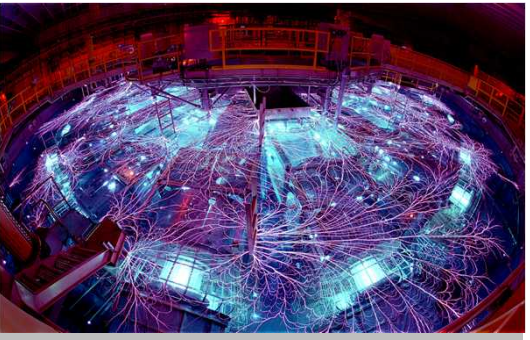
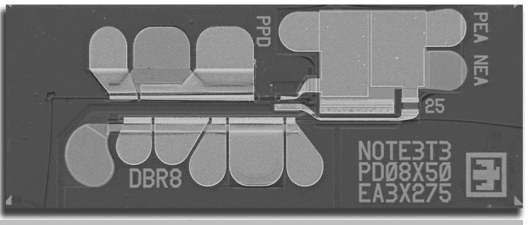
SAND2014-17026PE

Building a photonic streak camera

Streak camera meeting
Sandia National Laboratories
August 26-27, 2014





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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Fundamental Problem

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- How does one record short-duration, single-event data
  - Nanosecond time resolution (10-1000 ns duration)?
  - In harsh environments (Z)?
  - Spectrally and temporally resolved?

- Streak camera approach
  - Resolution is ~ 1024 x 1024 pixels
  - Trade-off between temporal resolution and total time duration
  - Limited to an effective 100-200 position/wavelength points
  - Based on vacuum tubes
  - Expensive

A photonic alternative

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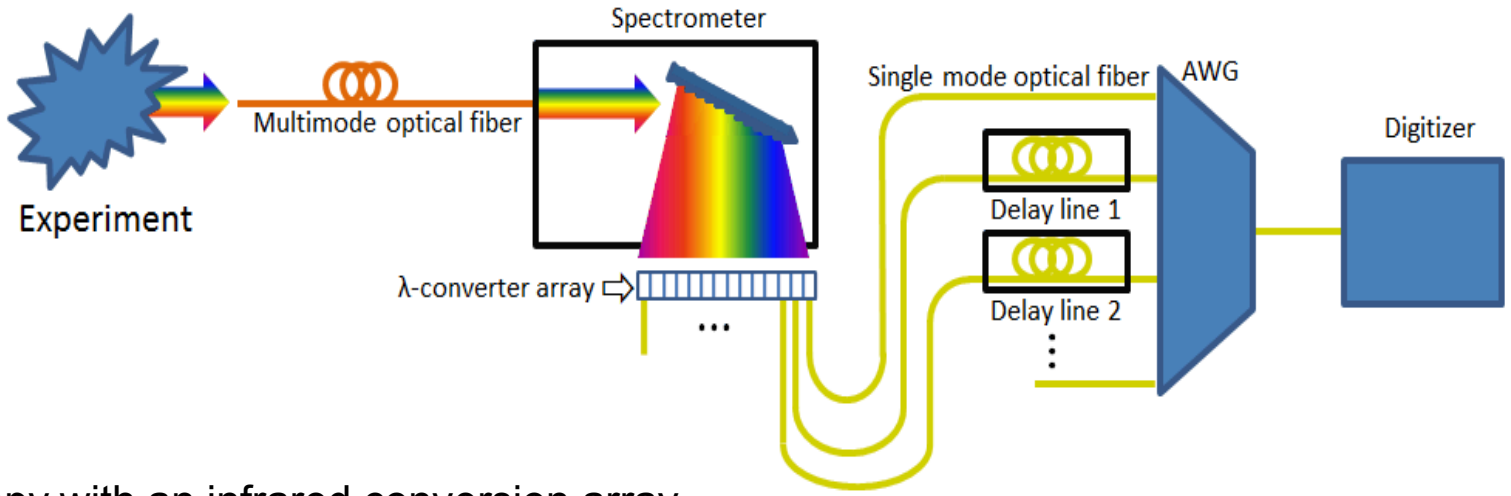
- Modern digitizers
  - Stores 500 million points at a time (upgradable to 1 billion)
  - Records 4 independent channels
  - Supports 40 GS/s (2.5 GHz bandwidth), higher bandwidth models available
- Telecommunications components to route/delay data
  - Example: photonic Doppler velocimetry (PDV)
  - Operate in the near-infrared (1550 nm) rather than visible spectrum
  - Almost entirely fiber-based
- Visible(x-ray)-to-infrared optical conversion
  - A wavelength conversion device is the missing link
  - Develop a visible-to-infrared conversion photonic integrated circuit

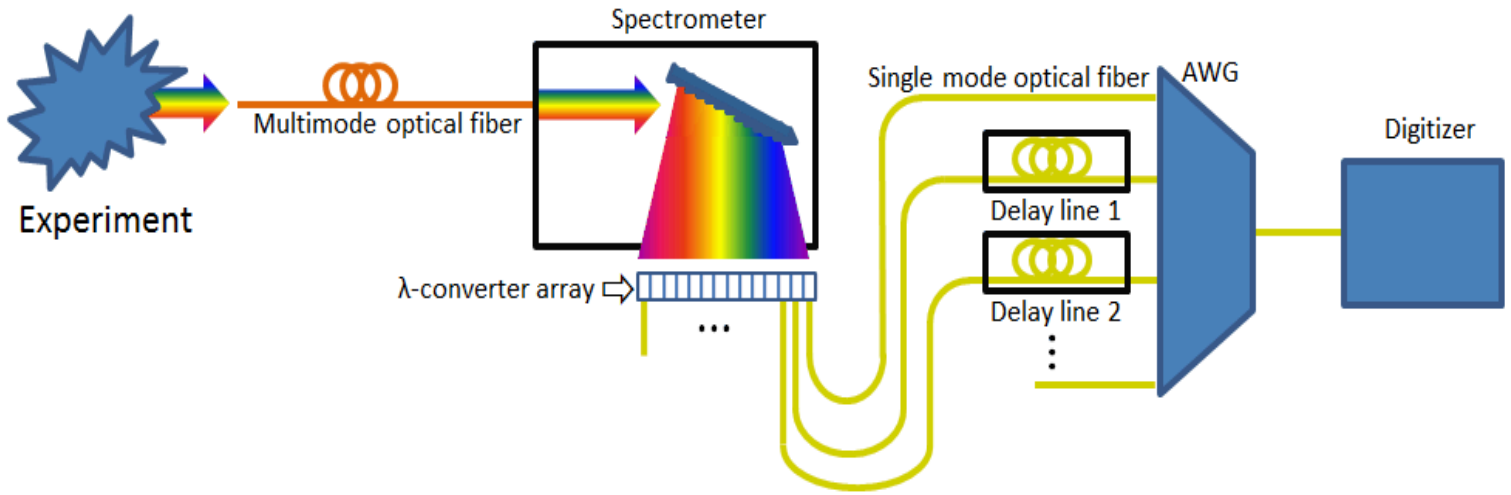
Infrared conversion

- Encoding information onto an infrared carrier opens up huge range of new possibilities
  - Fiber losses are minimal (0.2 dB/km), so time-multiplexing is feasible
  - High-efficiency mux/demux for different carrier signals
  - Everything after the converter is commercial equipment!

