Overview of Photonics Research at Calit2: Scaling from Nanometers to the Earth

UCSD-NICT Joint Symposium on Innovative Lightwave, Millimeter-Wave and THz Technologies for Future Sustainable Network
Calit2@UC San Diego

March 26, 2010

Dr. Larry Smarr

Director, California Institute for Telecommunications and Information Technology

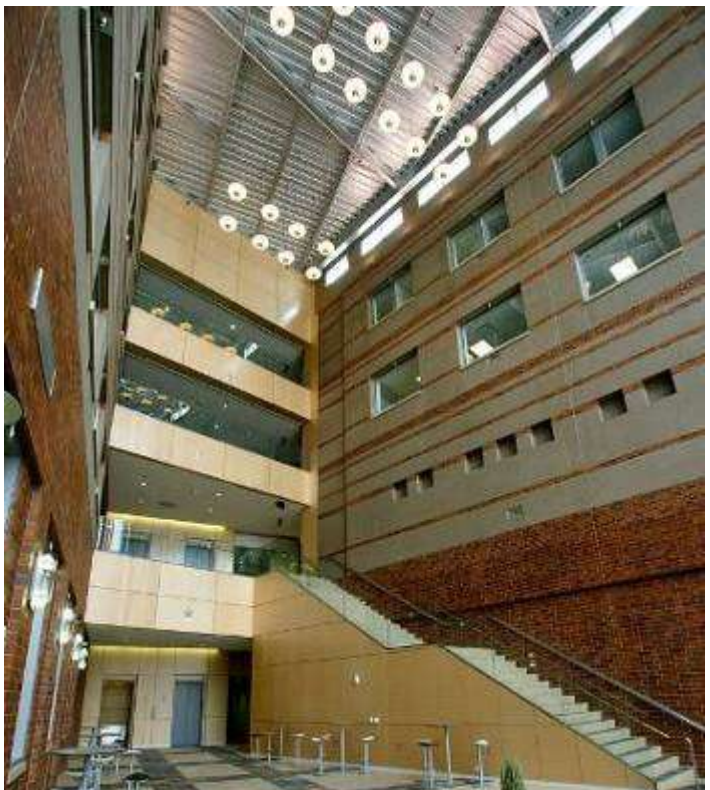
Harry E. Gruber Professor,

Dept. of Computer Science and Engineering

Jacobs School of Engineering, UCSD

Twitter: lsmarr

Two New Calit2 Buildings Provide New Laboratories for "Living in the Future"





- "Convergence" Laboratory Facilities
  - Nanotech, BioMEMS, Chips, Radio, Photonics
  - Virtual Reality, Digital Cinema, HDTV, Gaming
- Over 1000 Researchers in Two Buildings
  - Linked via Dedicated Optical Networks

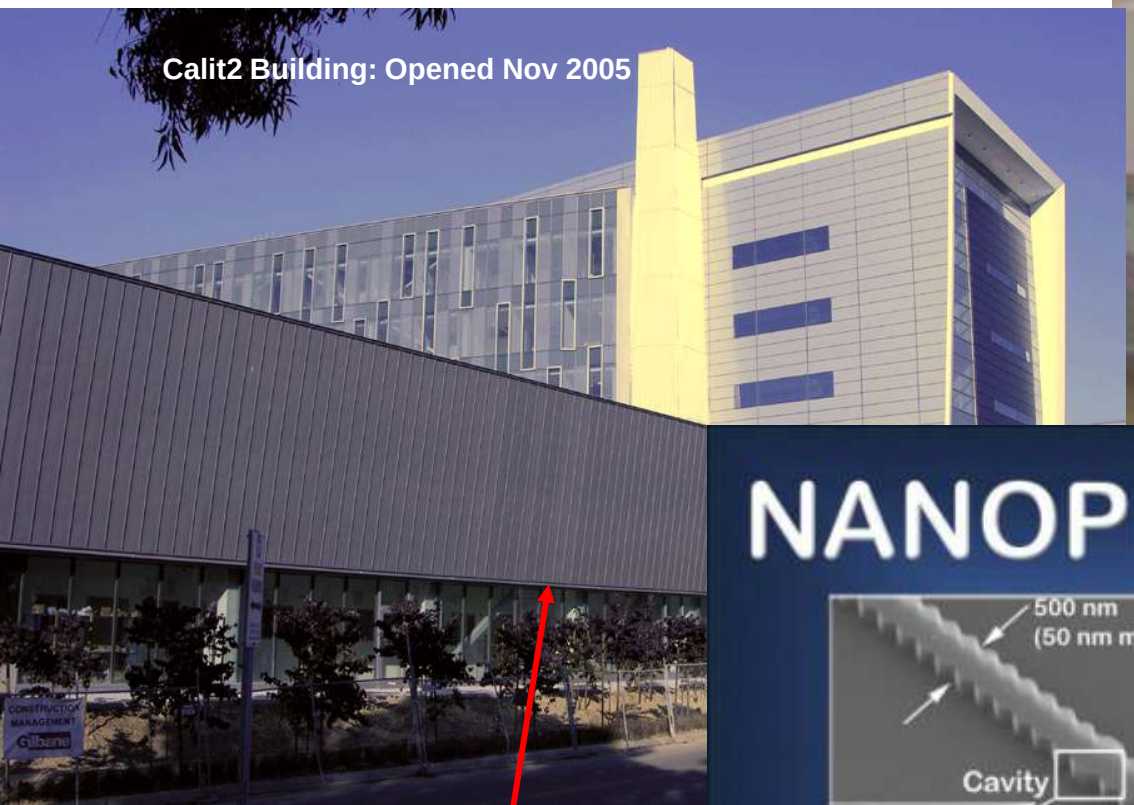


Preparing for a World in Which Distance is Eliminated…

www.calit2.net

$100M From State for New Facilities

New Calit2 Photonics Nanofabrication and Chip-Scale Testbed Facilities

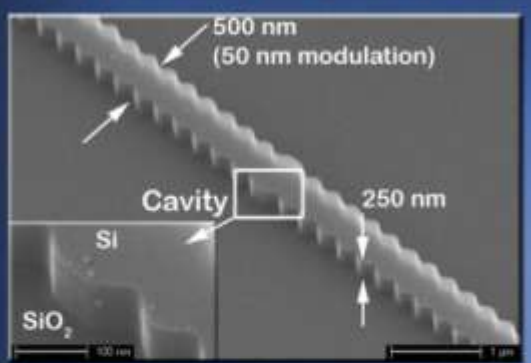




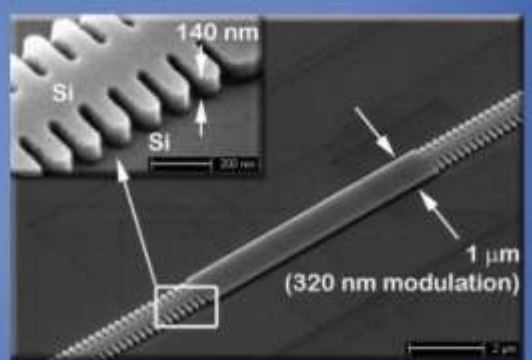
New Nanofabrication Facility→ Nano3

Agilent Technologies
Innovating the HP Way

NANOPHOTONICS



High quality resonators obtained with a one step lithographic process for realization of ultracompact filters, modulators, and detectors



