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Dept. of Applied Physics

Laser Accelerators for High Energy Physics

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On behalf of the LEAP and E163 Collaborations:

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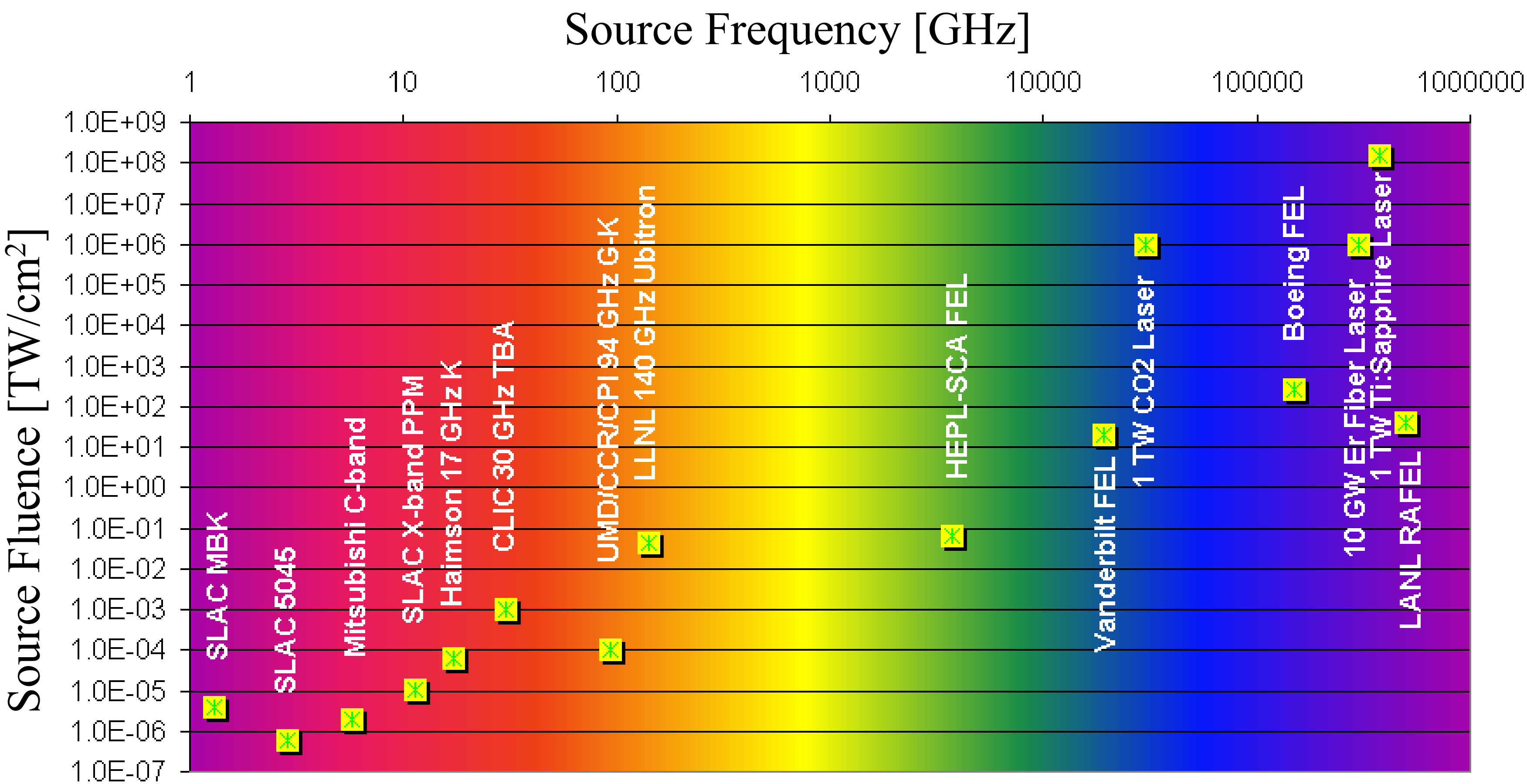
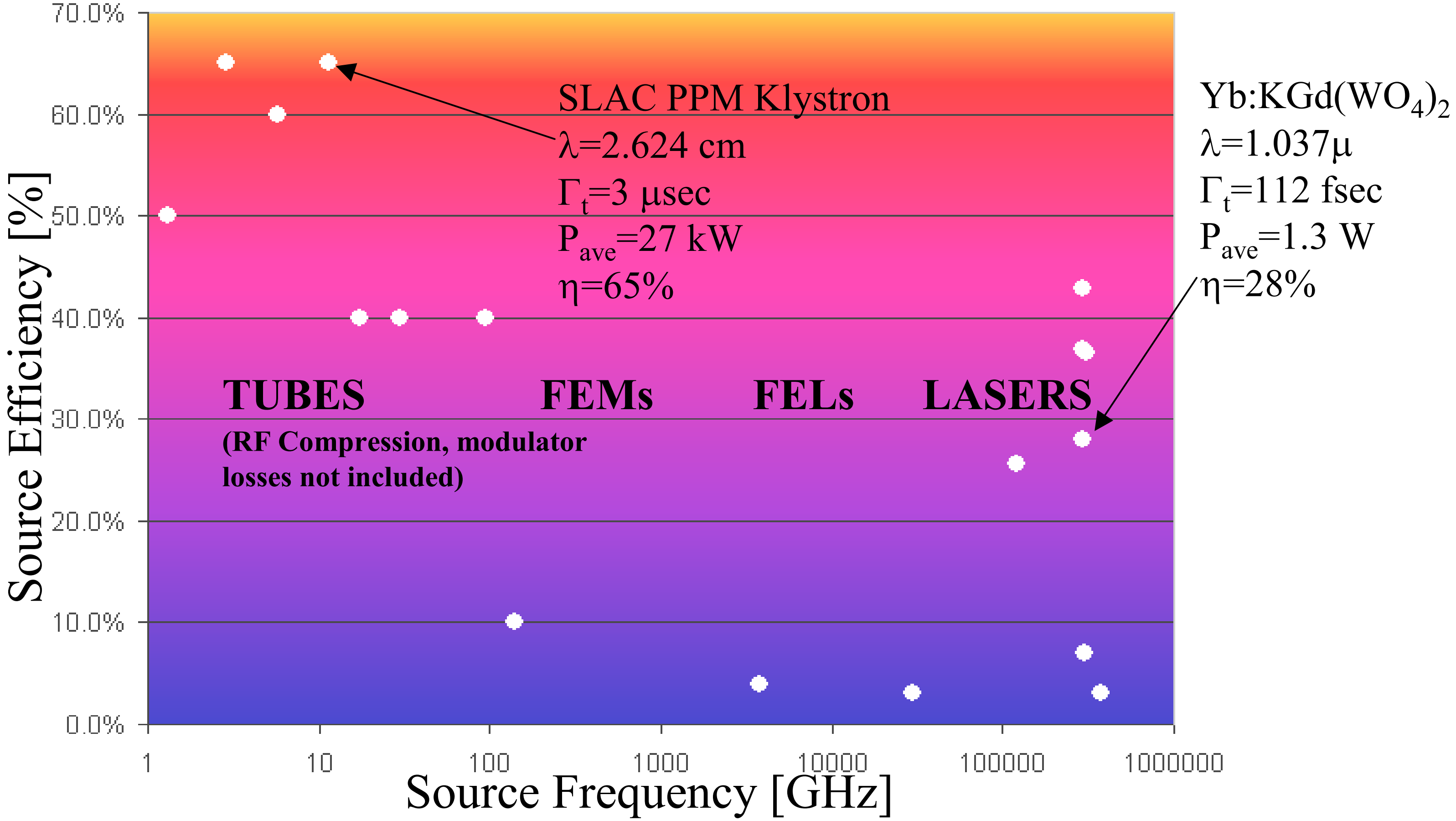
Stanford University / Hansen Experimental Physics Laboratory

