



IMPRESS Lidar
Integrated Micro-Photonics for Remote Earth
Science Sensing Lidar

**Jonathan Klamkin*, Larry Coldren, Sergio Pinna, Joseph Fridlander, Victoria
Rosborough, Fengqiao Sang**

University of California Santa Barbara

***klamkin@ece.ucsb.edu**

Mark Stephen, Jeffrey Chen, Kenji Numata, Randy Kawa

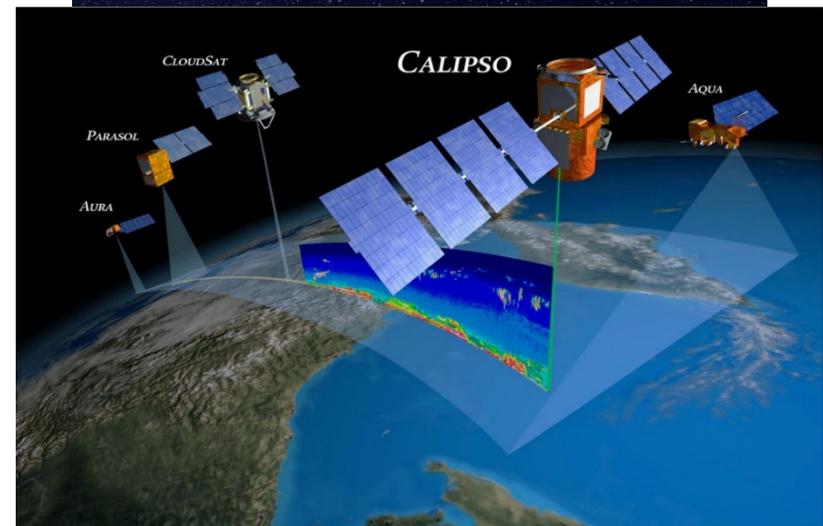
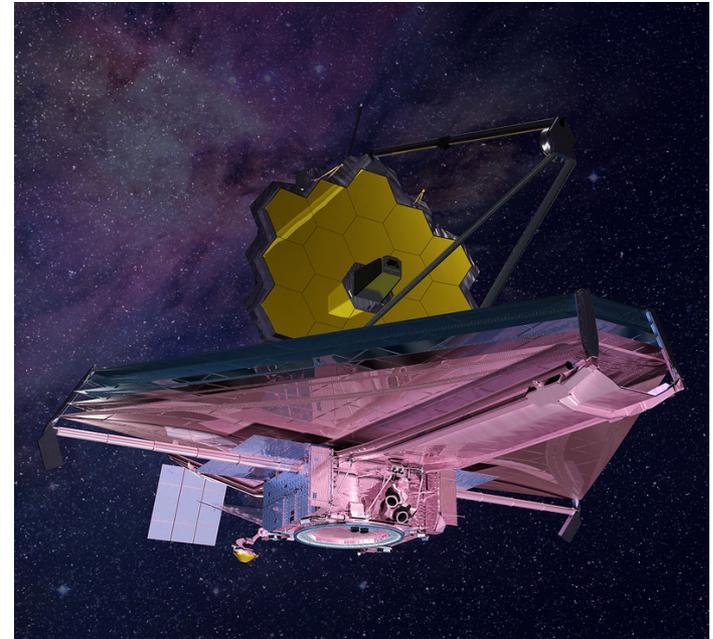
NASA Goddard Space Flight Center

Outline

- Background
- Photonic Integrated Circuits (PICs)
- PIC Design: Architecture, Simulations, and Fab
- Measurements
- On-going and Future Work

NASA Science in the Near Infrared

- Near IR science allows exploration of the cosmos and offers insight into gas compositions in the atmosphere, and the health of vegetation,
- NIRSpec spectrograph on the James Webb Space Telescope
- Moderate Resolution Imaging Spectroradiometer (MODIS) on Terra and Aqua satellites



NASA's ASCENDS Mission



Active Sensing of CO₂ Emissions over Nights, Days, and Seasons (ASCENDS) Mission

Science Mission Definition Study

Draft

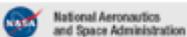
ASCENDS Ad Hoc Science Definition Team:

Kenneth W. Jucks,¹ Steven Neeck,² James B. Abshire,³ David F. Baker,⁴ Edward V. Browell,⁵ Abbashek Chatterjee,⁶ David Crisp,⁷ Sean M. Crowell,⁸ Scott Denning,⁹ Dorit Hammerling,¹⁰ Fenton Harrison,¹¹ Jason J. Hyon,¹² Stephan R. Kawa,¹³ Bing Lin,¹⁴ Byron L. Meadows,¹⁵ Robert T. Menges,¹⁶ Anna Michalak,¹⁷ Berrien Moore,¹⁸ Keith E. Murray,¹⁹ Lesley E. Ott,²⁰ Peter Rayner,²¹ Otilia I. Rodriguez,²² Andrew Schuh,²³ Yoichi Shiga,²⁴ Gary D. Spiers,²⁵ James Shah Wang,²⁶ and T. Scott Zaccheo.²⁷

April 15, 2015

Avail from:

http://cce.nasa.gov/ascends_2015/index.html



+ NASA Homepage
+ NASA Carbon Cycle and Ecosystems

ASCENDS 2015 Workshop

Home | Agenda and Presentations | Participants | ad hoc Science Definition Team

ASCENDS Workshop
June 19, 2015

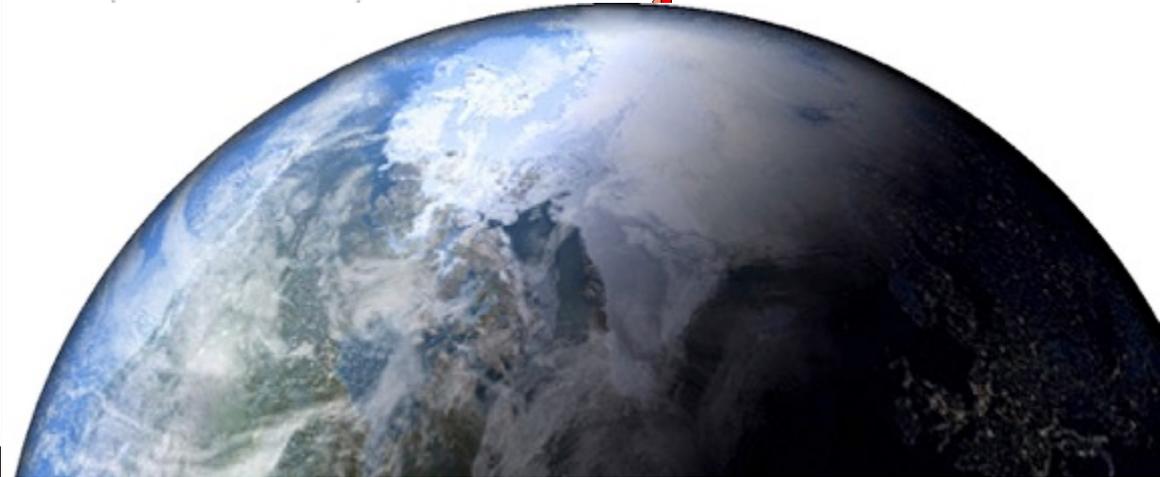
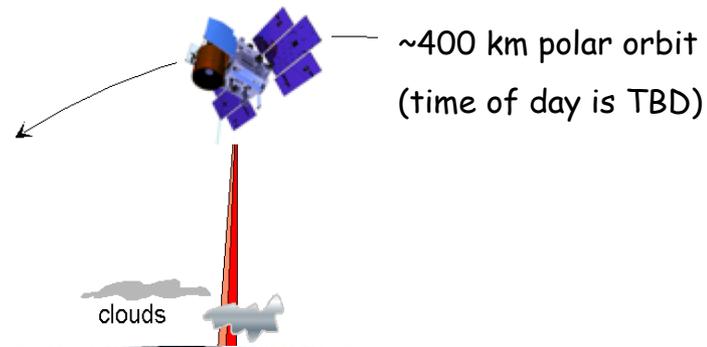
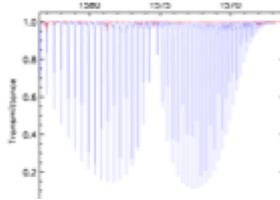
California Institute of Technology

This workshop will be held after the 11th International Workshop on Greenhouse Gas Measurements from Space at California Institute of Technology, Pasadena, California, USA, Friday, June 19th.