Fainman's "Ultrafast and Nanoscale Optics" group
fainman@ece.ucsd.edu
Electrical and Computer Engineering

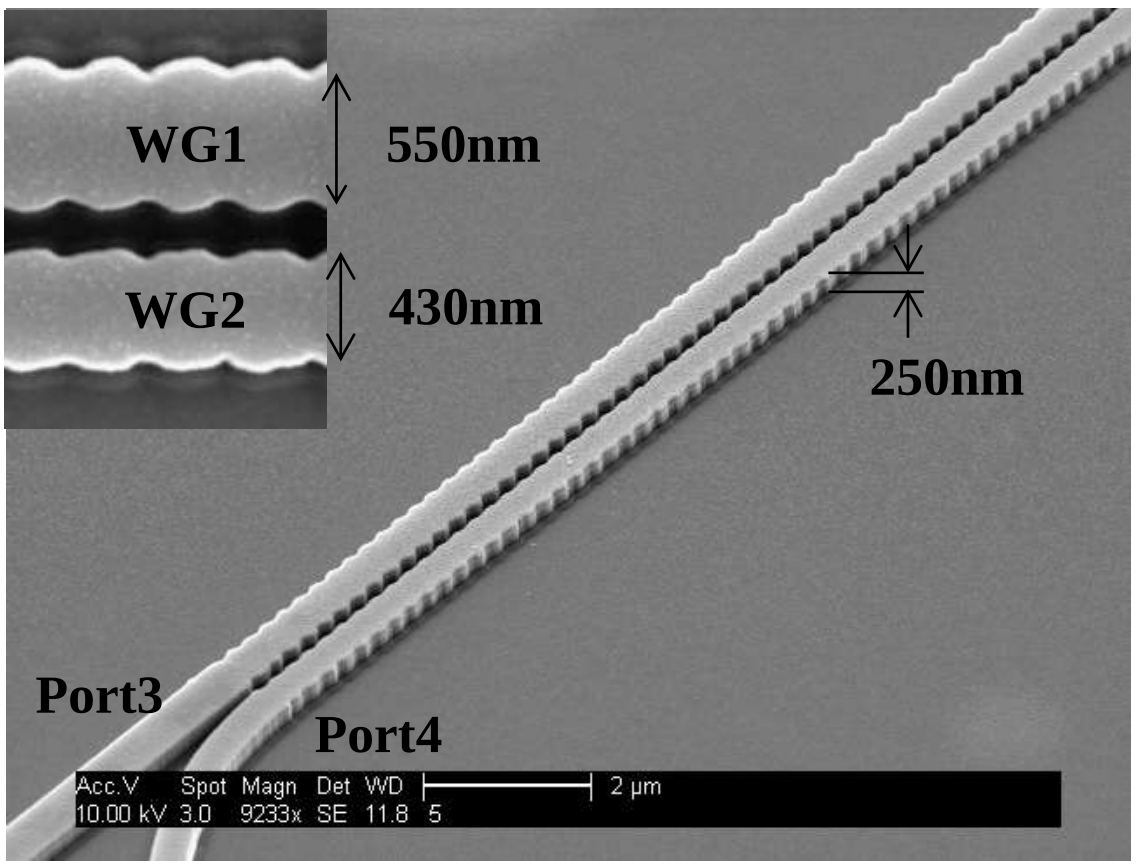
nano3 SCIENCE ENGINEERING MEDICINE

Calit2

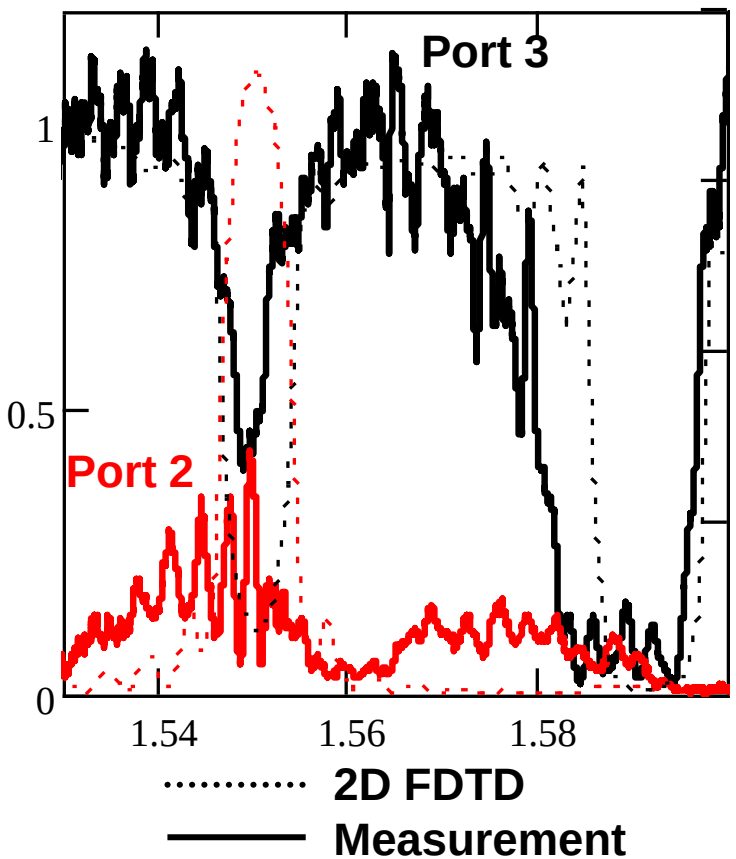
Photonic Nanowires: Add-Drop Filter for WDM