Coherent Sources of Radiation



Efficiency of Power Sources



Progress in Lithography

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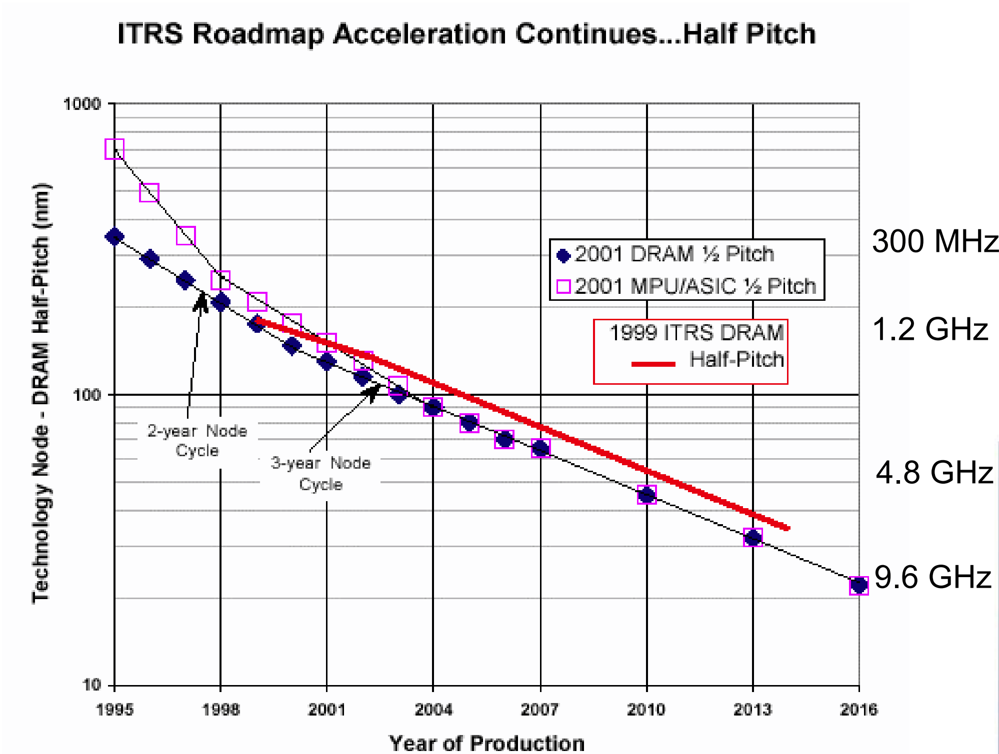
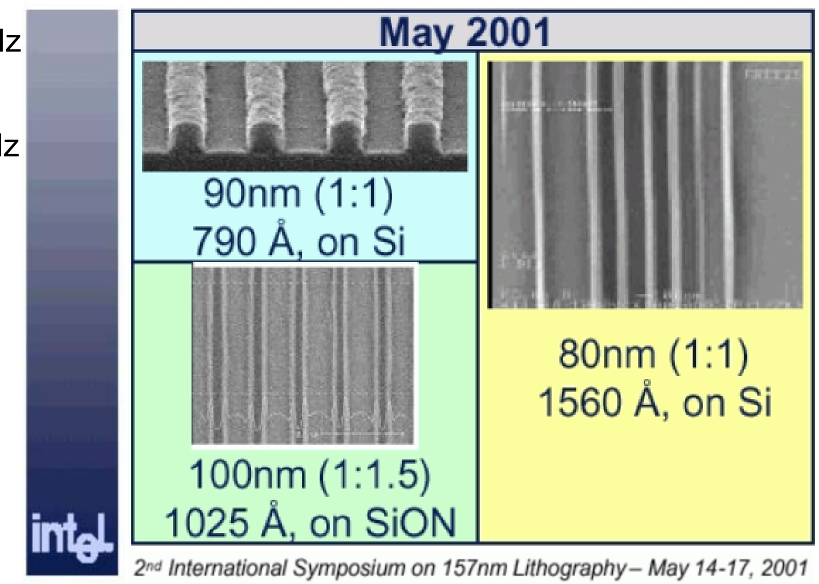