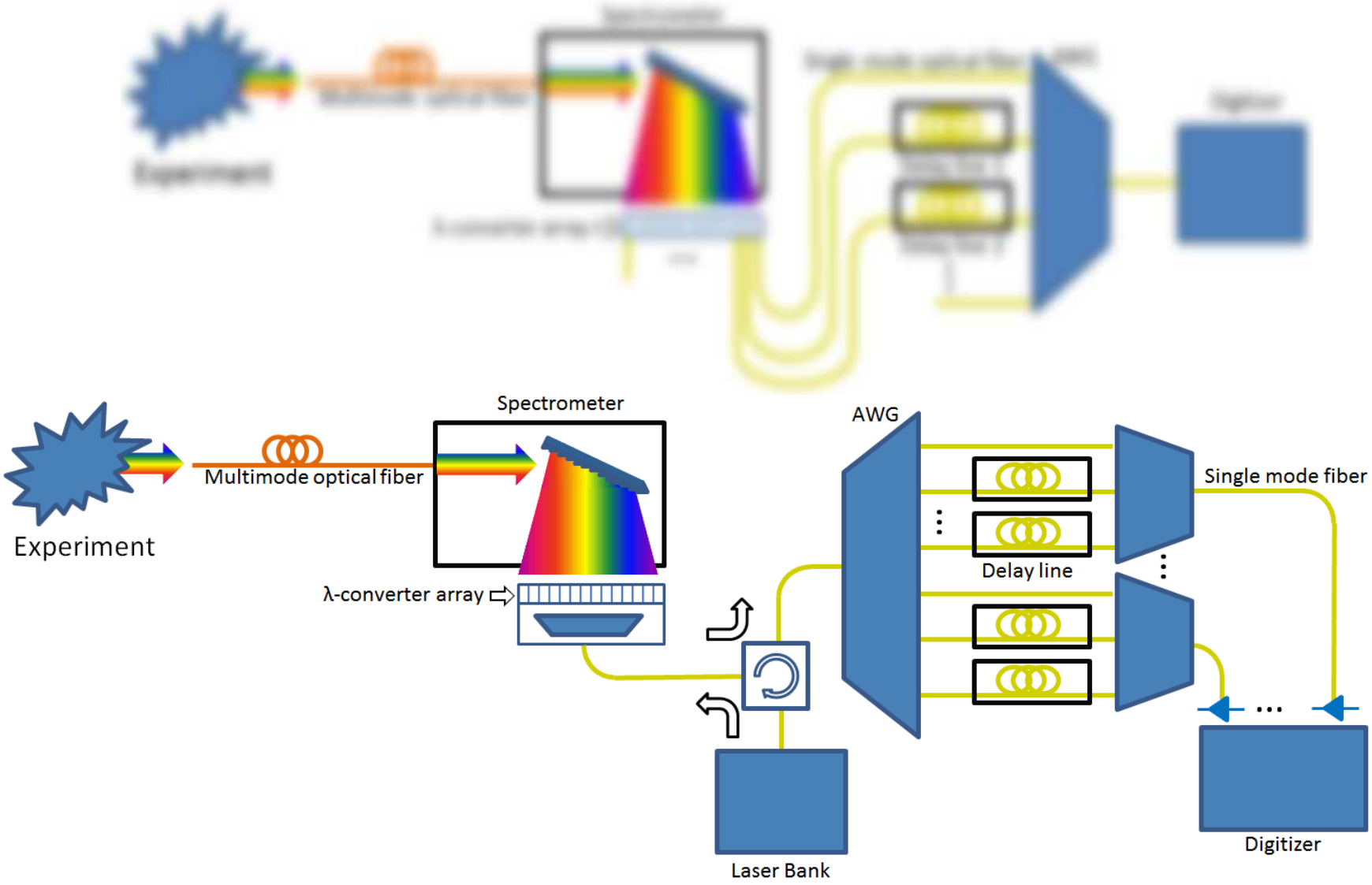


Spectroscopy with an infrared conversion array

System Architecture

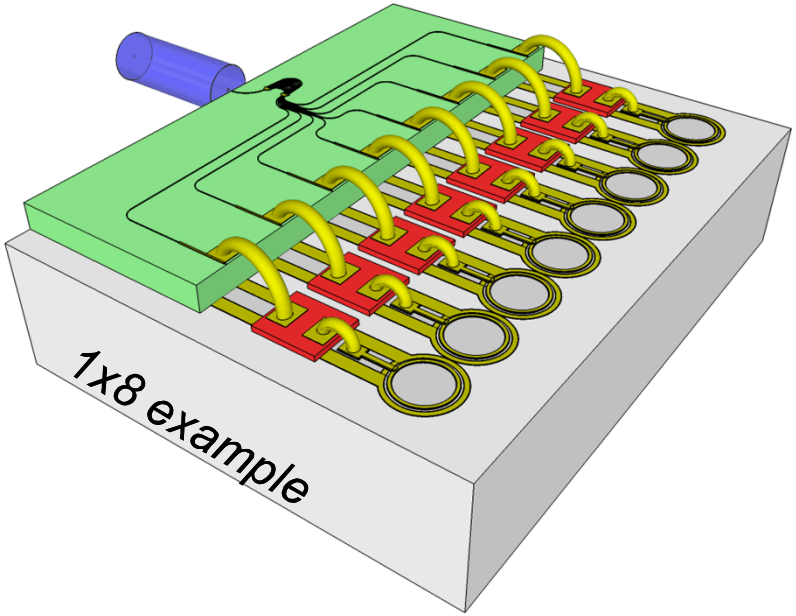


System Architecture

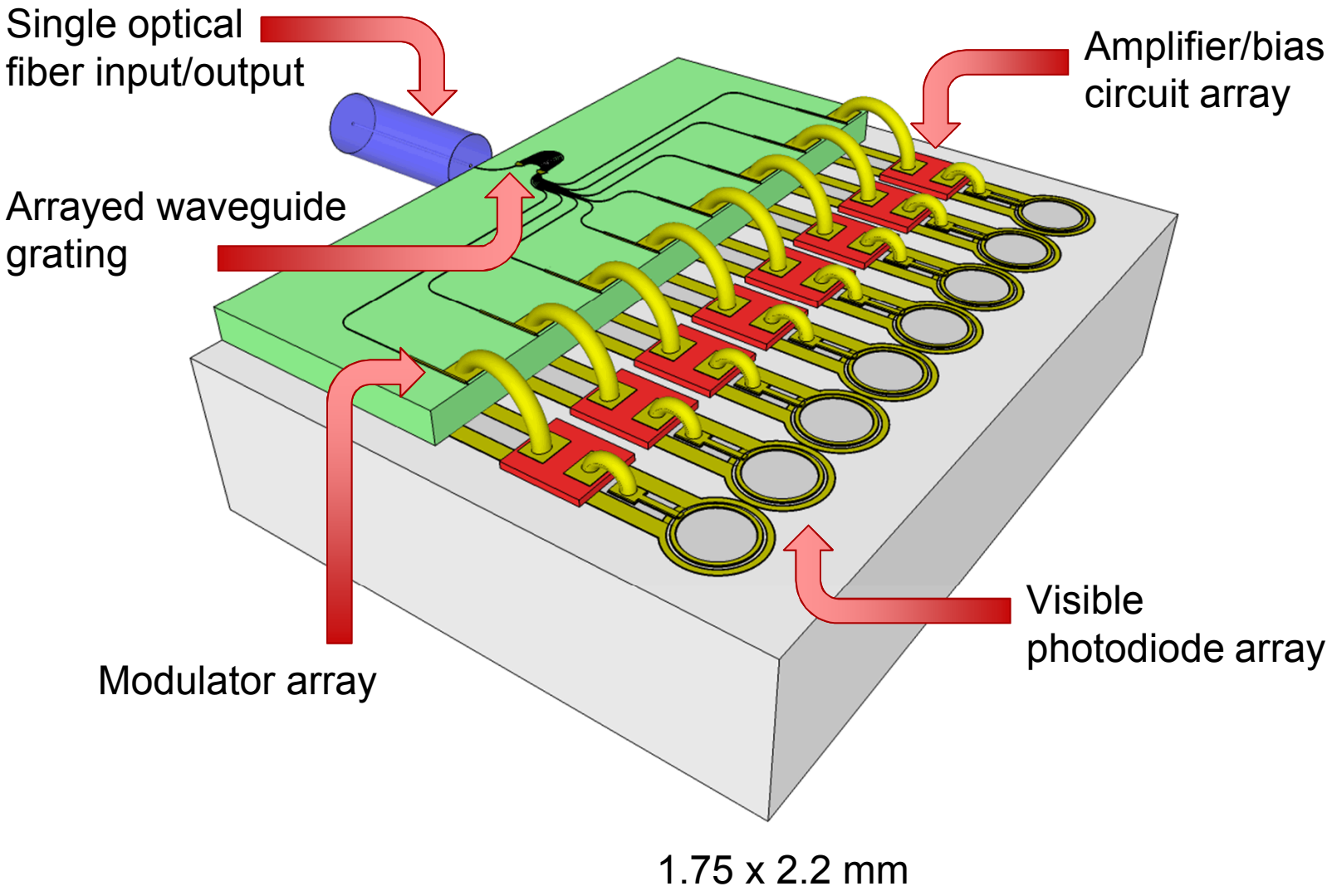


Conversion overview

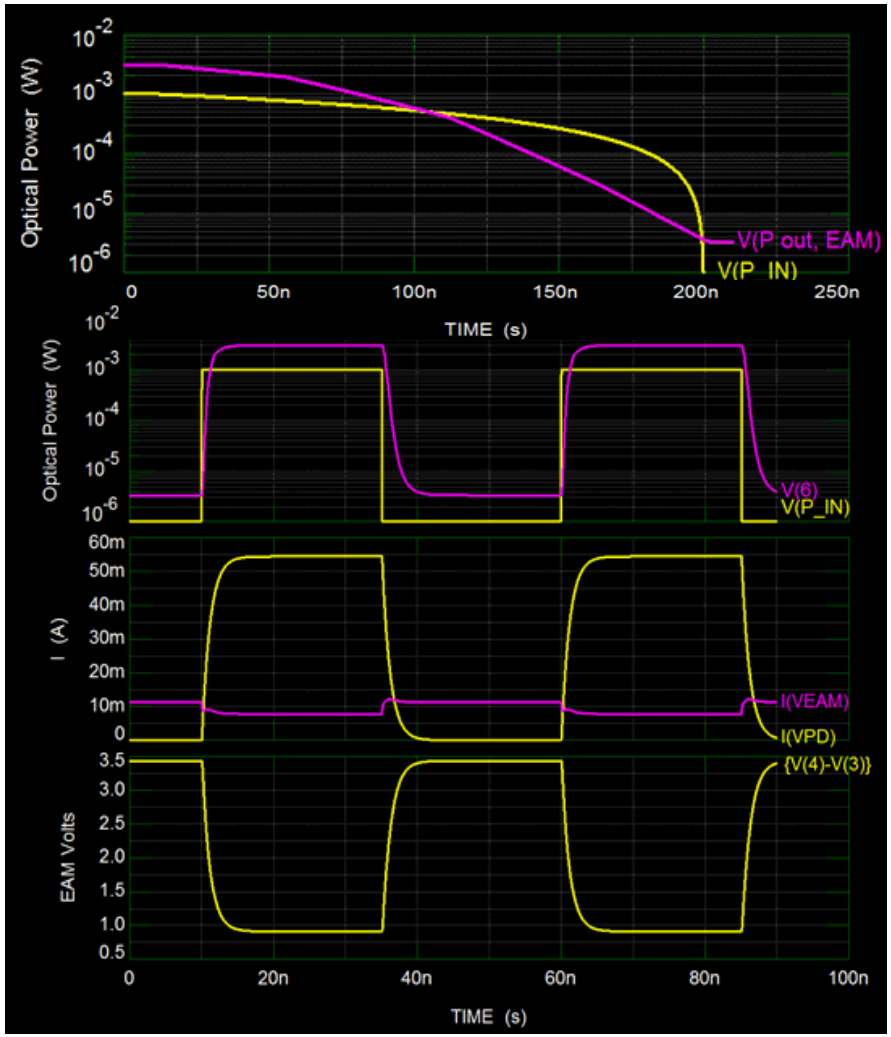
- Visible light strikes an array of photodiodes
  - Photons converted to electrons
- Electrical signal is:
  - Amplified
  - Passed to an infrared electroaborption modulator (EAM)
- Double-passed EAM modifies light from an external laser
  - Back to photons
  - Optically amplified as necessary
- Initial goal
  - 32 channel array of visible-to-infrared conversion devices with 1 ns or better time resolution (recorded with one 4-channel digitizer)