SEM micrograph



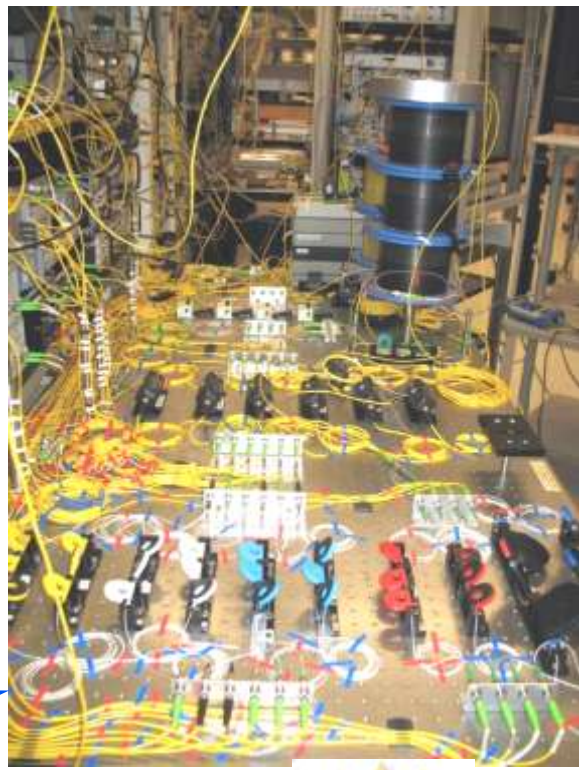
Measured spectrum



K. Ikeda, M. Nezhad and Y. Fainman,
"Wavelength Selective Coupler with Vertical Gratings on Silicon Chip,"
APPLIED PHYSICS LETTERS Volume: 92 Issue: 20 MAY 19 2008

Calit2 Photonics Systems Laboratory: Multi-Investigator Public Private Partnership

- **Real-Time Terabit/s Processing**
- **Single 640Gbps Channel Transport over >100km**
- **Scalable Channel Transport to 5Tbps**





ECE Testbed Faculty

Stojan Radic
Optical communication networks; all-optical processing; parametric processes in high-confinement fiber and semiconductor devices.



George Papen
Advanced photonic systems including optical communication systems, optical networking, and environmental and atmospheric remote sensing.



Joseph Ford
Optoelectronic subsystems integration (MEMS, diffractive optics, VLSI); Fiber optic and free-space communications.



Shaya Fainman
Nanoscale science and technology; ultrafast photonics and signal processing



Shayan Mookherjea
Optical devices and optical communication networks, including photonics, lightwave systems and nano-scale optics.