Source: 2001 ITRS - Exec. Summary, ORTC Figure



Large-Market Technologies

U.S. Government, projected for 2002[1]:

Revenue:	$2.1 trillion
DOE and NSF: 3.2+4.5=	$7.7 billion

Semiconductor industry, domestic, in 1999[2]:

Revenue:	$168.6 billion
R&D:	$22 billion

Telecommunications industry, worldwide, proj. for 2001[3]:

Revenue:	$1 trillion (including services)
R&D:	$25 billion [4] (top 30)

Laser machining & welding, $30 billion/year → laser diode bars

[1] "The Budget of the United States Government, FY2002", OMB.
[2] "Is Basic Research the Government's Responsibility?", Cahners Business Information, (2000).
[3] J. Timmer, "Telecommunications Services Industry", Hoover's Business Network, (2000).
[4] "International Science Yearbook 2001", Cahners Business Information, 2001.

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Technical Roadmap

LEAP

1. Demonstrate the physics of laser acceleration in dielectric structures
2. Develop experimental techniques for handling and diagnosing picoCoulomb beams on picosecond timescales
3. Develop simple lithographic structures and test with beam

E163

Phase I. Characterize laser/electron energy exchange in vacuum

Phase II. Demonstrate optical bunching and acceleration

Phase III. Test multicell lithographically produced structures

Now and Future

1. Demonstrate carrier-phase lock of two ultra fast lasers [NIST, Stanford, SP]
2. Continue development of highly efficient DPSS-pumped broadband mode- and carrier-locked lasers [DARPA Grant, SBIR Solicitation]
3. Devise power-efficient lithographic structures [CIS, SBIR Solicitation]
4. Devise stabilization and timing systems for large-scale machine [LIGO]
5. …