View their website for logistical information: <https://sites.google.com/site/wggrms11/>

Measures:

- CO₂ tropospheric column
- O₂ tropospheric column
- Cloud backscattering profile



Requirements for CO₂ Mixing Ratio:

Random error: ~ 1 ppm in ~100 km along track, or
~ 0.5 ppm in ~10 sec over deserts

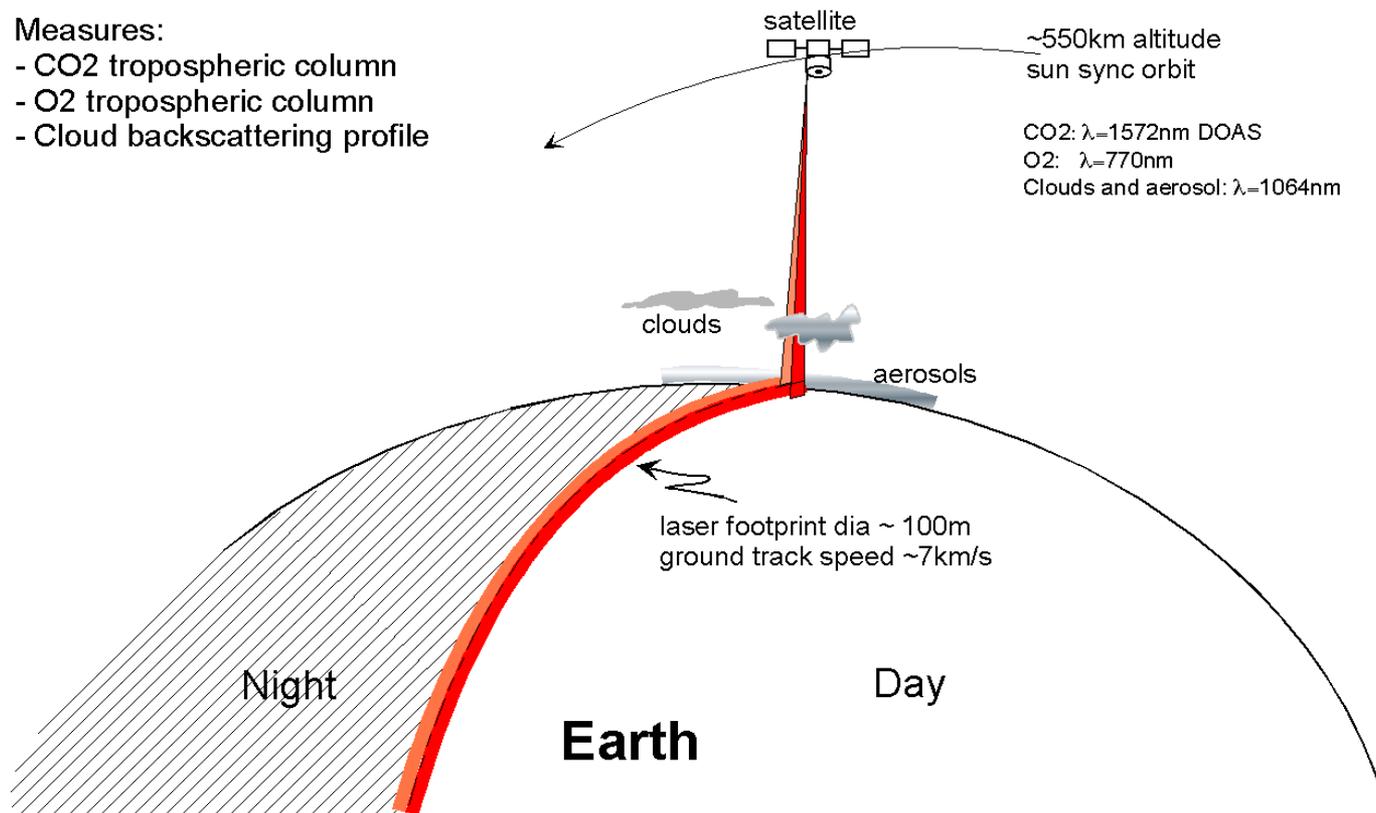
Bias: < 0.5 ppm (< 1 part in 800)

Lower errors provide more benefit for flux est's.

Precision Spectroscopy Lidar

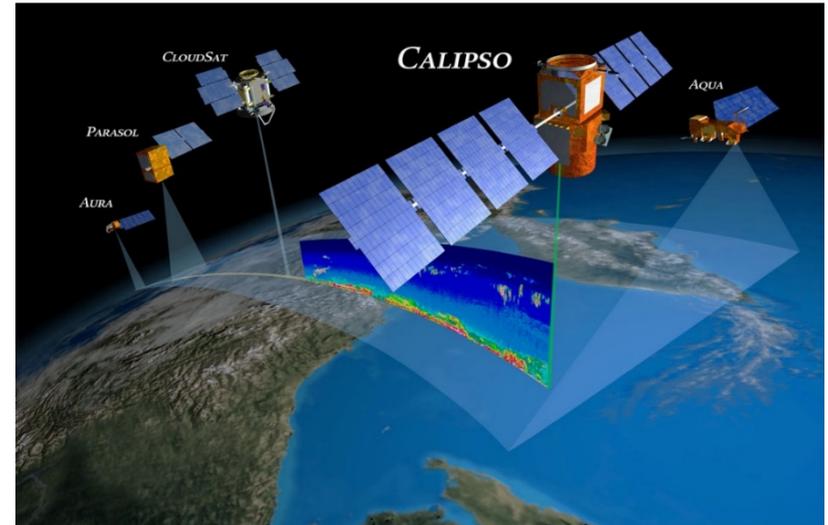
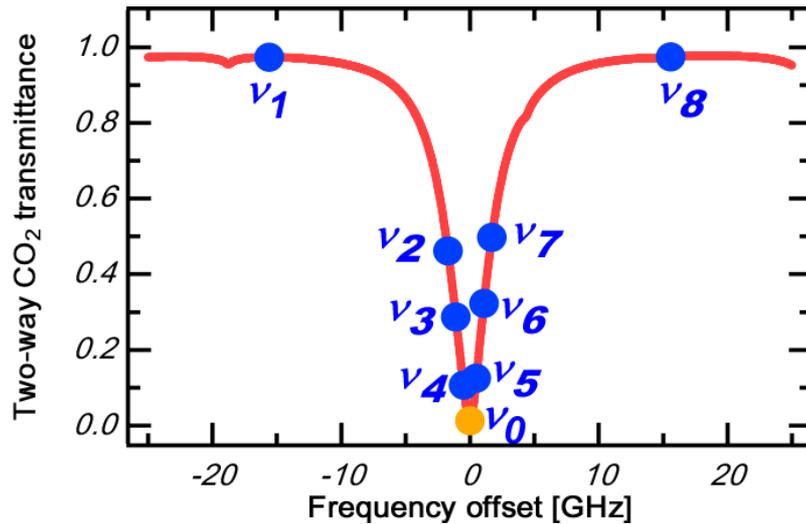
Measures:

- CO₂ tropospheric column
- O₂ tropospheric column
- Cloud backscattering profile