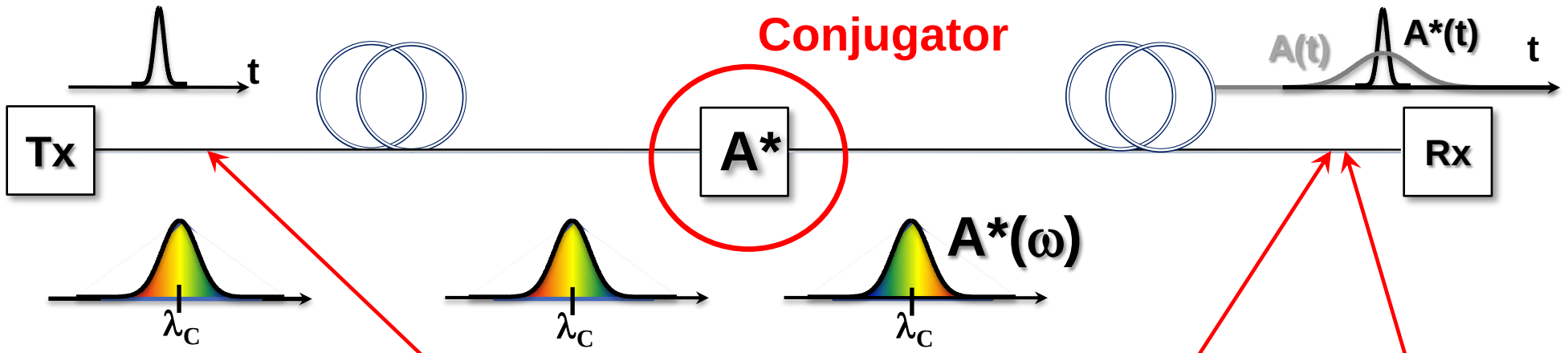


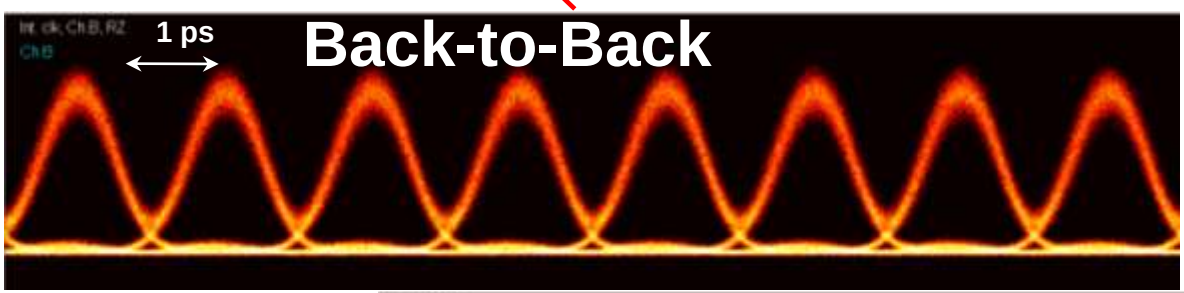
UCSD Photonics

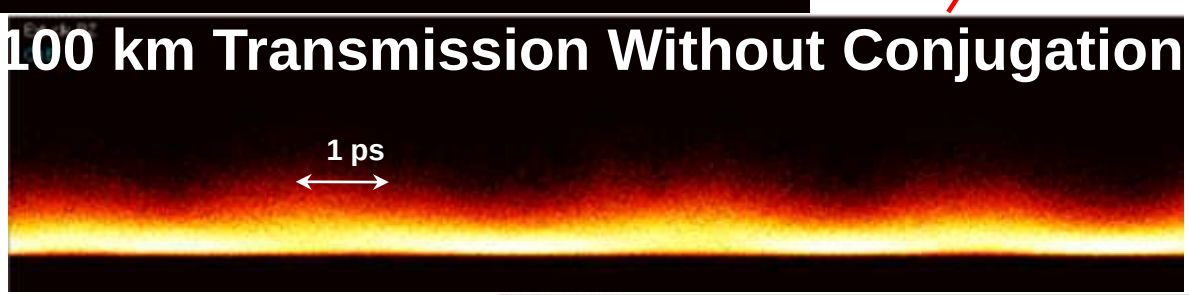
PARAMETRIC OPTICAL PROCESSES & SYSTEMS

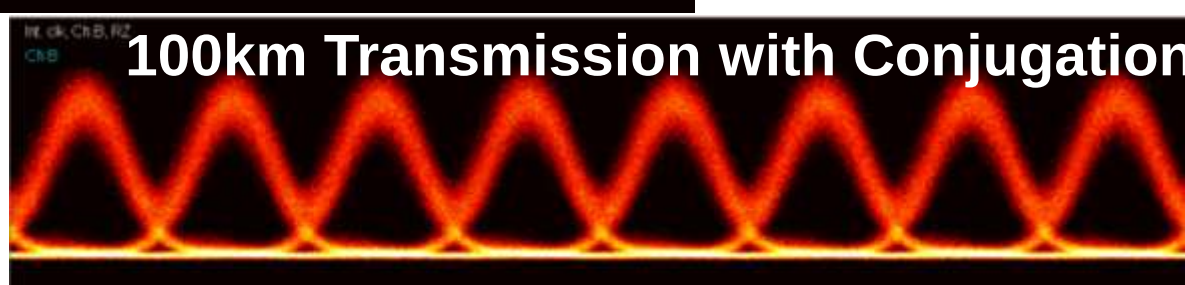
OptIPuter

First Uncompensated Transmission of 640 Gbps Channel over 100km Distance









Source: Stojan Radic, UCSD

Berkeley University of California

CALTECH

Columbia University in the City of New York

NSU Norfolk State University

STANFORD

TUSKEGEE UNIVERSITY

UCLA

USC

CIAN

CENTER FOR INTEGRATED ACCESS NETWORKS



Director:
N. Peyghambarian

The University of Arizona
Tucson Arizona

Deputy Director:
S. Fainman

University of California
San Diego

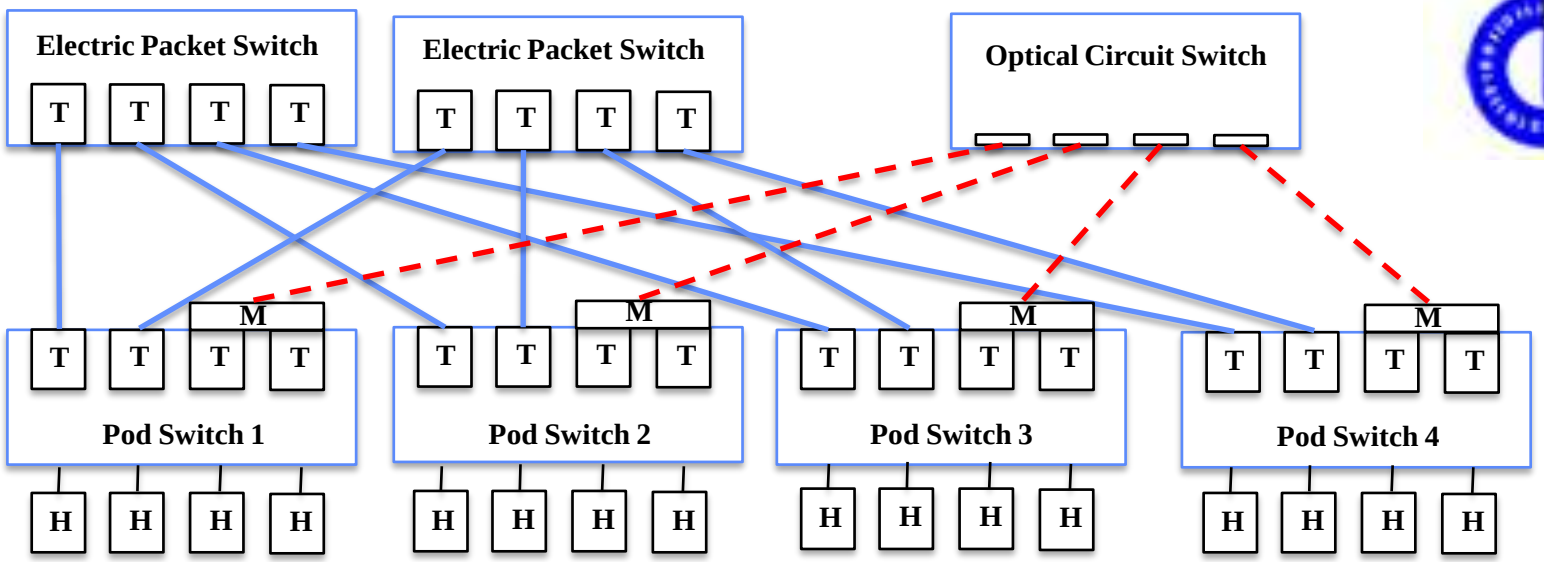


Industrial Partners



- 30 industrial partners.
- 7 companies added during the last month, 6 being system companies including Alcatel-Lucent, AT&T, BAE Systems, Ice, Telcordia and NEC.
- 13 companies are small firms with <50 employees.
- Majority of PIs have industrial background.
- 8 PIs have founded companies, have been involved in innovation and entrepreneurship.

Scalable Energy Efficient Data Centers (SEED): Hybrid Electrical Optical Switch



- **Mix electrical and optical switching components to interconnect modular data centers**
  - **Electrical elements for bursty short-lived communication**
  - **Optical circuit switching for long-lived inter-module communication**
- **Leverage WDM and energy-neutral nature of optics to deliver orders of magnitude improvements in complexity, cost/performance, energy**

Center for Networked Systems UCSanDiego

Source: Shaya Fainman, George Papen, Amin Vahdat, UCSD

OptIPuter

The GreenLight Project: Instrumenting the Energy Cost of Computational Science

- **Focus on 5 Communities with At-Scale Computing Needs:**
  - **Metagenomics**
  - **Ocean Observing**
  - **Microscopy**
  - **Bioinformatics**
  - **Digital Media**





