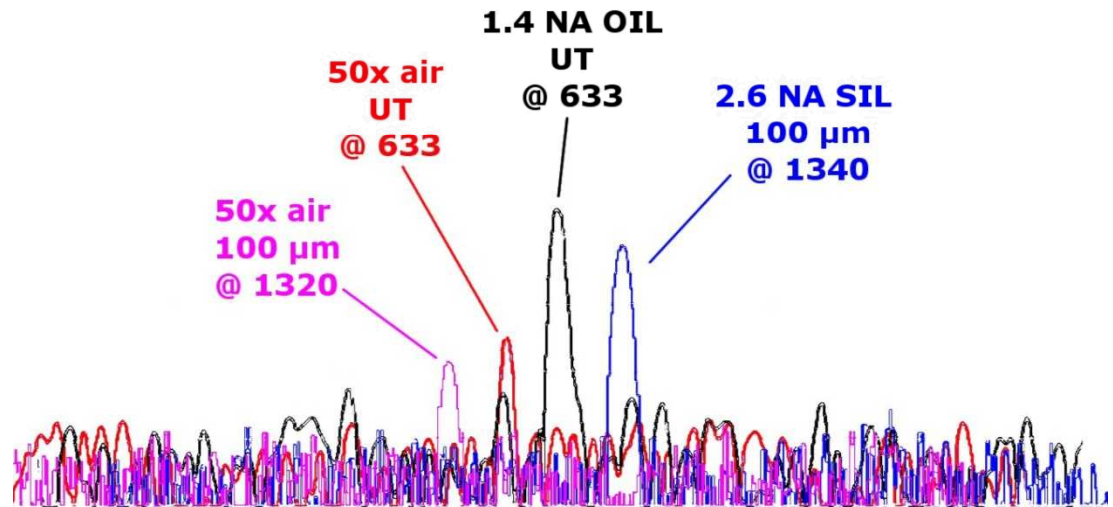
1320 nm



LVP
2.6 NA SIL

Effects on Signal Strength

- Higher power density with improved NA
- Short wavelength signal improvement



Conclusions

- **Demonstrated visible light UTLVP**
 - **Desired for improved spatial resolution**
 - **Unexpected signal enhancement**
 - **Relatively straightforward to implement**
 - **Demonstrated waveforms and imaging**
- **Requires Backside Ultra-Thinning**
 - **Effective SOI thinning process established**
- **Bulk devices are target of future work**