Damage Threshold Improvement ↓

The Laser Electron Accelerator Project

LEAP

SLAC: R.H. Siemann
J.E. Spencer
E. Colby
C. Barnes
B. Cowan

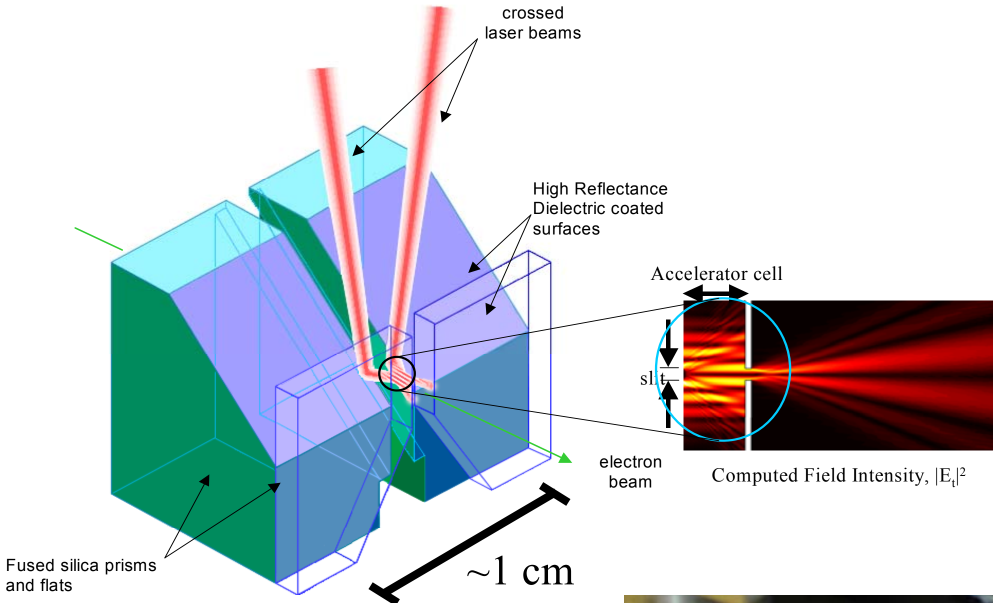
HEPL: T.I. Smith
R.L. Swent

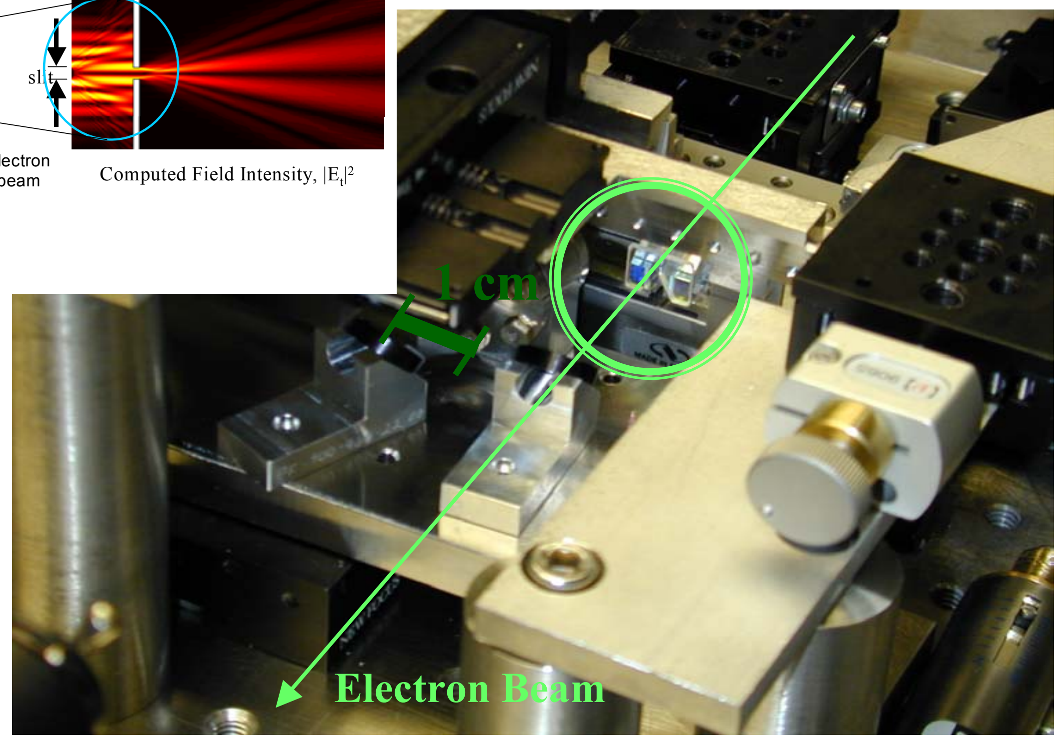
Ginzton Labs: R.L. Byer
T. Plettner
J. A. Wisdom

First funded by Stanford patent money, subsequently funded though the DOE-HEP office of Advanced Accelerator Research in 1997, renewed in 2000.

Objective: To demonstrate laser driven electron acceleration in a dielectric structure in vacuum.

The LEAP Accelerator Cell





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Progress to Date

Accomplished

1. Sub-picoCoulomb electron beam pulse characterization
2. Transmission through <5 μm slit
3. Spatial overlap to better than 20 μm (w_o=40μm)
4. Temporal overlap better than 100 psec
5. Laser optical phase monitor
6. Detailed laser damage threshold measurements

Present Challenges

1. Energy spread and timing jitter
2. Lack of knowledge of e-beam pulse duration
3. Drifting experimental parameters at SCA

Before the next run

1. Momentum collimator to reduce from 13→6 keV RMS
2. Simple lithographic accelerator cell design
3. Continued laser-damage threshold measurements
4. Improve temporal overlap measurement to <30 psec

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E163: Laser Acceleration at the NLCTA

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Stanford Linear Accelerator Center

R. L. Byer, T. Plettner, J. A.Wisdom

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September 24, 2001

* Spokesman.