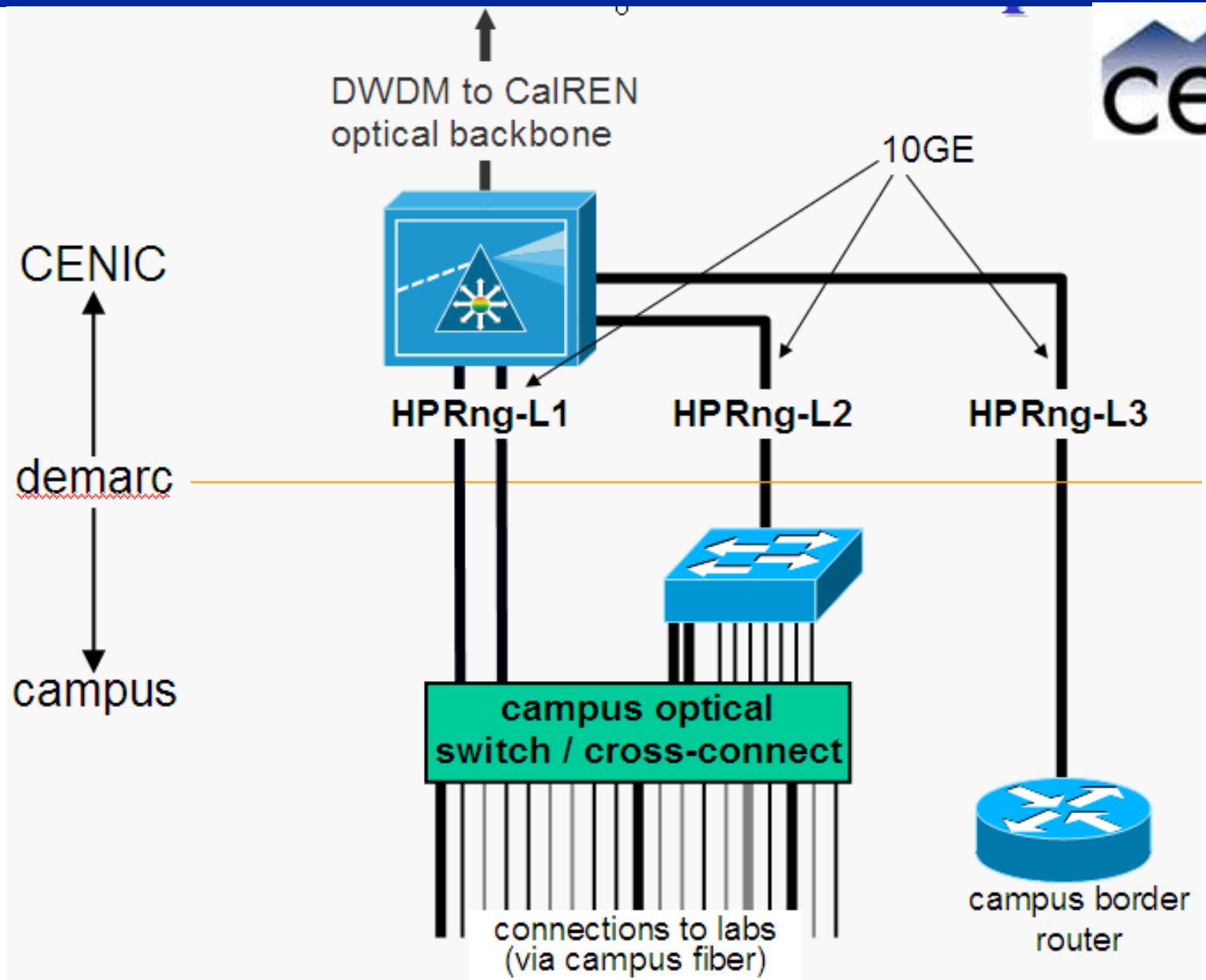
- **Measure, Monitor, & Web Publish Real-Time Sensor Outputs**
  - **Via Service-oriented Architectures**
  - **Allow Researchers Anywhere To Study Computing Energy Cost**
  - **Enable Scientists To Explore Tactics For Maximizing Work/Watt**
- **Develop Middleware that Automates Optimal Choice of Compute/RAM Power Strategies for Desired Greenness**
- **Partnering With Minority-Serving Institutions Cyberinfrastructure Empowerment Coalition**

NSF

Source: Tom DeFanti, Calit2; GreenLight PI

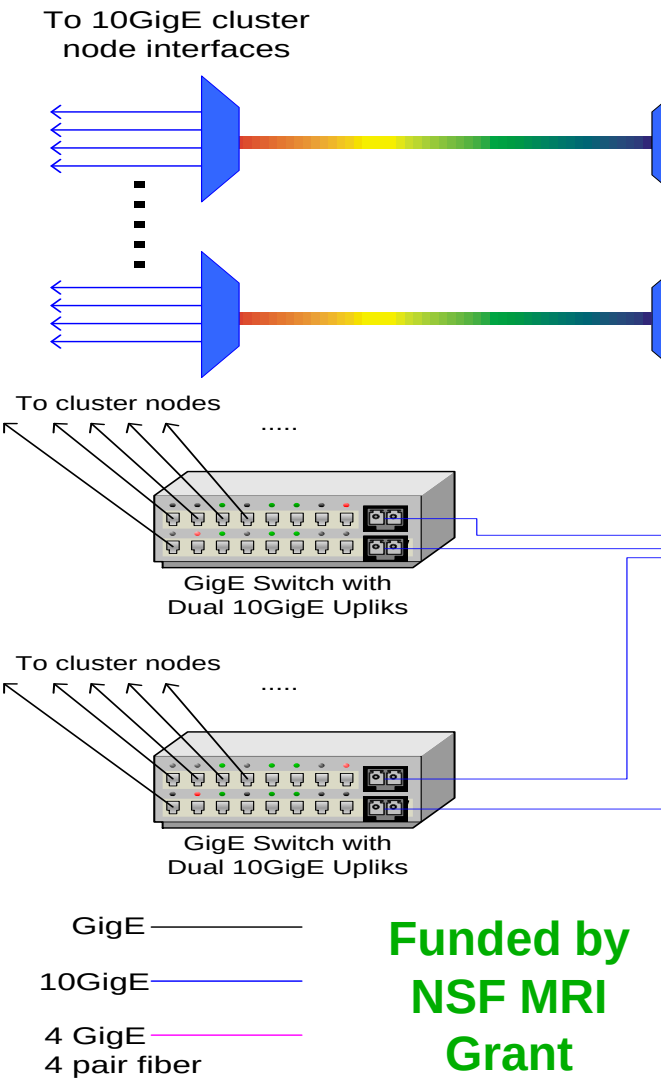
OptIPuter

Campus Preparations Needed to Accept CENIC CalREN Handoff to Campus



Source: Jim Dolgonas, CENIC

Current UCSD Experimental Optical Core: Ready to Couple to CENIC L1, L2, L3 Services