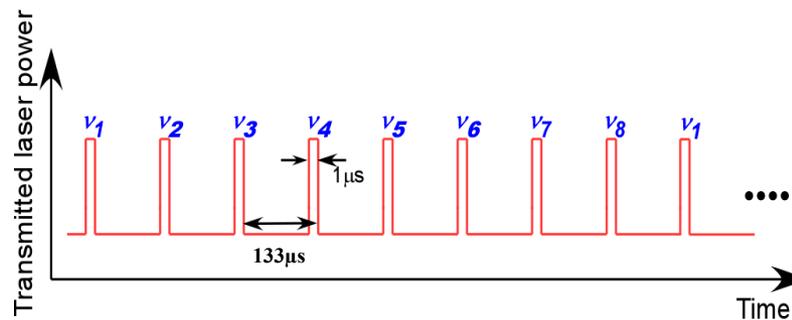
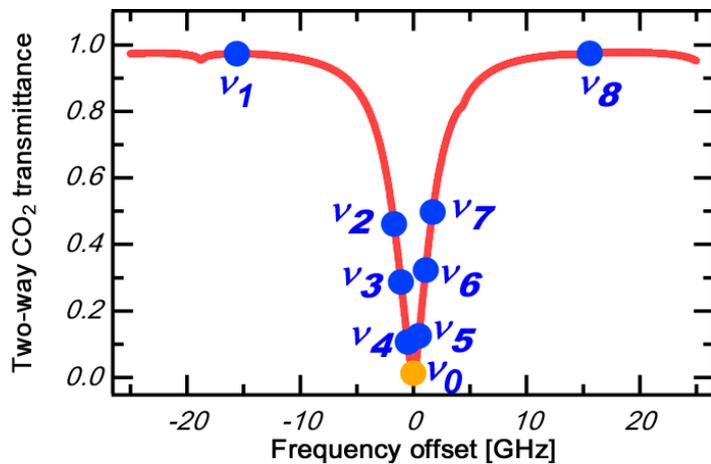
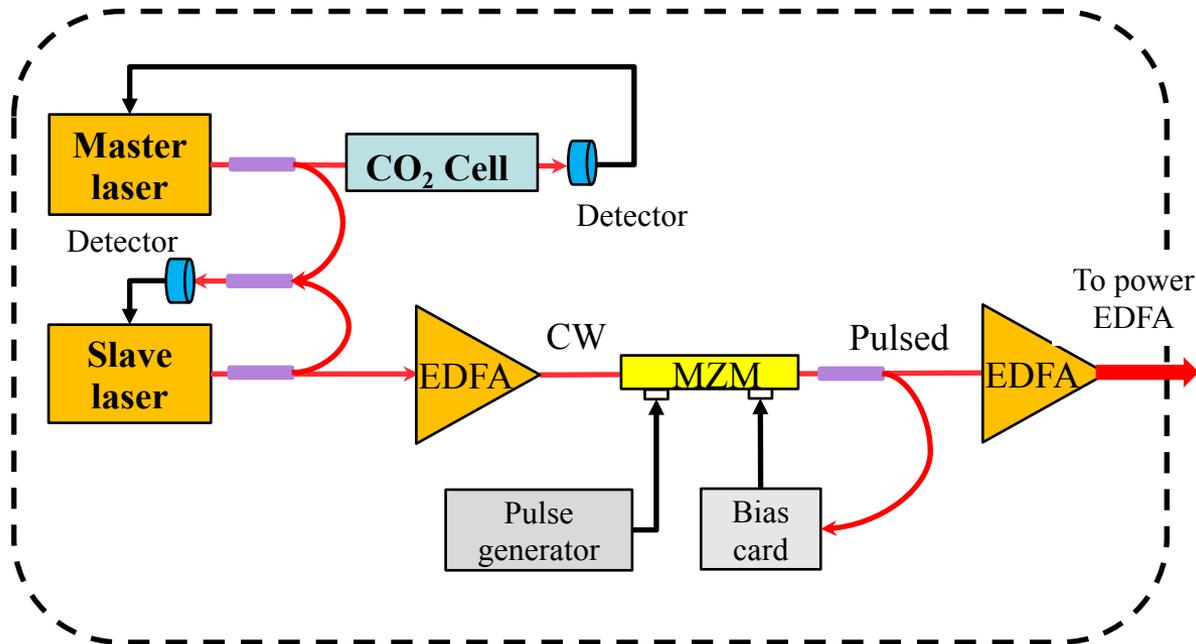
- DIAL and IPDA LIDARs enable the determination of range-resolved concentrations and column-integrated concentrations of a molecule, respectively.

Precision Spectroscopy Applications



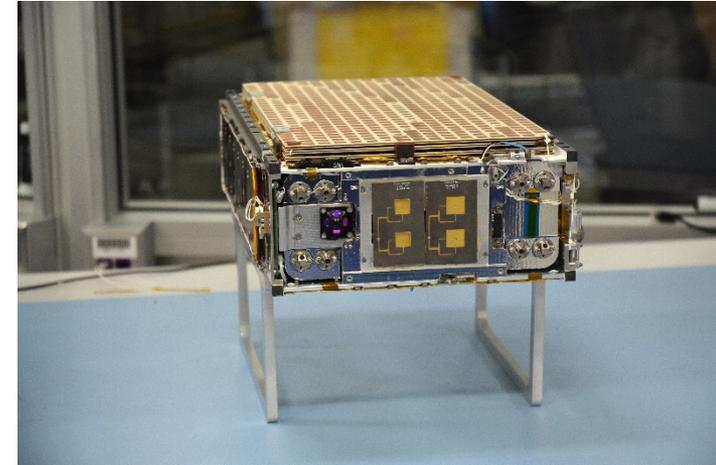
- CO₂ has diurnal, vertical transport. Ideally a CO₂ measurement is uniformly sensitive to concentrations in the lower troposphere.
- Sampling the sides of the line where the absorption is pressure-broadened in the lower atmosphere allows measurement of a molecule under different atmospheric conditions and concentrations.

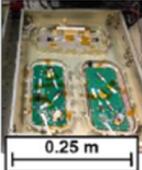
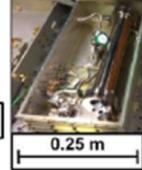
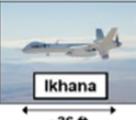
System Overview



Photonic Integrated Circuits

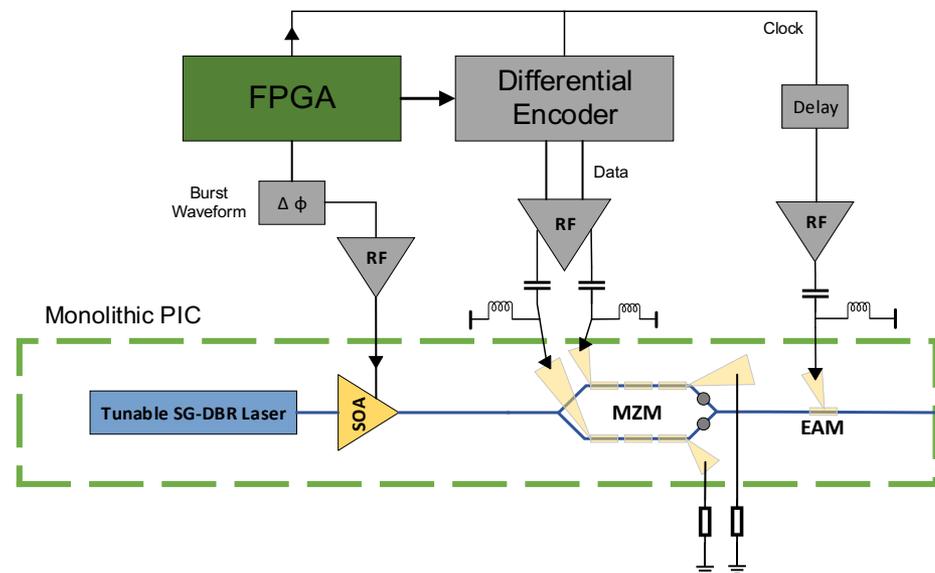
- Photonic Integrated Circuits (PICs)
 - Eliminate interconnect losses
 - Integrate built-in test capabilities
 - Reduced C-SWaP and complexity
 - Better electronic performance
 - Miniature references
 - CubeSats



Existing Technology		IMPRESS Lidar
<p>Rack of equipment</p> <ul style="list-style-type: none"> • PLL electronics • Control electronics • Electronic amplifiers  <p>1 m</p>	<p>Photonic components</p> <ul style="list-style-type: none"> • Seed module • Optical amplifiers  <p>0.25 m</p> <p>Herriott gas reference cell</p>  <p>0.25 m</p>	<p>Fully integrated PIC-EIC</p> <ul style="list-style-type: none"> • Photonic seed module • PLL electronics • Control electronics • Electronic amplifiers  <p>Footprint = 1.8 cm x 1.5 cm</p> <p>Compact all-fiber gas reference cell</p>  <p>10 cm</p>
 <p>DC-8</p> <p>~150 ft.</p>	 <p>ISS</p> <p>~300 ft.</p>	 <p>Ikhana</p> <p>~1 ft.</p>  <p>~36 ft.</p>