Laser Acceleration at the NLCTA

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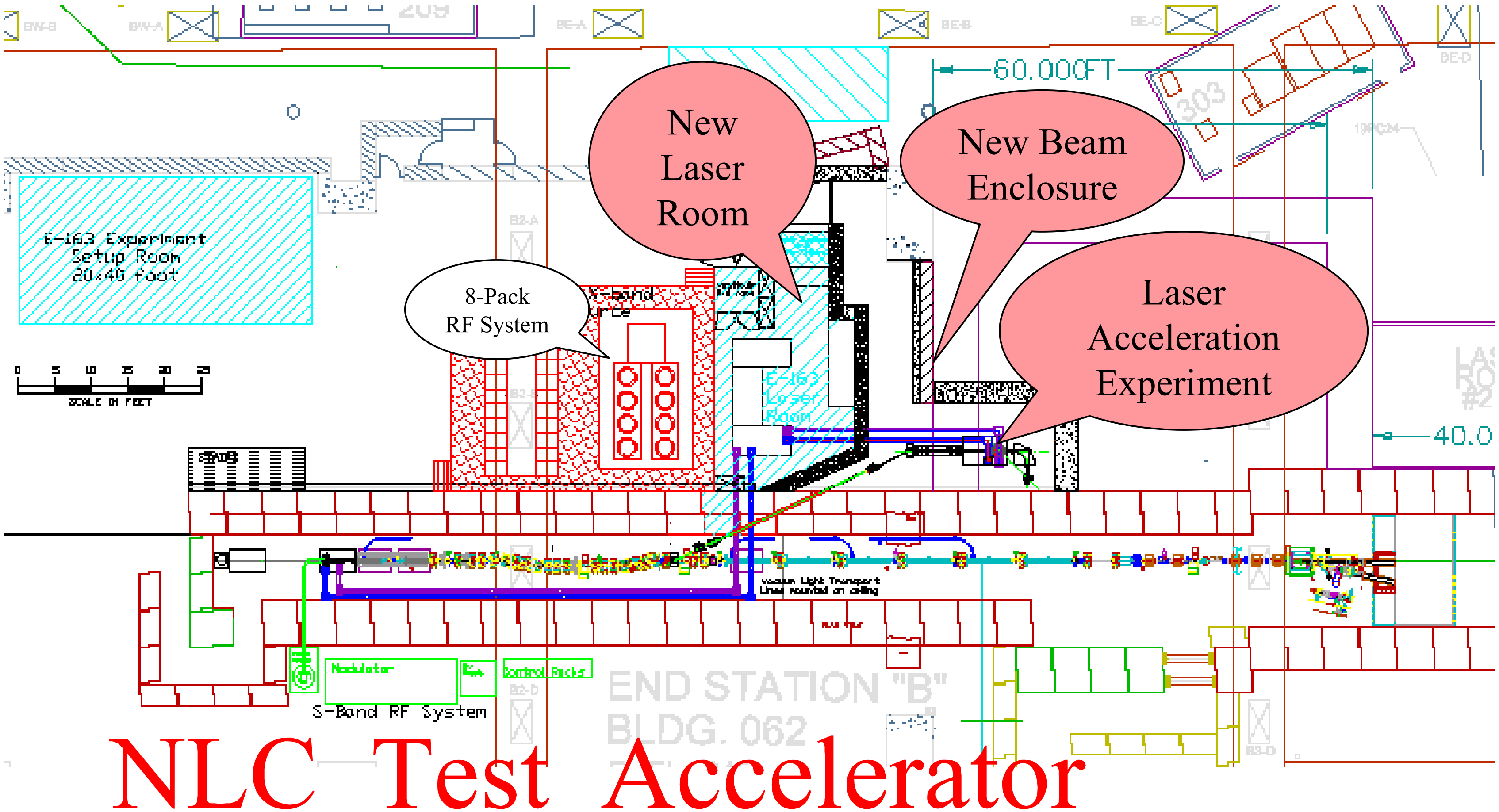
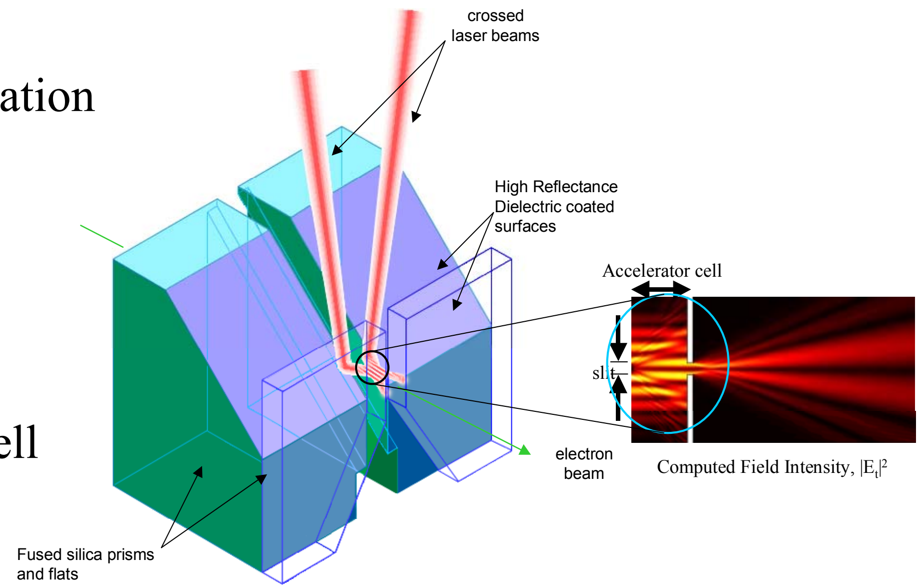