Enpoints:

>= 50 endpoints at 10 GigE

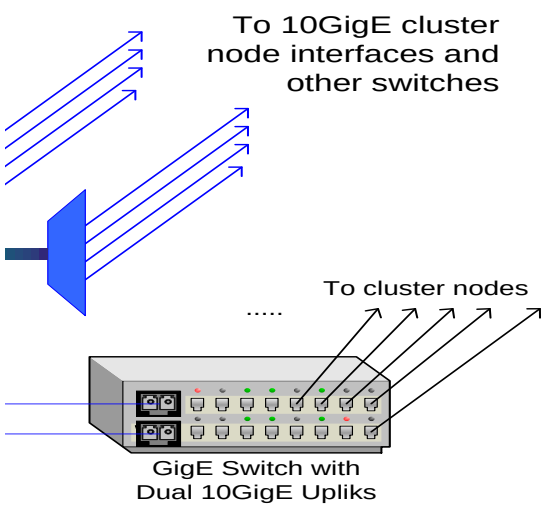
>= 32 Packet switched

>= 32 Switched wavelengths

>= 300 Connected endpoints

Approximately 0.5 TBit/s Arrive at the "Optical" Center of Campus
Switching will be a Hybrid Combination of:
Packet, Lambda, Circuit -- OOO and Packet Switches Already in Place

CENIC L1, L2 Services



CalREN-HPR Research Cloud

Campus Research Cloud

Funded by NSF MRI Grant

OptIPuter Border Router

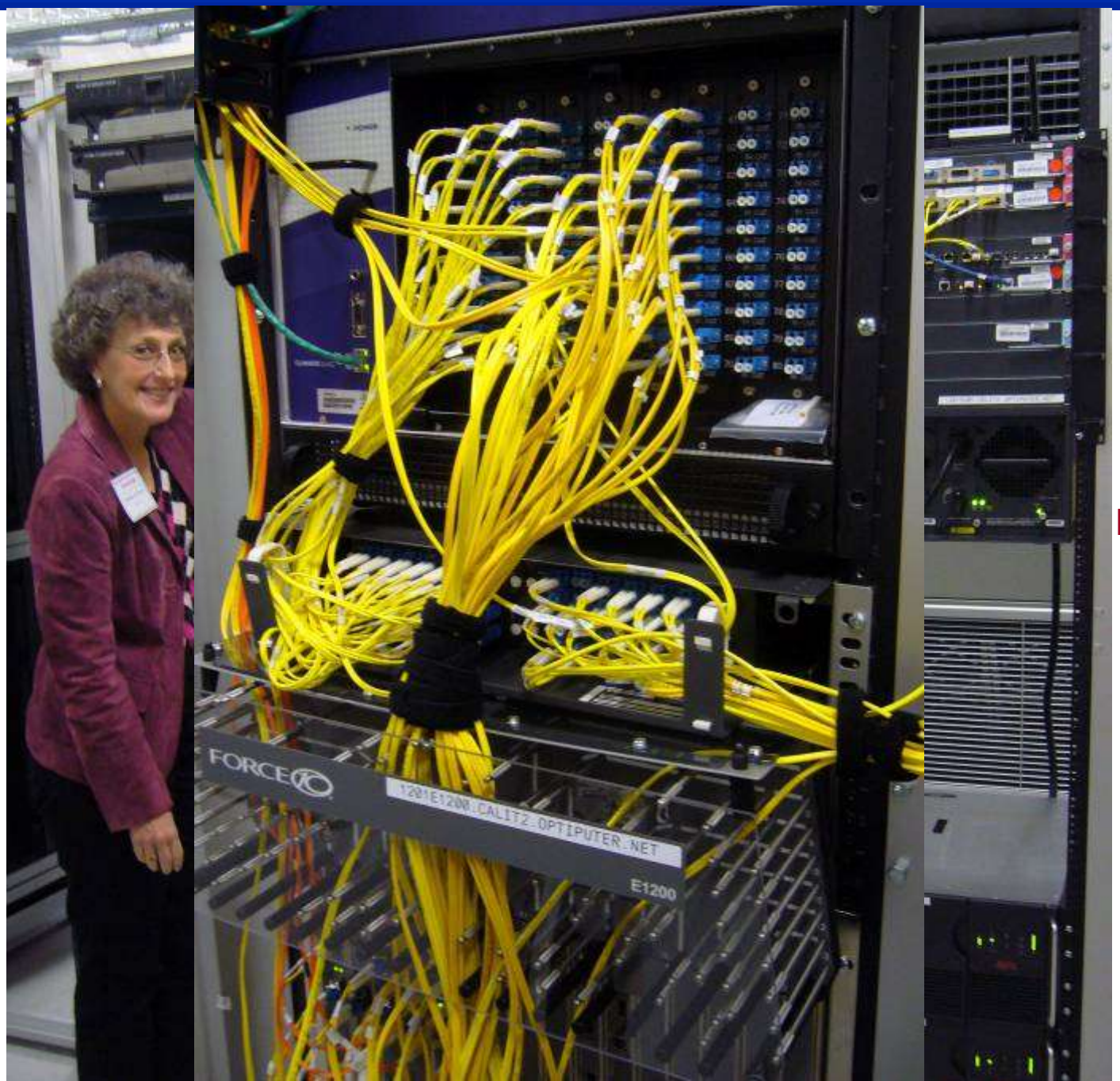
Source: Phil Papadopoulos, SDSC/Calit2 (Quartzite PI, OptIPuter co-PI)

SDSC

NSF

OptIPuter

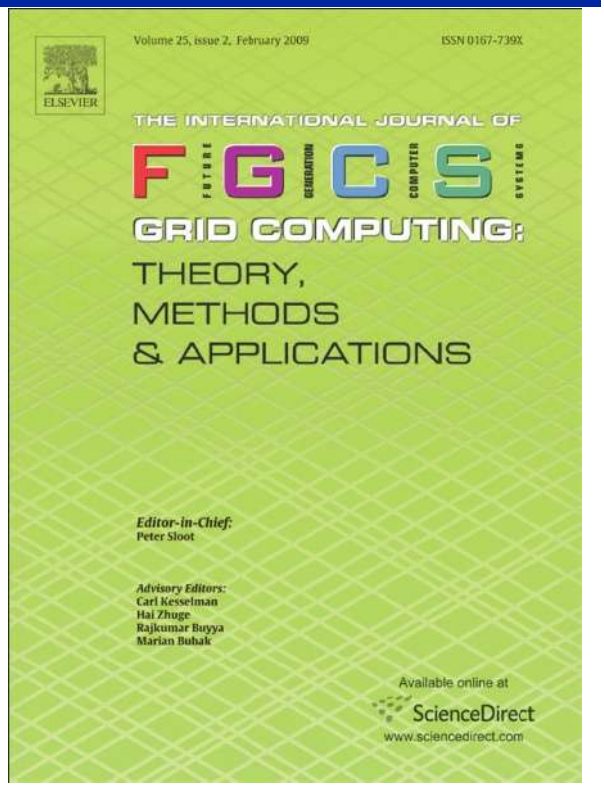
Calit2 Sunlight
Optical Exchange Contains Quartzite