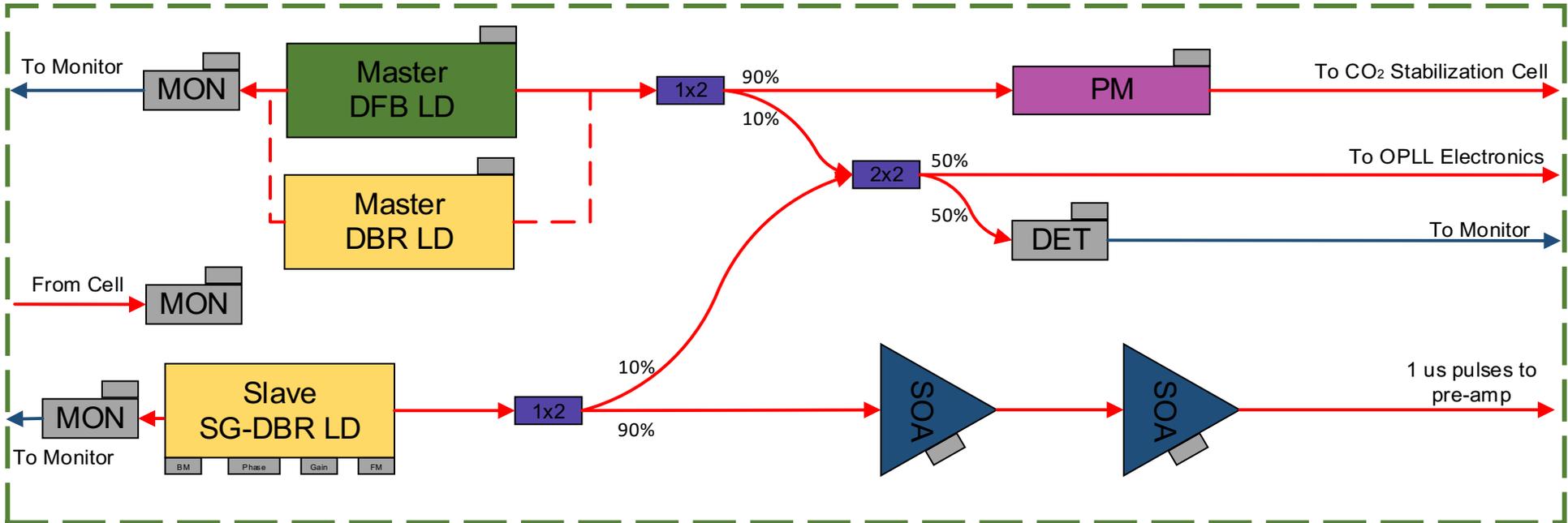
PIC Transmitter

- Photonic integrated circuit includes:
 - C-Band Tunable SG-DBR Laser
 - Semiconductor Optical Amplifier (SOA)
 - Dual Drive Mach-Zehnder Modulator (MZM)
 - Electro-absorption Modulator (EAM)
- Straight-forward non-coherent detection with a delay line interferometer
- RZ improves sensitivities of optically preamplified receivers over standard DPSK.

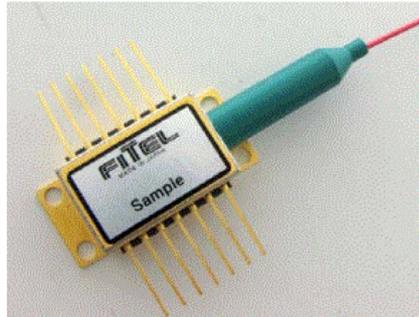


PIC Design

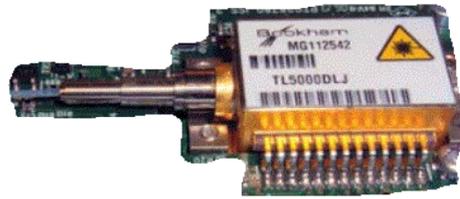
Monolithic PIC



Photonic Integrated Circuits



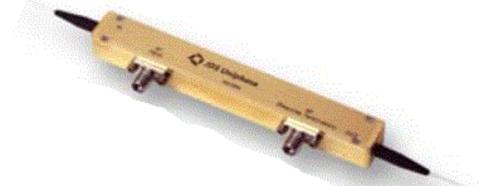
Master DFB



Slave DS-DBR



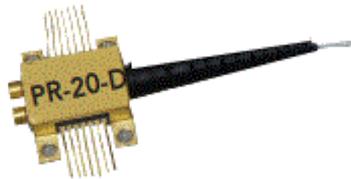
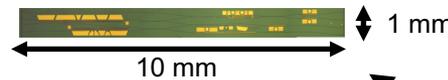
EDFA



Phase Modulator



Intensity Modulator

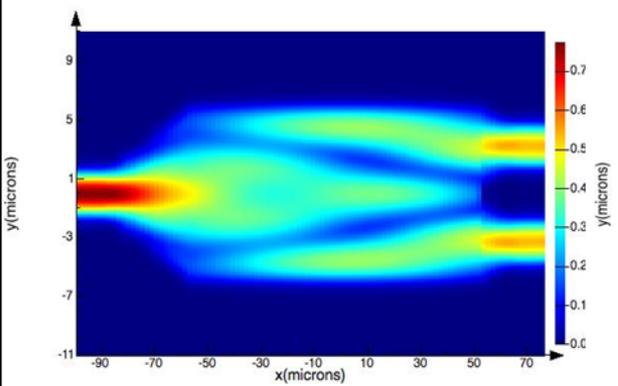
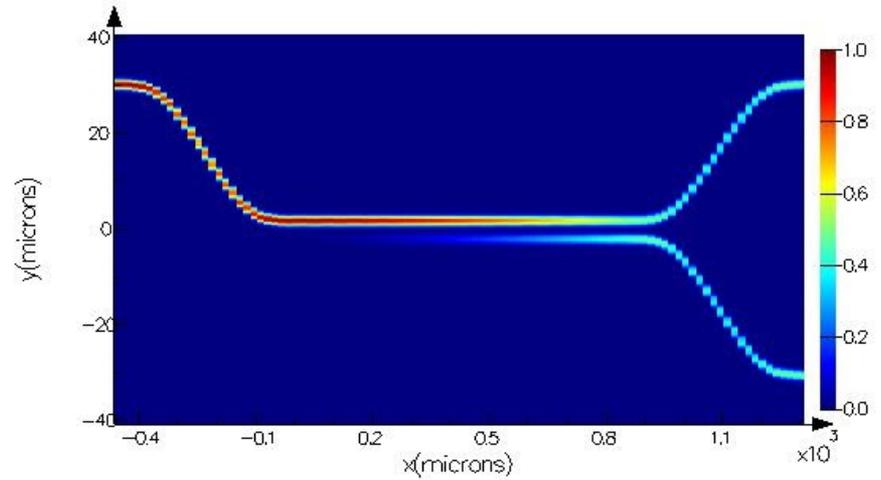
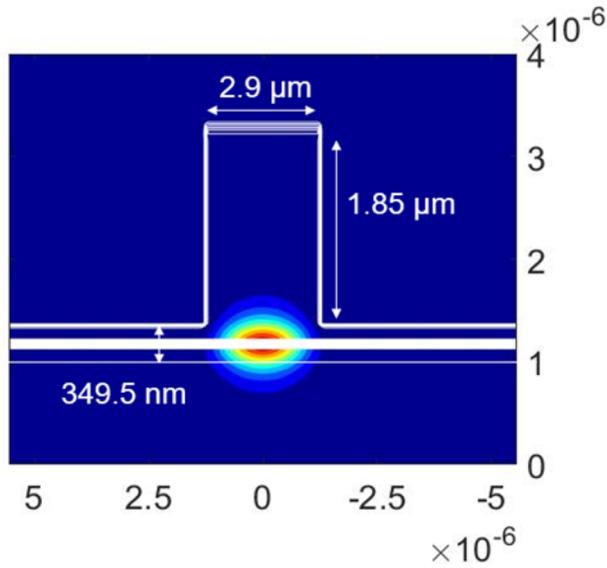