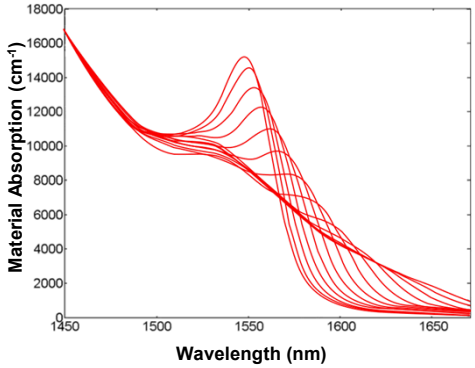


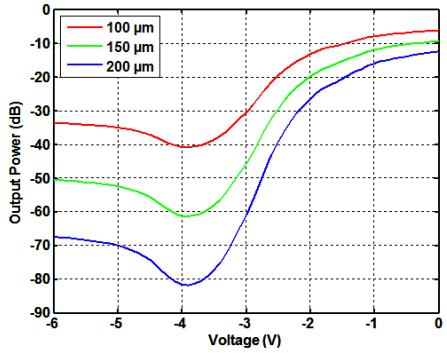
Integrated Design



Modeling

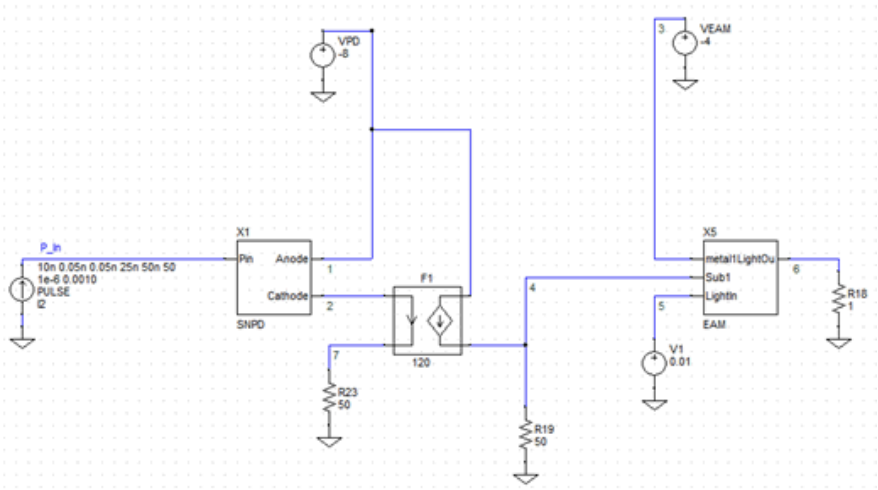






Wavelength converter model

- 1 mW input change → 30 dB output change



Visible-to-Infrared Conversion Demo

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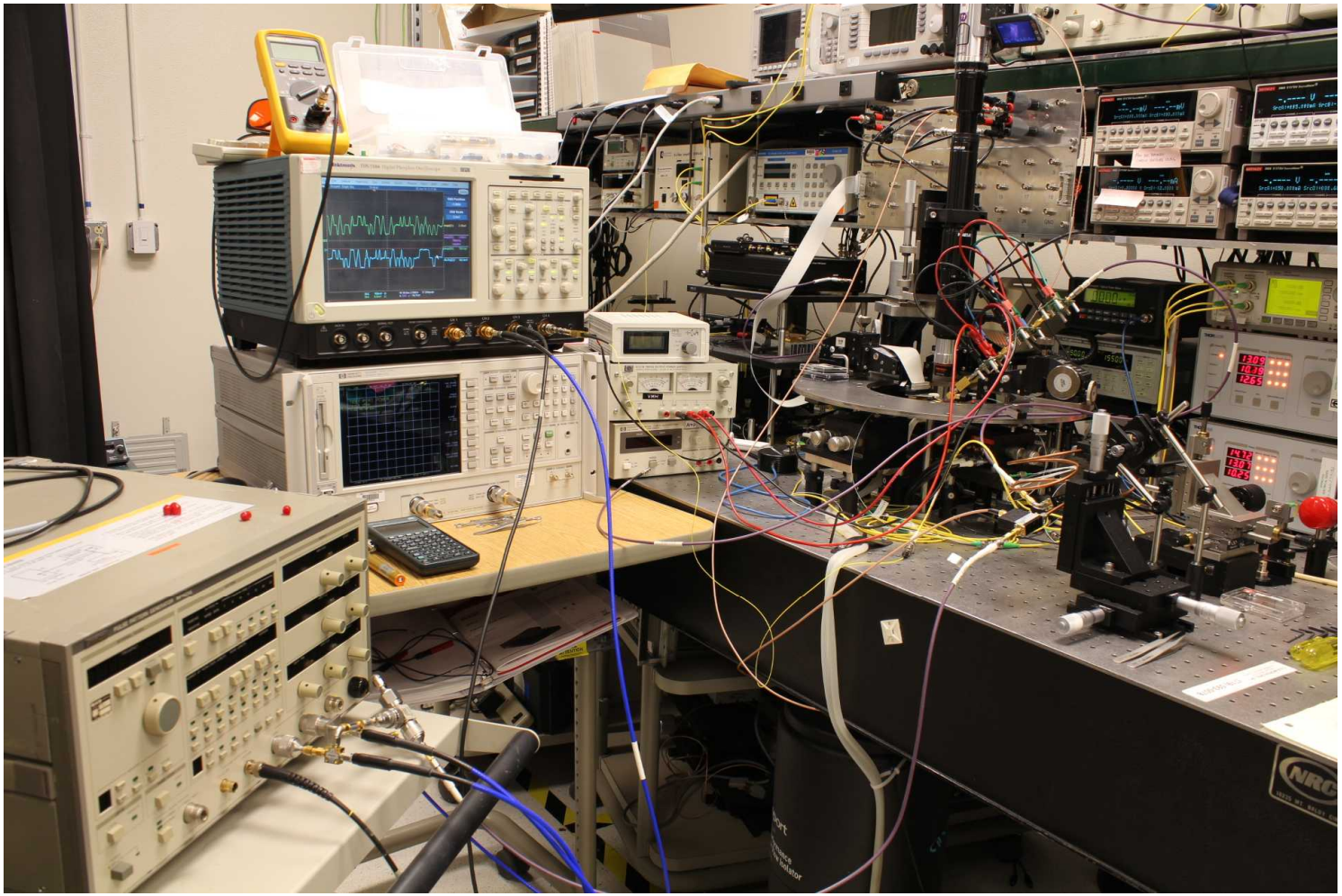