Phase I: Laser Acceleration

Scientific Goals:

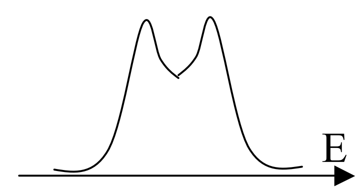
•Thoroughly characterize the dependencies of the energy modulation on:

- Interaction length
- Crossing angle
- Slit width
- Relative laser phase
- Physical tolerances of the cell



Technical Goals:

- Commission the experiment at the NLCTA
- Make progress understanding electric field breakdown issues and the attendant design implications
- Timing synchronization



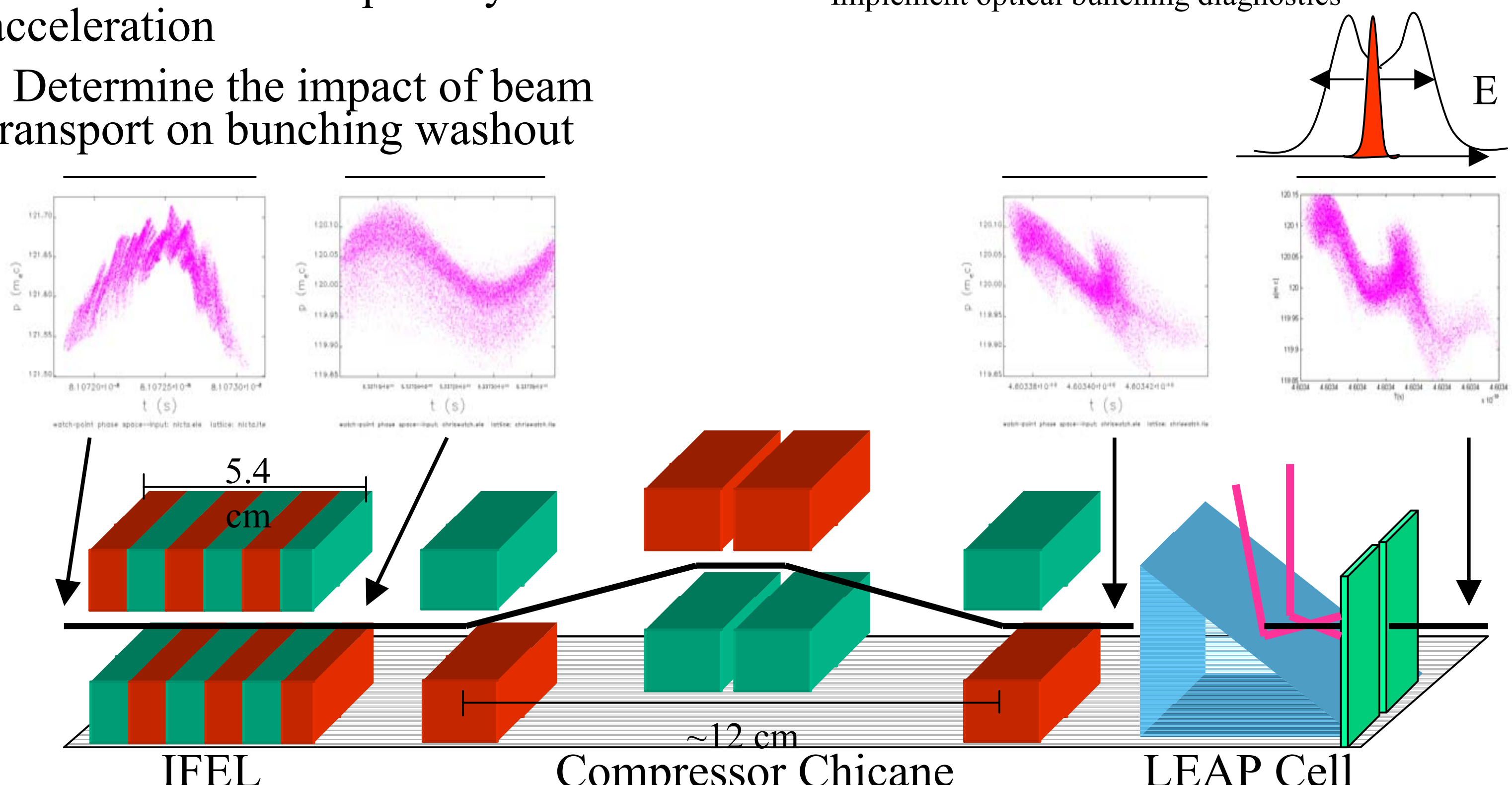
Phase II: Prebunch and Accelerate

Scientific Goals:

- Demonstrate and quantify optical bunching
- Demonstrate and quantify acceleration
- Determine the impact of beam transport on bunching washout

Technical Goals:

- Commission the IFEL prebuncher
- Understand mechanical stability required to maintain attosecond-scale timing synchronism
- Implement optical bunching diagnostics