20 GHz Photoreceiver

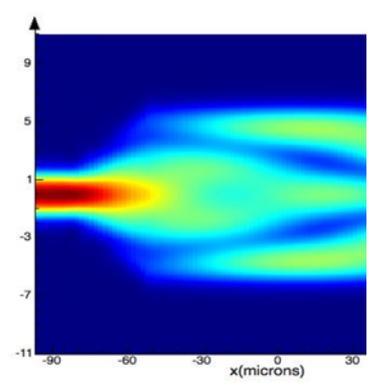


Couplers & MMIs

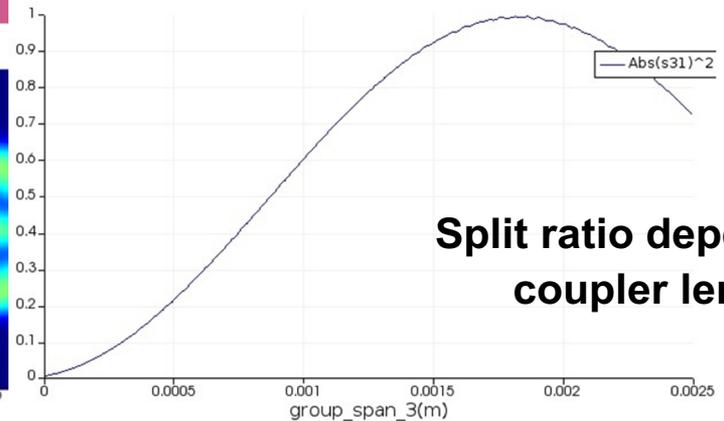
Simulations



QWI



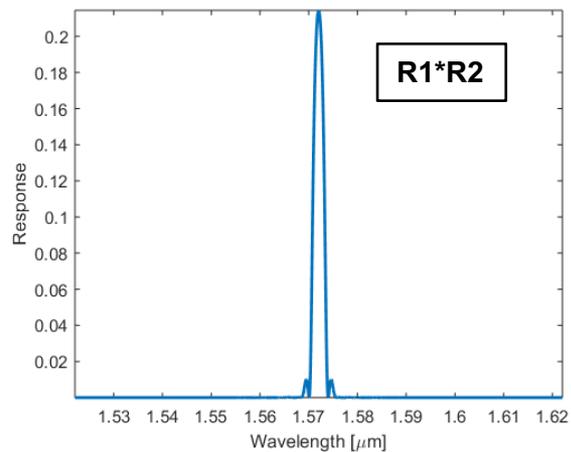
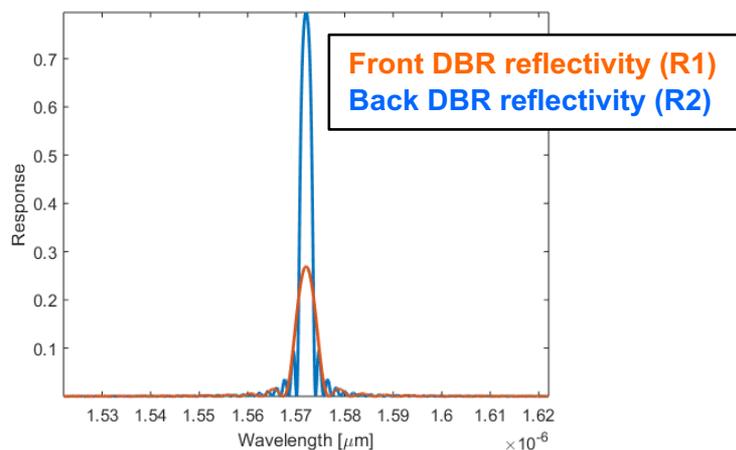
OQW



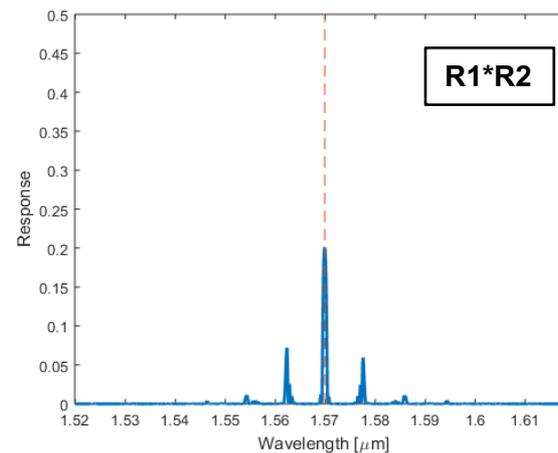
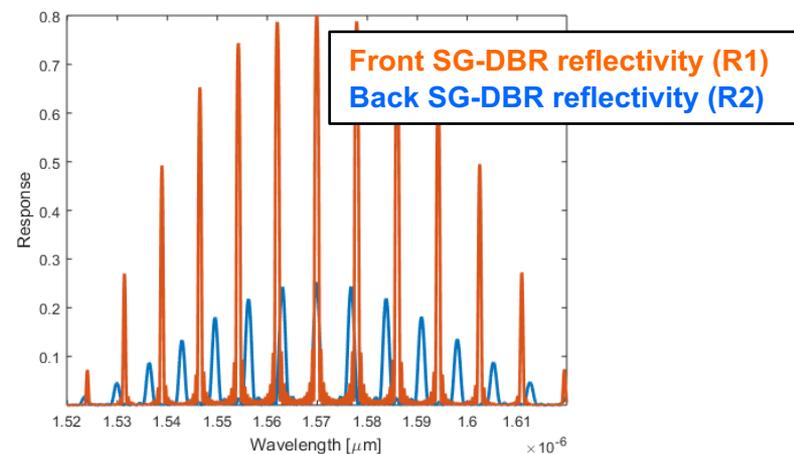
Split ratio depends on coupler length