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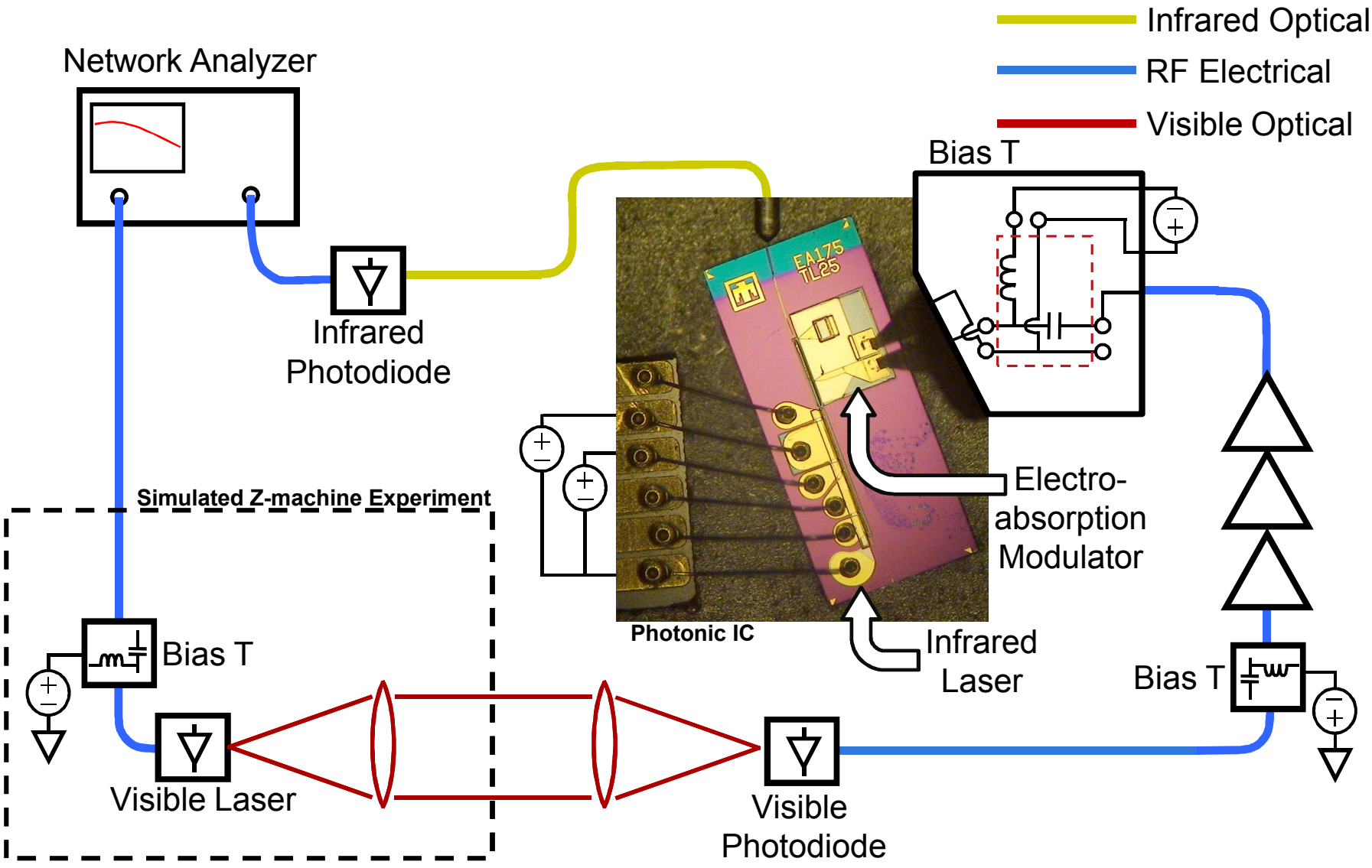
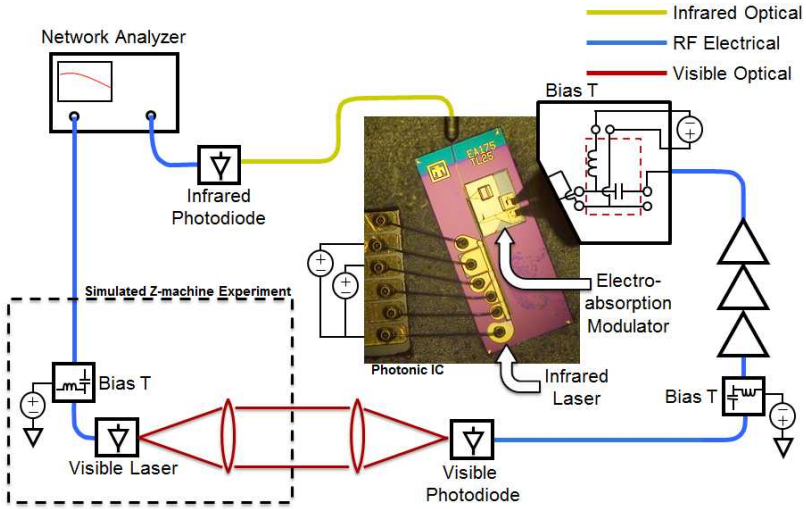
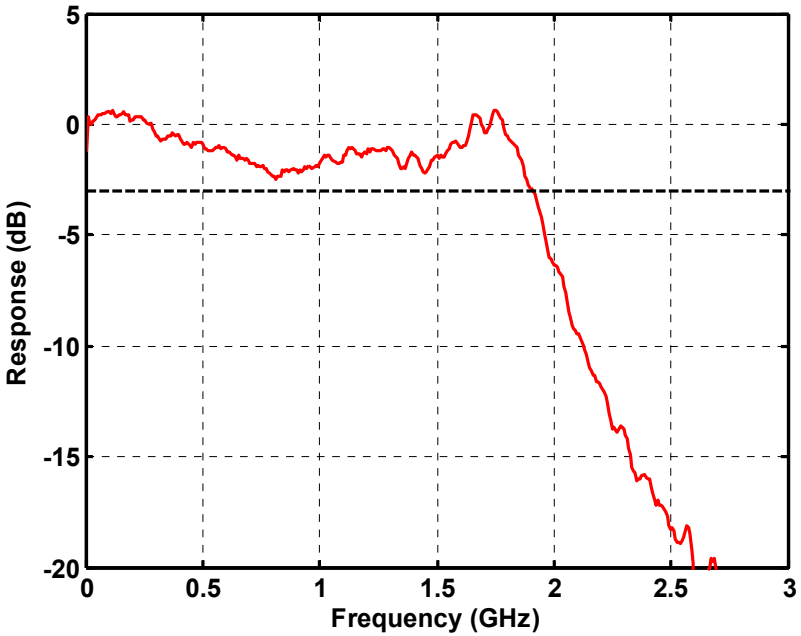