10:45 am
Feb. 21, 2008

The OptIPuter Creates an OptIPlanet Collaboratory: Enabling Data-Intensive e-Research





"OptIPlanet: The OptIPuter Global Collaboratory" –
Special Section of Future Generations Computer Systems, Volume 25, Issue 2, February 2009

evl electronic visualization laboratory

NSF

ROCKS www.rocksclusters.org

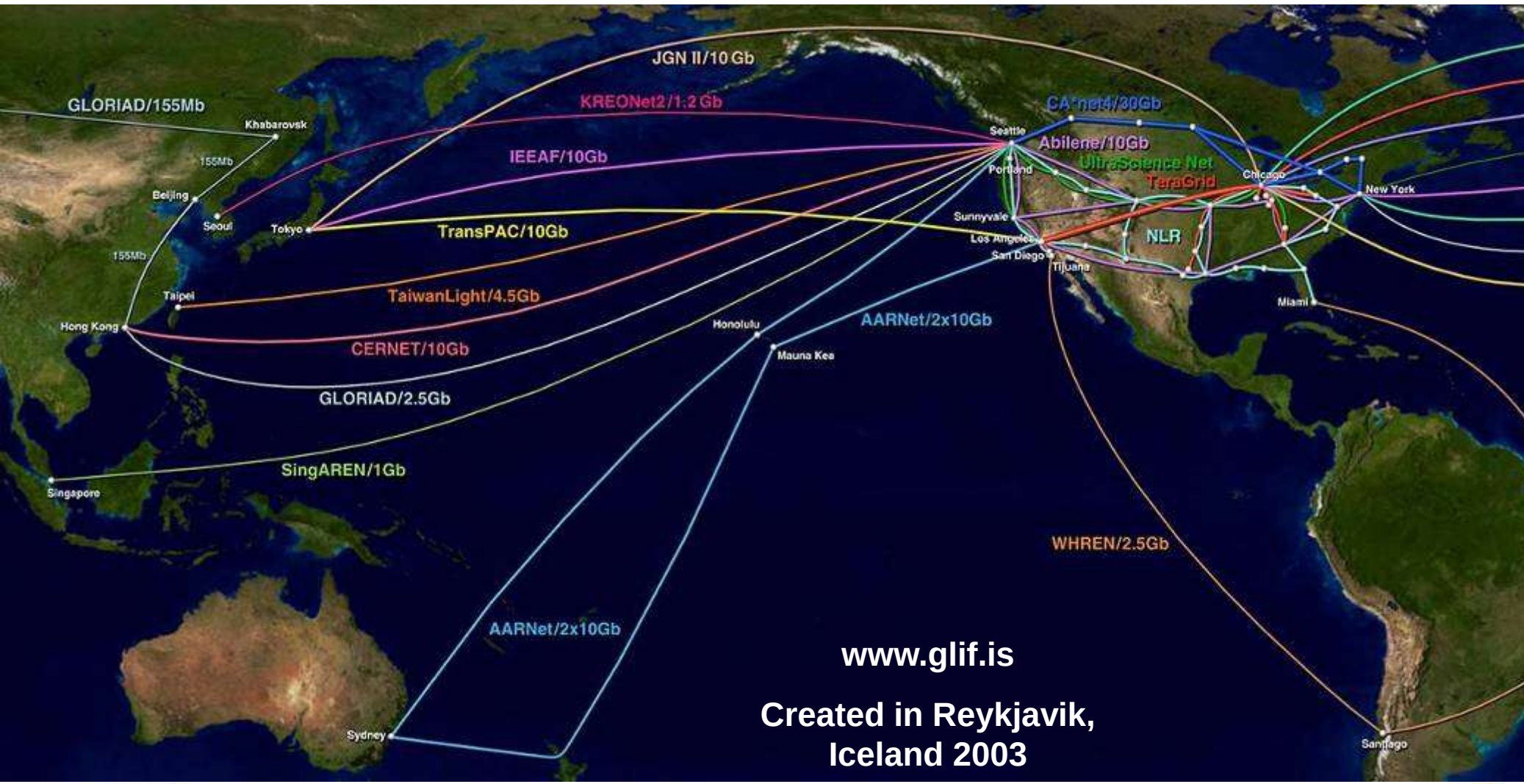
SAGE

Calit2 (UCSD, UCI), SDSC, and UIC Leads—Larry Smarr PI
Univ. Partners: NCSA, USC, SDSU, NW, TA&M, UvA, SARA, KISTI, AIST
Industry: IBM, Sun, Telcordia, Chiaro, Calient, Glimmerglass, Lucent

it2

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The Global Lambda Integrated Facility--
Creating a Planetary-Scale High Bandwidth Collaboratory



www.glif.is

Created in Reykjavik, Iceland 2003

Visualization courtesy of
Bob Patterson, NCSA.

Gigabit HD Streams Over Lambdas Will Radically Transform Global Collaboration





Telepresence Using Uncompressed 1.5 Gbps HDTV Streaming Over IP on Fiber Optics-- 75x Home Cable "HDTV" Bandwidth!