Mirror Simulations

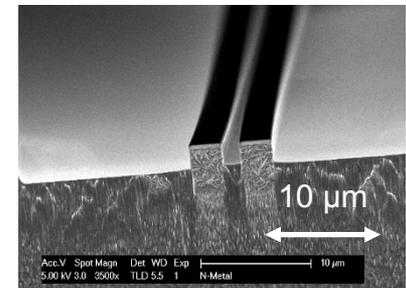
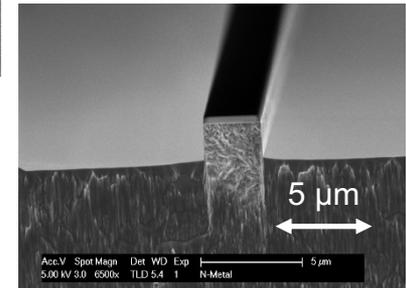
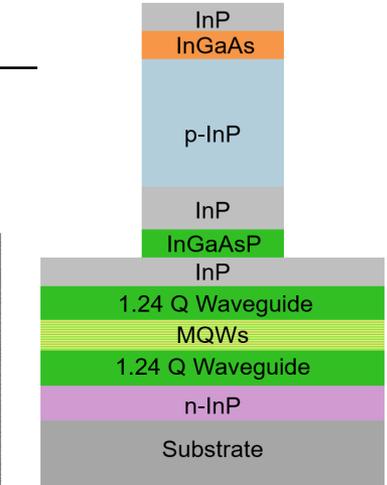
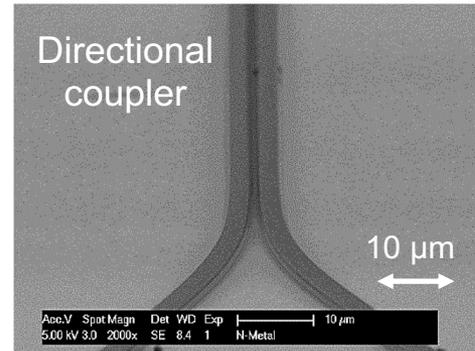
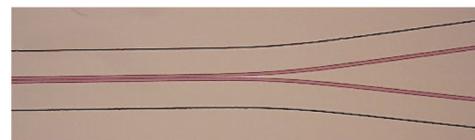
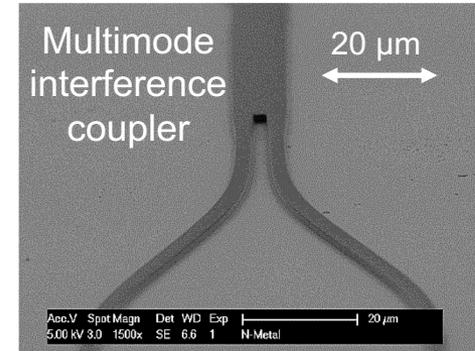
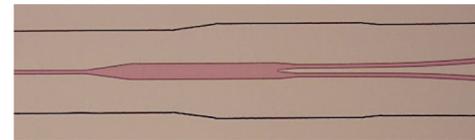
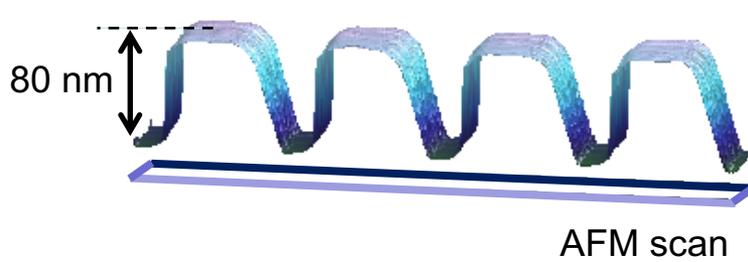
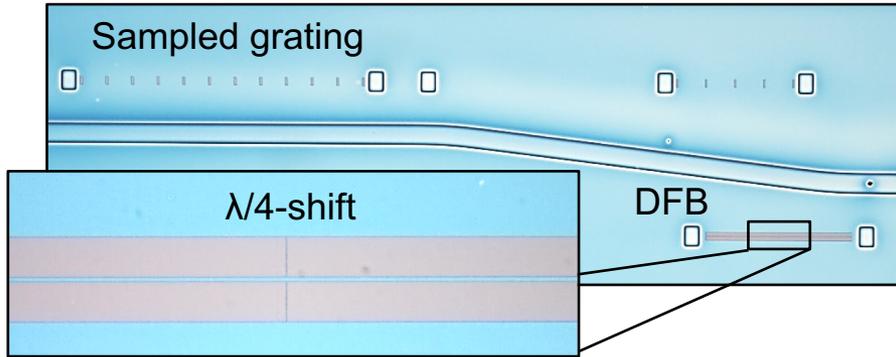
DBR/DBR



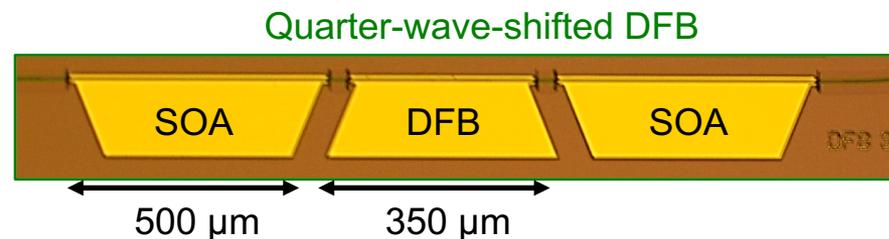
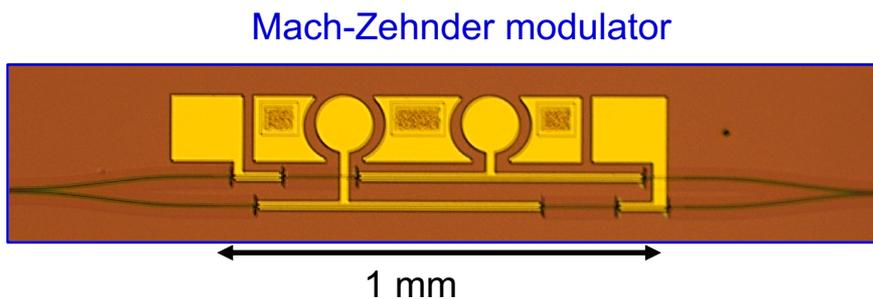
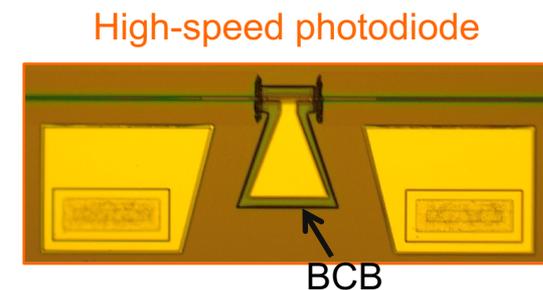
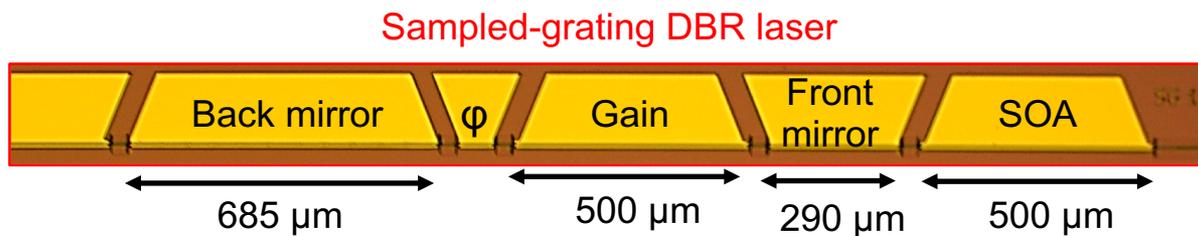
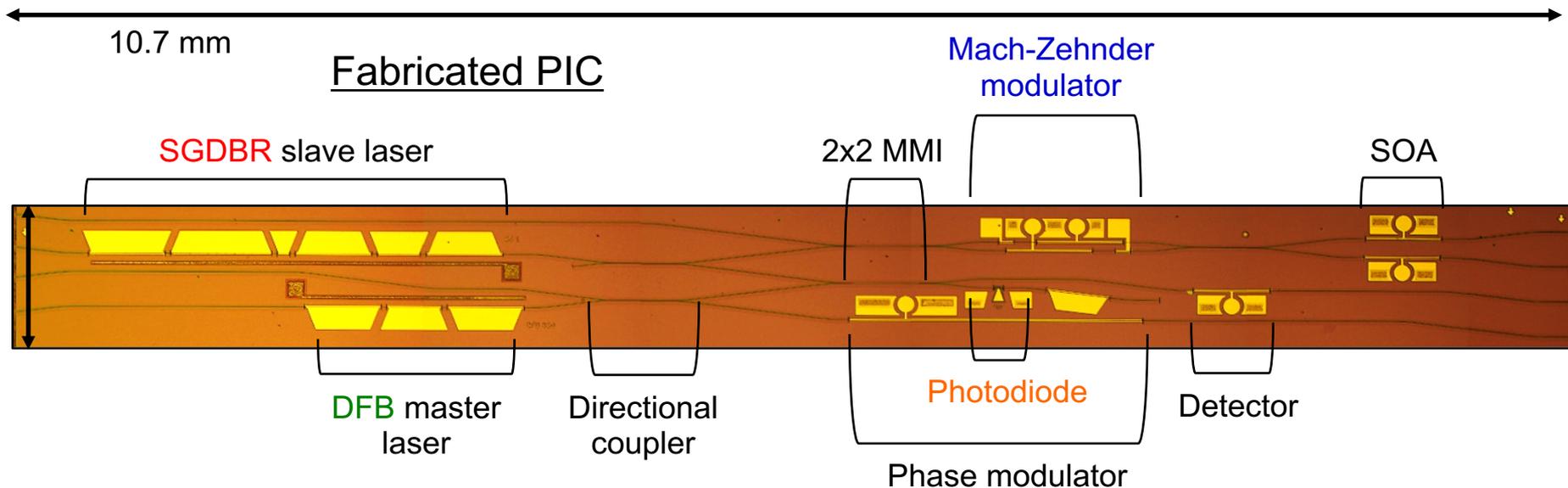
SGDBR/SGDBR