Visible-to-Infrared Conversion Demo

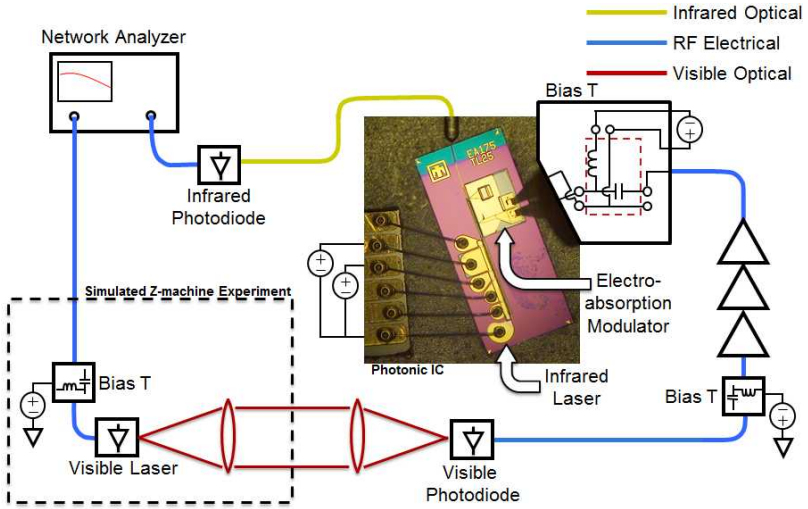
- Proof-of-principle demonstrations
  - Frequency response measurement
    - 1.9 GHz bandwidth
    - Limited by electrical-amplifiers

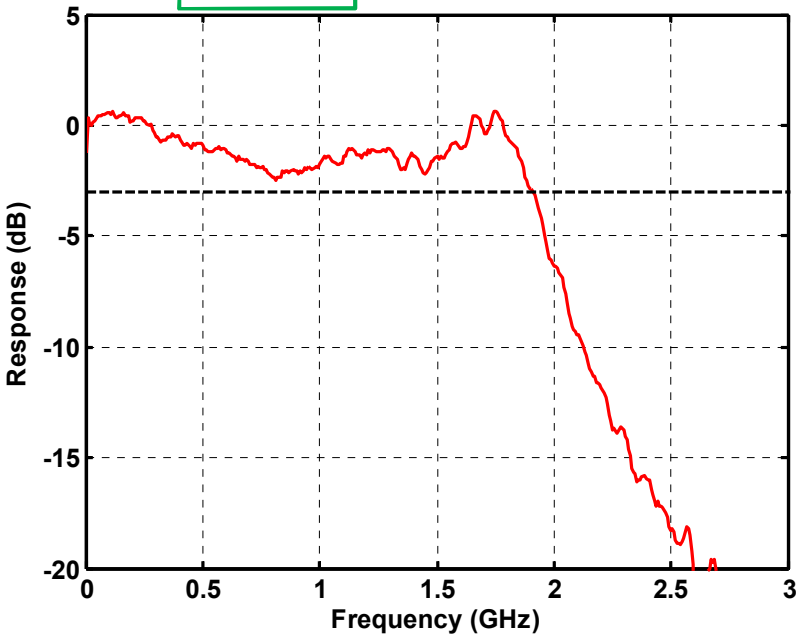


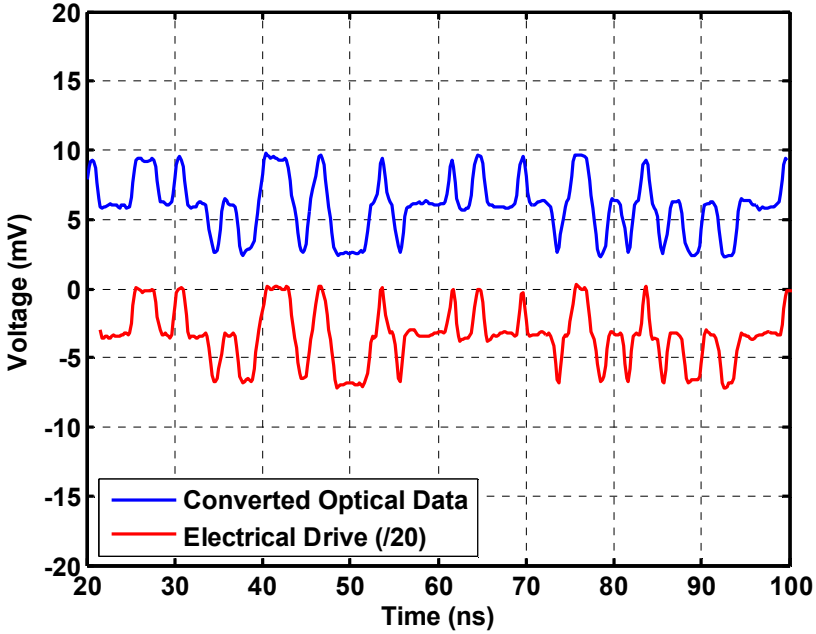


Visible-to-Infrared Conversion Demo

- Proof-of-principle demonstrations
  - Frequency response measurement
    - 1.9 GHz bandwidth
    - Limited by electrical-amplifiers
  - Waveform tracking
    - Electrical – visible – electrical – infrared - electrical