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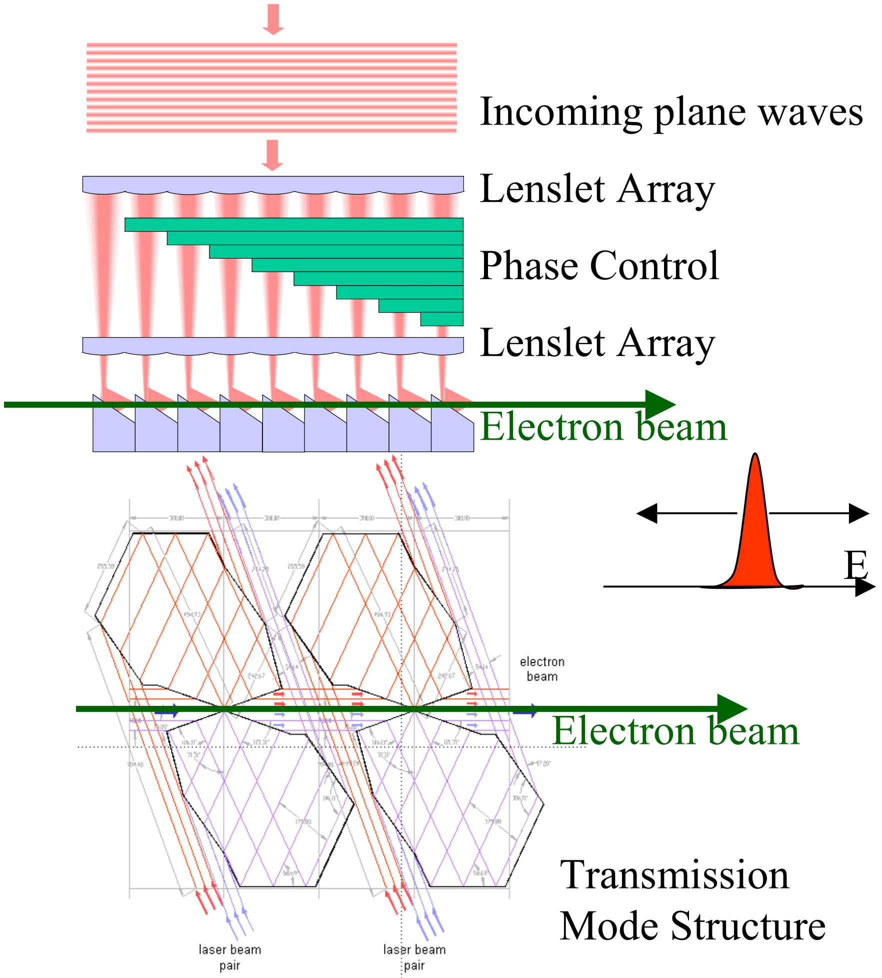
Phase III: Multicell Structures



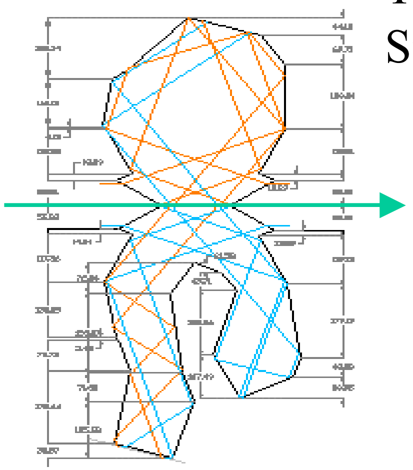
Scientific Goals:

- Demonstrate multi-stage acceleration of optically bunched beam
- Quantify micropulse wakefields

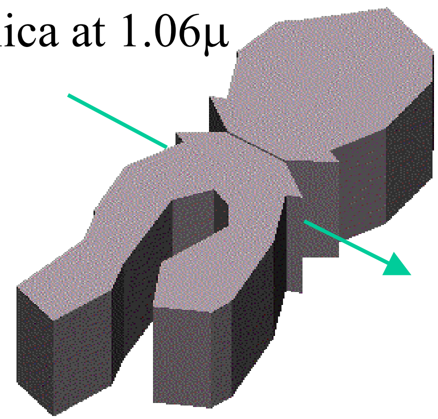
Technical Goals:

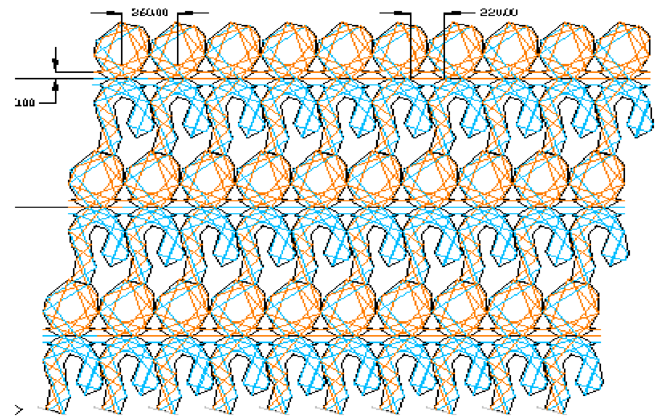
- Master lithographic production techniques for silica or silicon microstructures
- Make progress understanding damage threshold issues
- Fabricate integrated accelerator components
- Devise and test methods of beam focussing