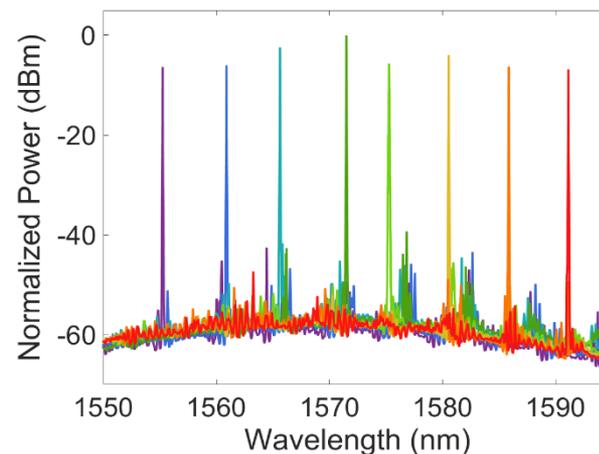
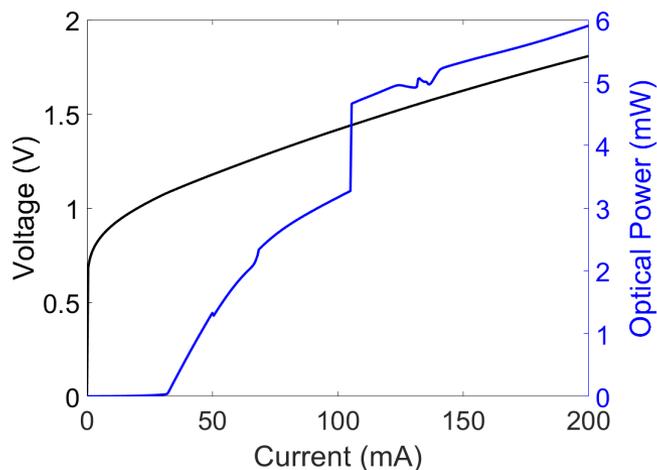
Fabrication