Challenges and opportunities

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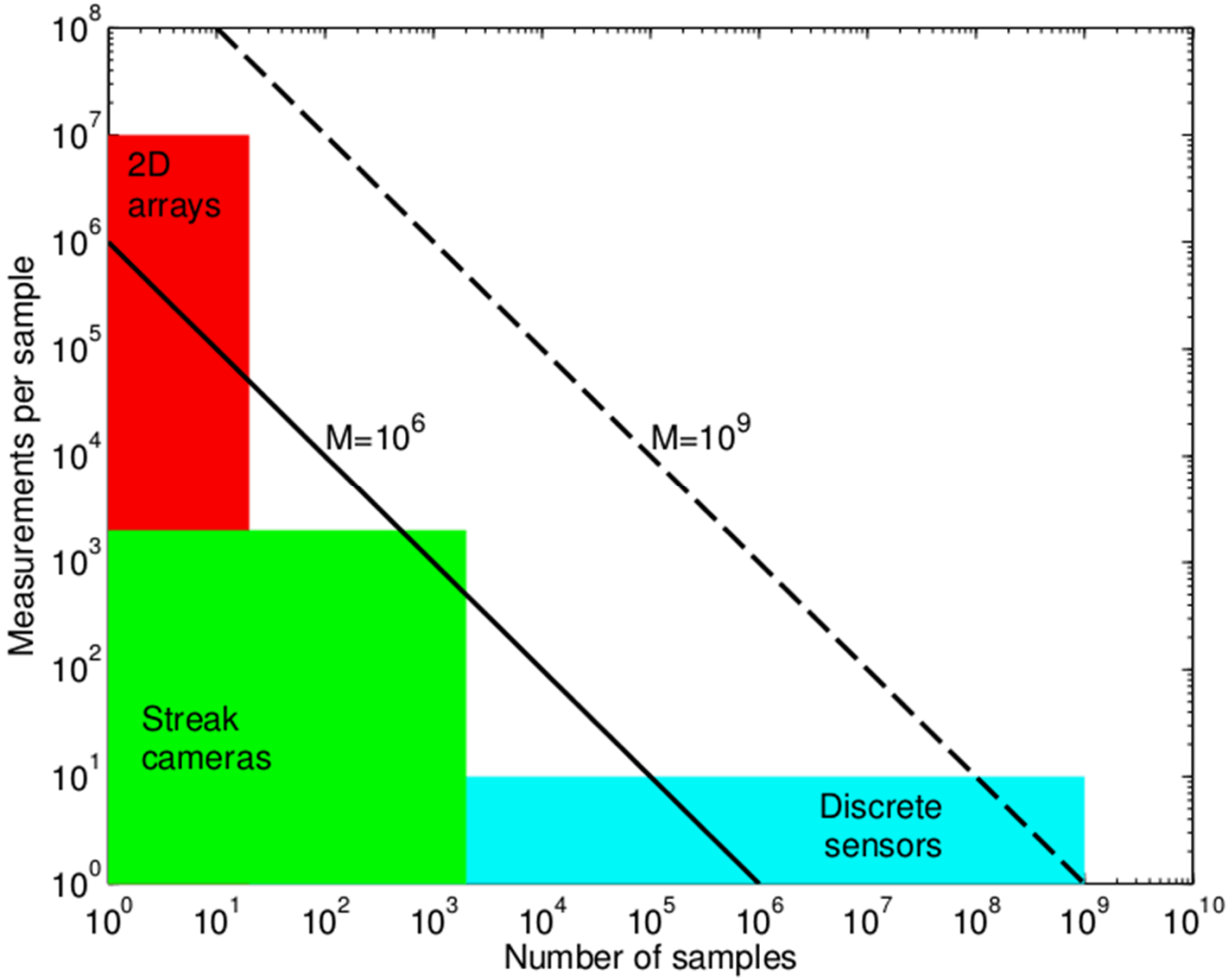
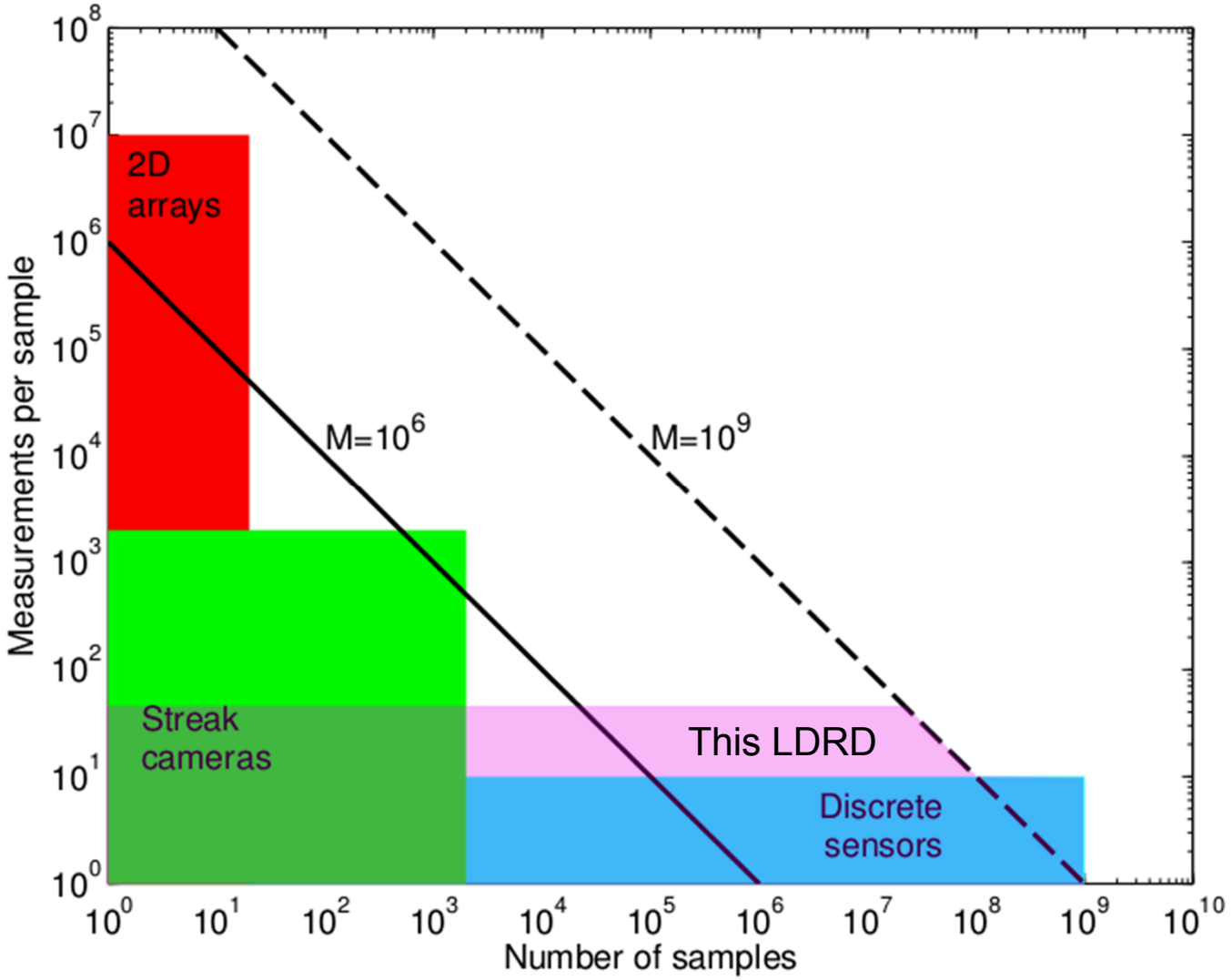
- This particular photonic circuit has never been built before
  - Conceptually similar devices already exist at 20+ GHz bandwidths
  - Wavelength conversion is already available, but for shorter spans (1550/1310 nm)
- Individual components
  - Electroabsorption modulator (power handling)
  - Photodetector (quantum efficienty)
  - Amplifiers (noise and gain/bandwidth limitations)
- System integration design underway
  - Current technology is limited to a few hundred distinct elements
- If successful, wavelength convertors allow immense information storage