Multicell Structure Concepts

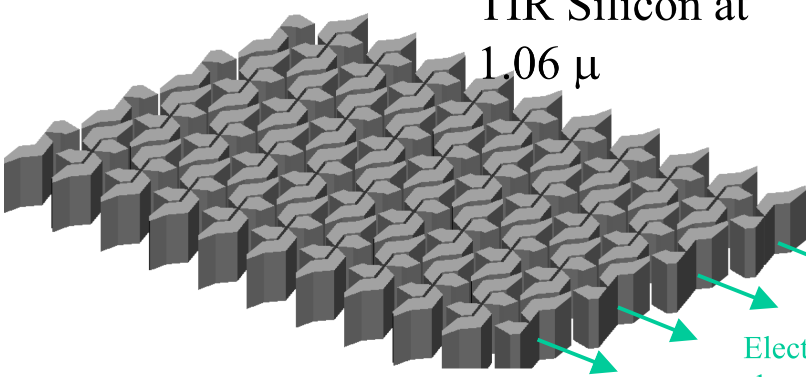


TIR Fused Silica at 1.06μ

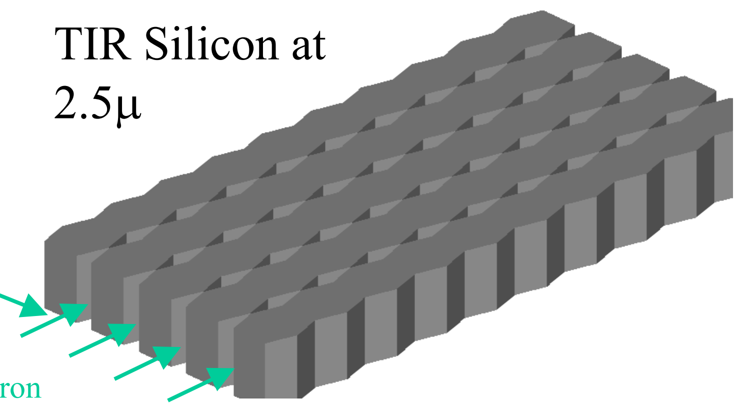




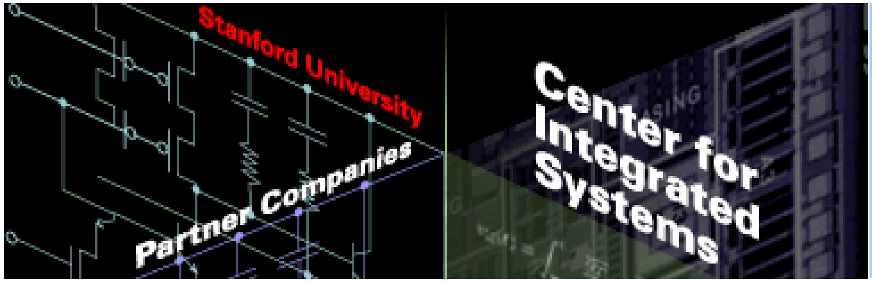
TIR Silicon at 1.06 μ



TIR Silicon at 2.5μ



Electron beams



Stanford Photonics Research Center

incorporating the Center for Novel Optoelectronic Materials (CNOM)

•Infrastructure: 10,500-square-foot class 100 cleanroom

•Research includes a wide range of disciplines and processes

–Used for optics, MEMS, biology, chemistry, as well as traditional electronics

–Equipment available for chemical vapor deposition, optical photolithography, oxidation and doping, wet processing, plasma etching, and other processes

–Characterization equipment including SEM and AFM available

A $60-million dollar 120,000-square-foot photonics laboratory with 20 faculty, 120 doctoral, and 50 postdoctoral researchers, completed in 2004.

Current Research:

Diode Pumped Solid State Lasers

Diode pumped lasers for gravitational wave receivers

Diode pumped Laser Amplfier Studies

Quantum Noise of solid state laser amplifiers

Adaptive Optics for Laser Amplifier beam control

Thermal Modeling of Diode Pumped Nd:YAG lasers

Laser Interferometry for Gravity Wave detection

Sagnac Interferometer for Gravitational Wave Detection

Laser Inteferometer Isolation and Control Studies

Interferometry for Gravitational Wave Detection

Time and Frequency response characteristics of Fabry Perot Int.

GALILEO research program: gravitational wave receivers

Quasiphasematched Nonlinear Devices

Quasi Phasematched $LiNbO_3$ for SHG of diode lasers, cw OPO studies in $LiNbO_3$, and diffusion bonded, GaAs nonlinear materials

Direct laser acceleration offers the promise of a new acceleration method built from technologies that are being aggressively developed by industry.

The LEAP collaboration is motivated by this promise to develop accelerators from these technologies and has developed the expertise for working in this challenging arena. Stanford University offers the knowledge and facilities to carry out microfabrication and laser development.

Cost-effective expansion of the NLC Test Accelerator can provide the electron beam for testing laser accelerator concepts, either as a single-purpose (E163) or multi-purpose (ORION) facility.