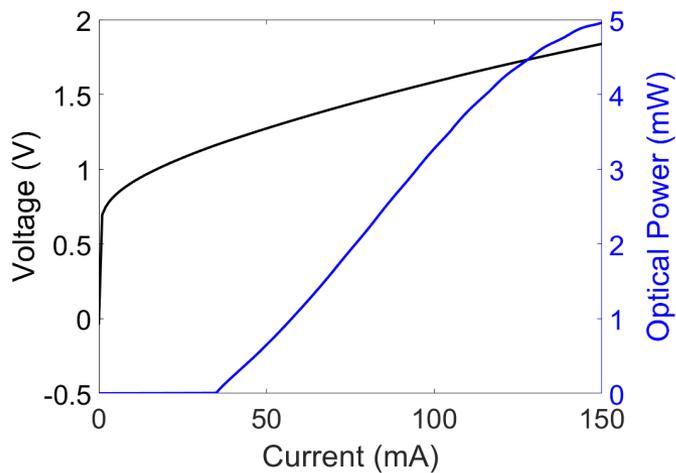
Fabricated Devices



Measurements Diode Lasers



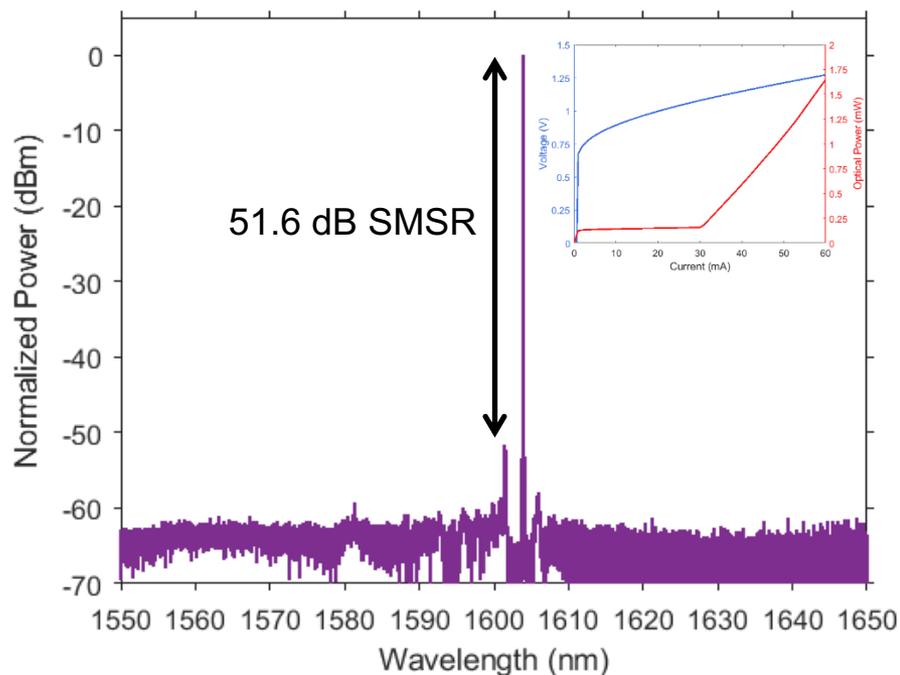
Lasing Spectrum SG-DBR



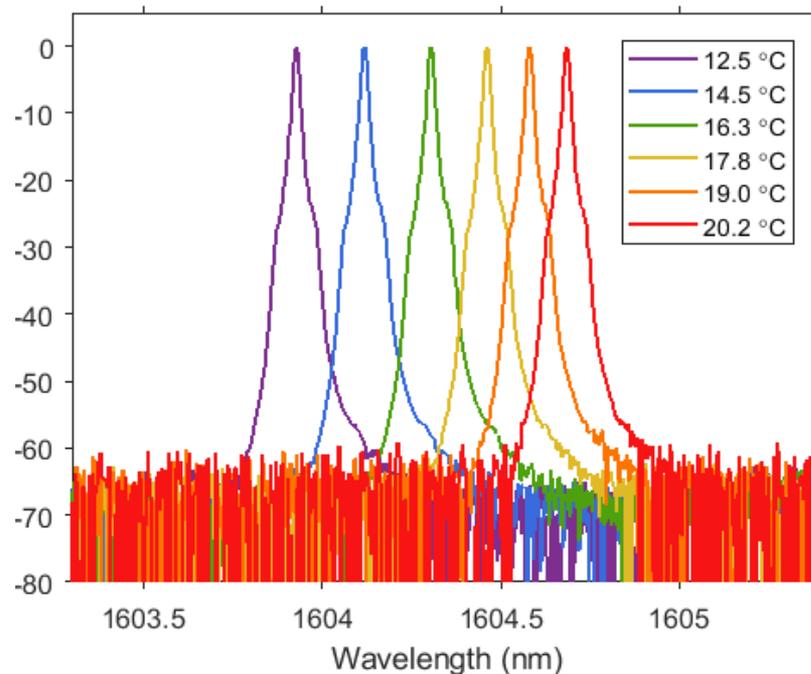
Light-Current-Voltage Curves

Measurements Diode Lasers

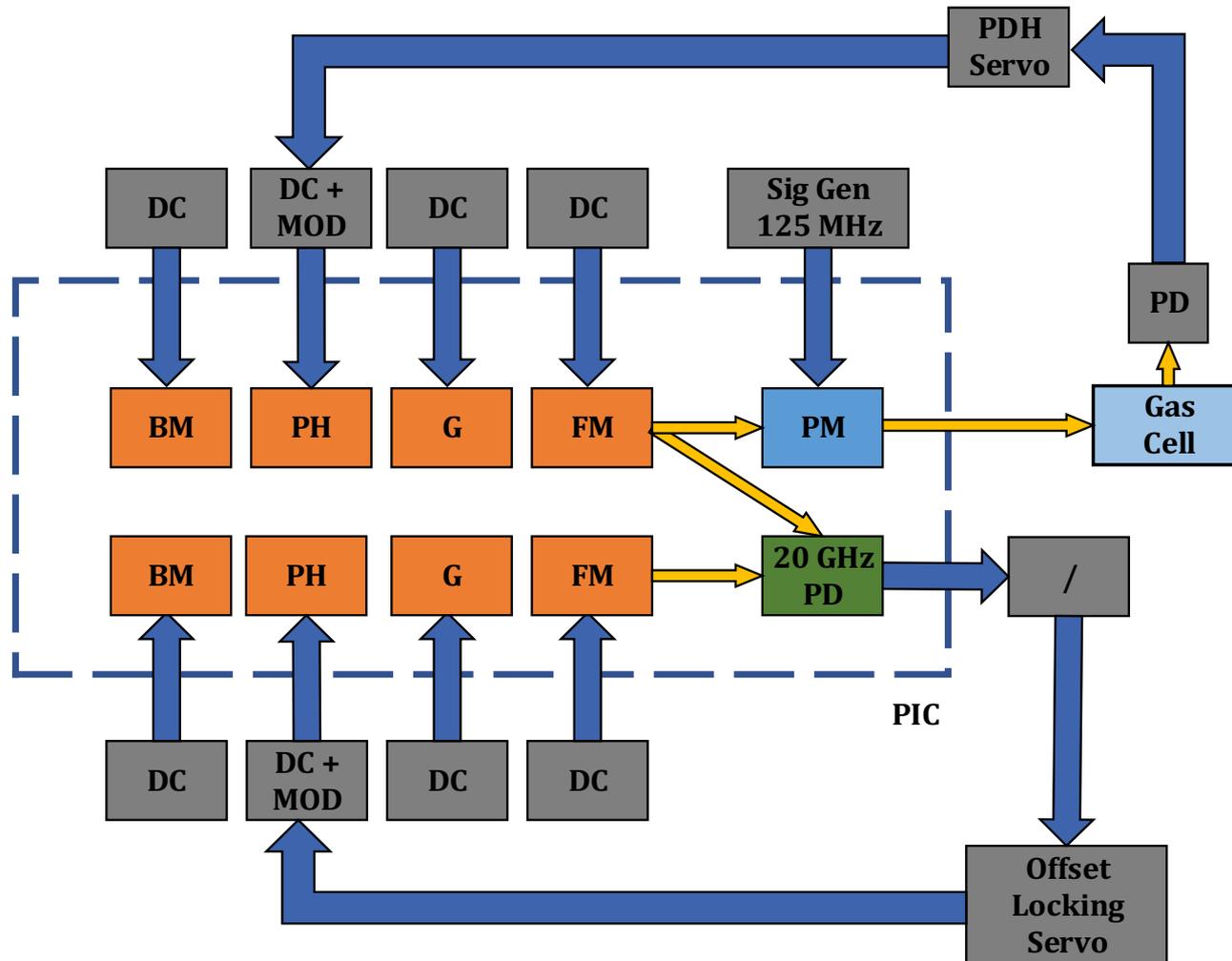
Lasing Spectrum



Tuning with Stage Temperature



Measurement Setup

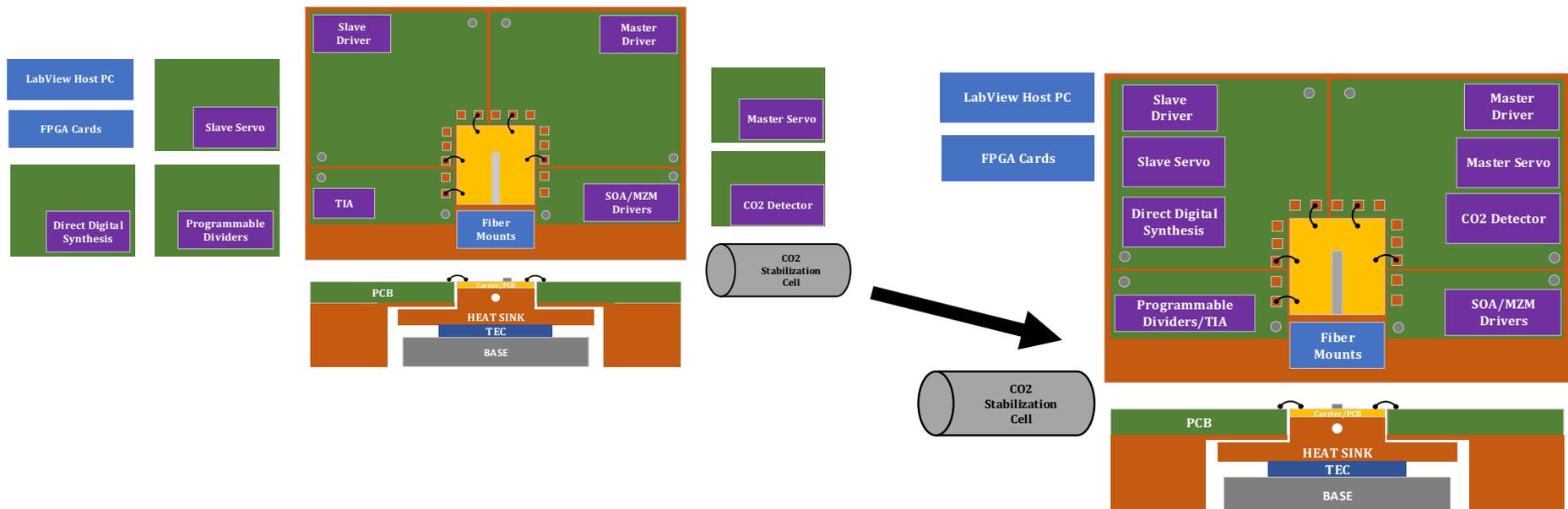


- Measurement with bench-top equipment

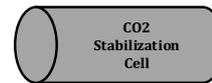
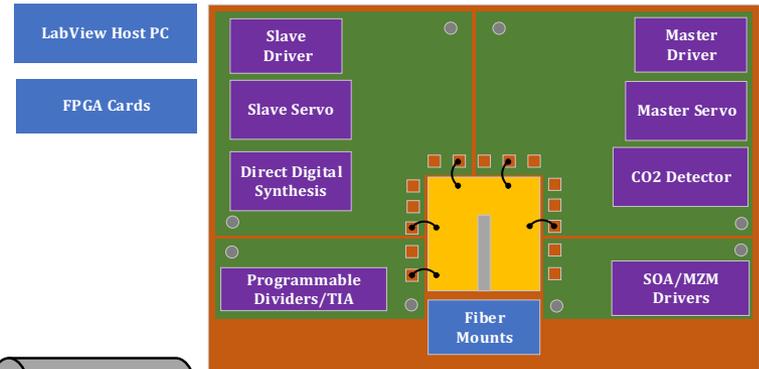
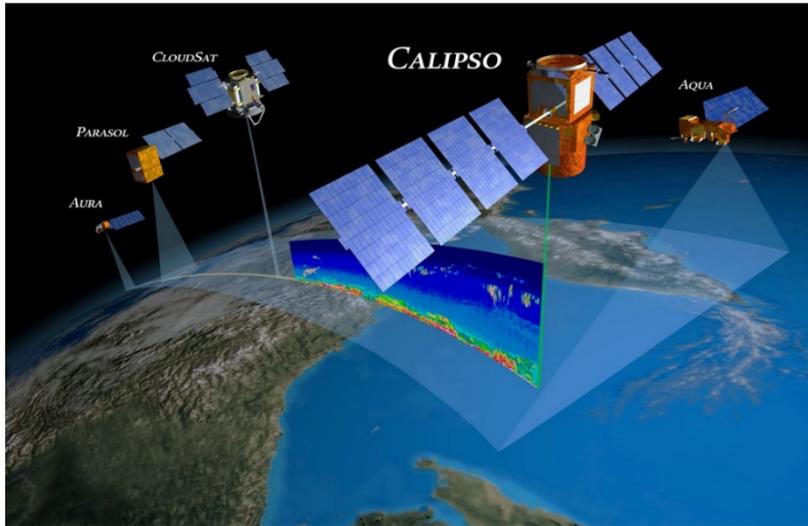
Electrical Design

Multi-stage electrical design effort to:

- Reduce system footprint
- Improve system performance by reducing signal delay and loss in the feedback loop
- Allows use of closely placed high-speed (20 GHz) TIA
- Should simplify overall system complexity.
- Offers path towards co-packaged microwave and photonic circuits



Thank You!



Mach-Zehnder modulator