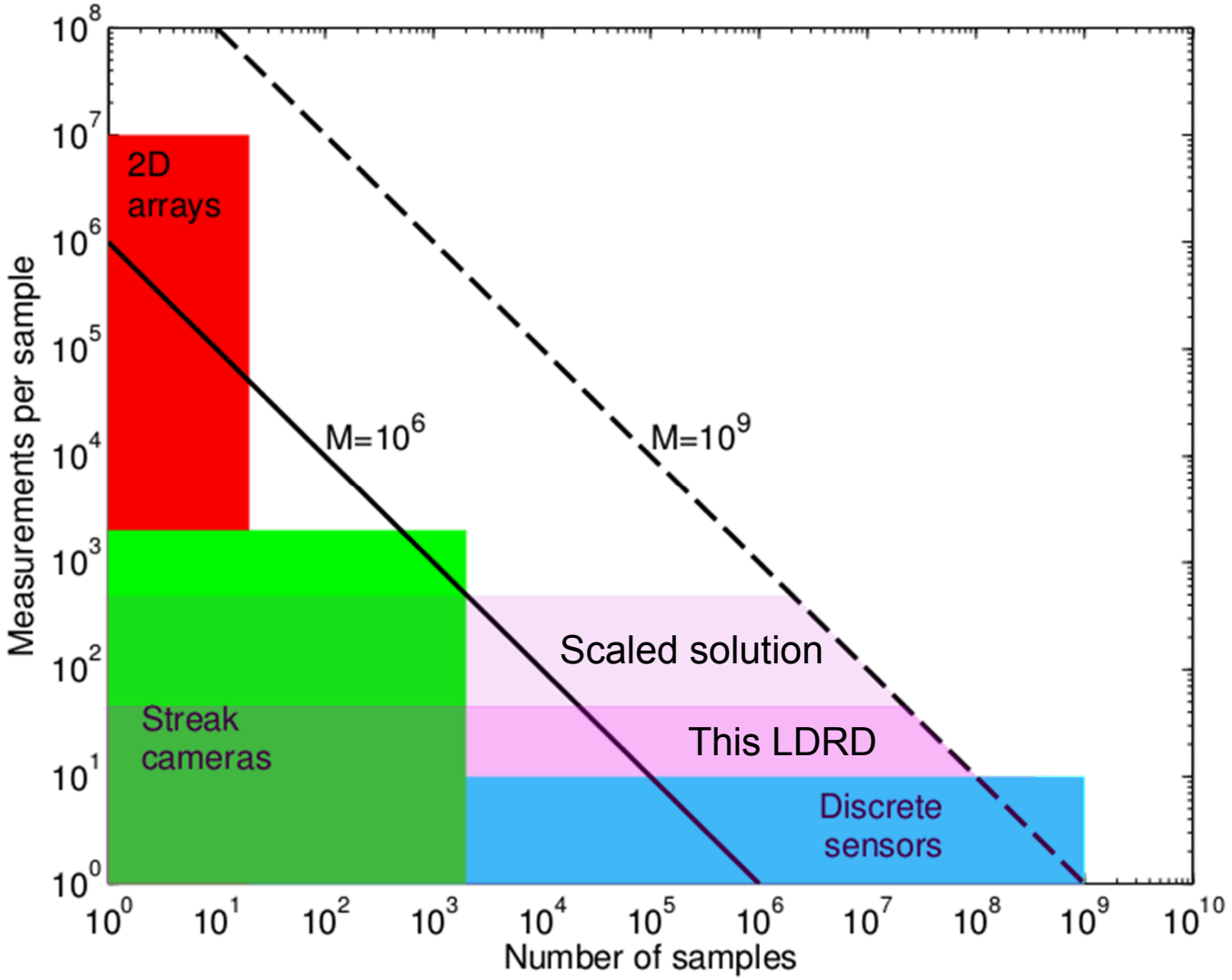
Information storage



Information storage



Information storage



Summary

- It is conceptually possible to build a photonic streak camera
  - Convert measurement to a set of 1550 nm signals
  - Use low fiber loss and telecom devices to cleverly combine measurements
  - Take advantage of deep digitizer memory
- Visible-to-infrared proof-of-principle demonstration complete
- What is next
  - Fabricate modulator arrays
  - Develop hybrid integration techniques
  - Test prototypes in time-resolved spectroscopy measurements