"I can see every hair on your head!"—Prof. Aoyama

Source: U Washington Research Channel

OptIPlanet Collaboratory Persistent Infrastructure Between Calit2 and U Washington

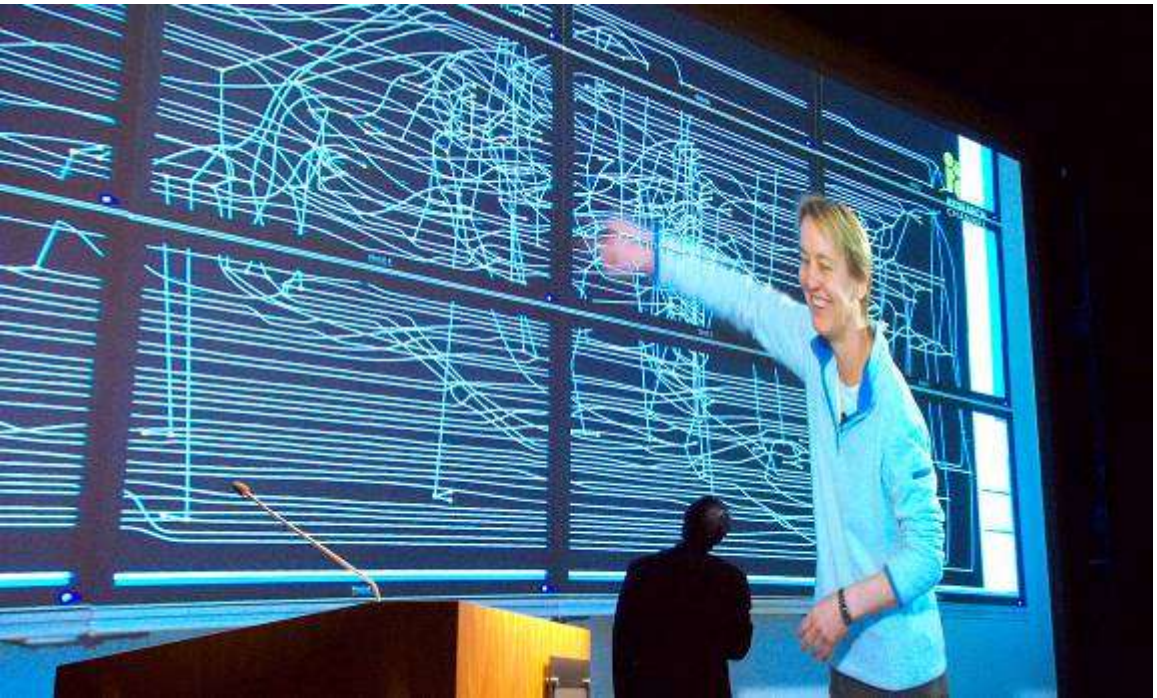


OptIPuter

Ginger Armbrust's Diatoms: Micrographs, Chromosomes, Genetic Assembly

ROCKS





iHDTV: 1500 Mbits/sec Calit2 to UW Research Channel
Over 10,000 Mbps
Pacific Wave/CENIC
Dedicated Optical Fiber

OptIPuter

First Tri-Continental Premier of a Streamed 4K Feature Film With Global HD Discussion



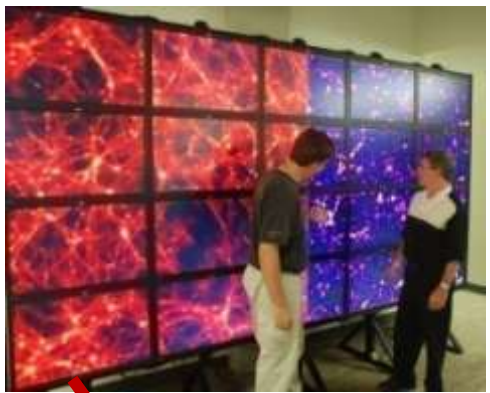
4K Transmission Over 10Gbps--
4 HD Projections from One 4K Projector

CineGrid 4K Remote Microscopy
USC to Calit2



Richard Weinberg, USC

Academic Research "OptIPlatform" Cyberinfrastructure: A 10Gbps Lightpath Cloud



End User OptIPortal



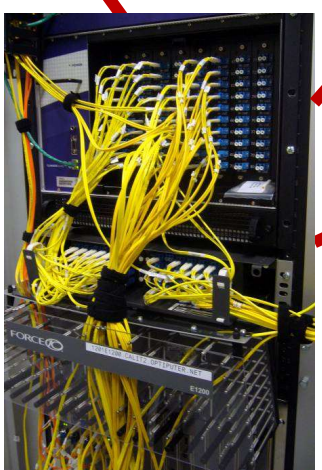
Instruments



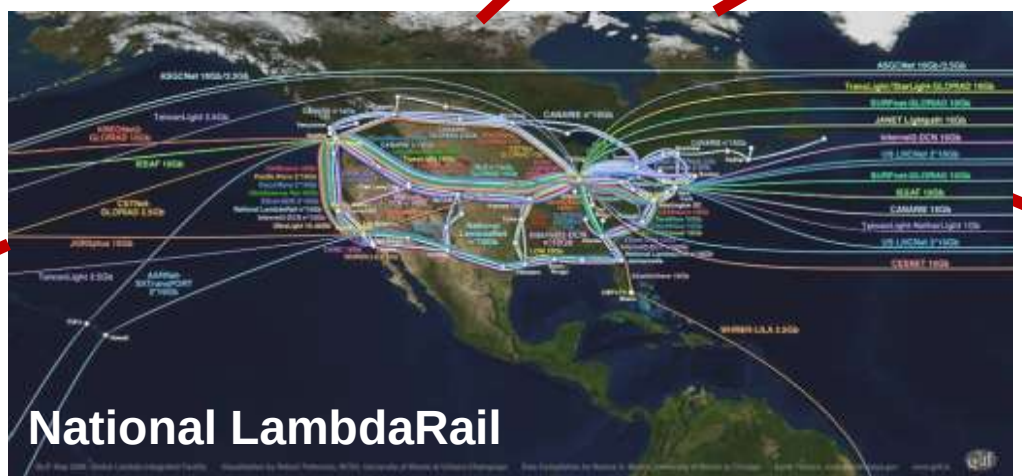
HD/4k Telepresence



HD/4k Video Cams



10G Lightpaths



National LambdaRail

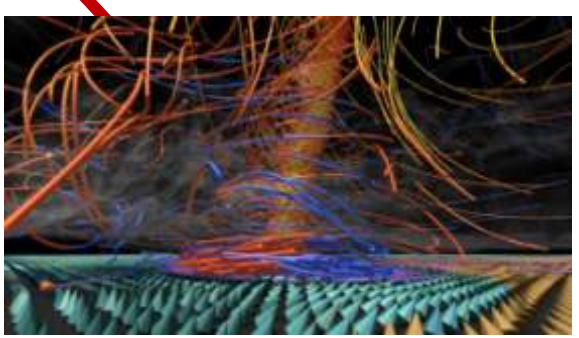
HPC

TeraGrid



Campus Optical Switch

Data Repositories & Clusters



HD/4k Video Images

it2

OptIPuter