Gamma-gamma laser development at LLNL

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UIC, Chicago

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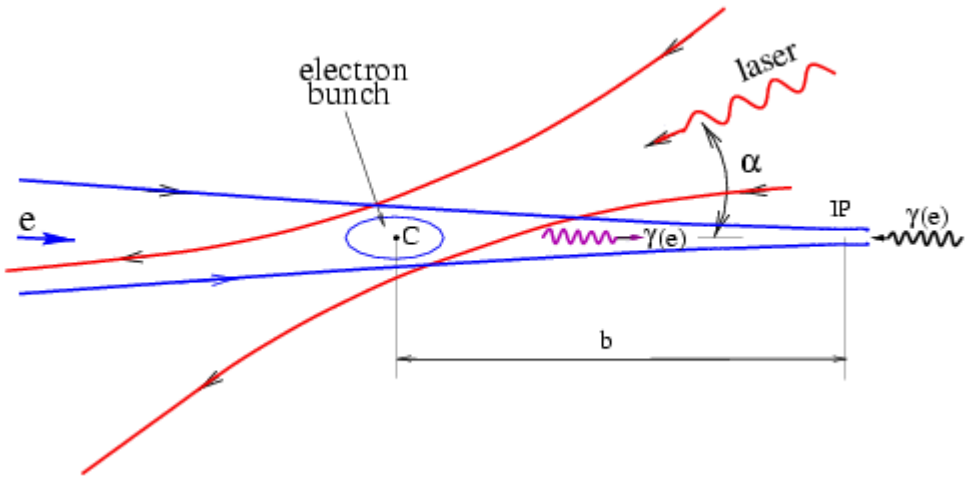
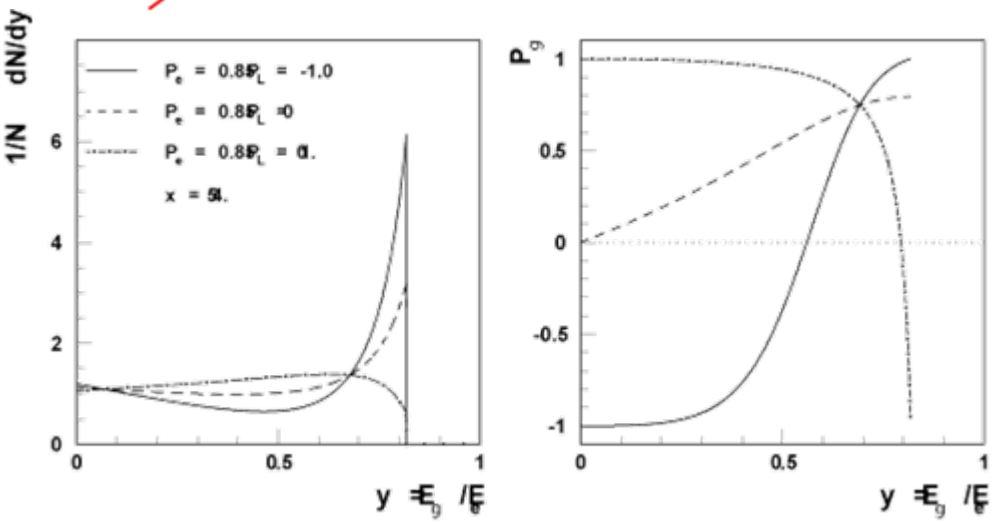
Photon Linear Collider (PLC) is a simple and elegant idea

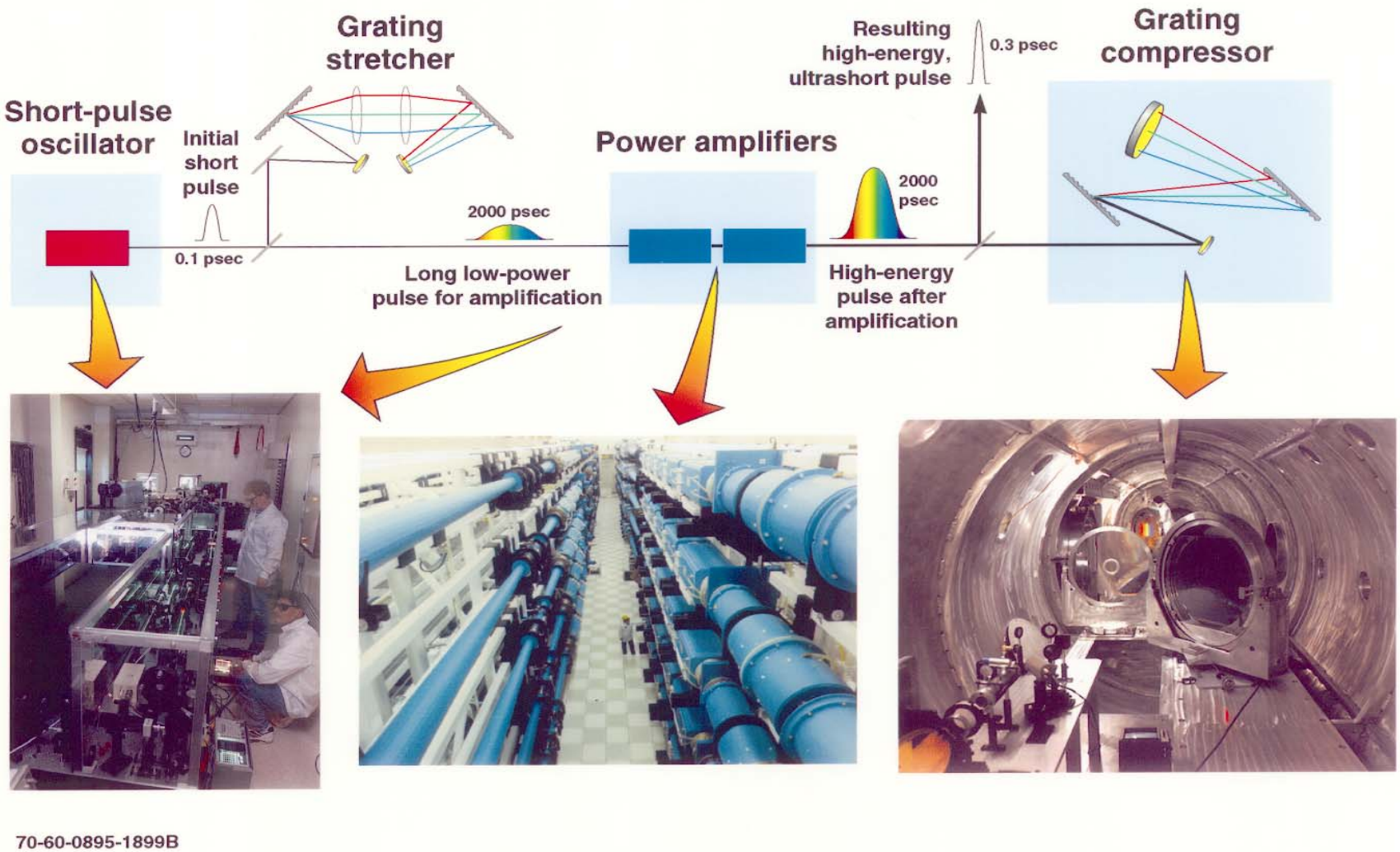




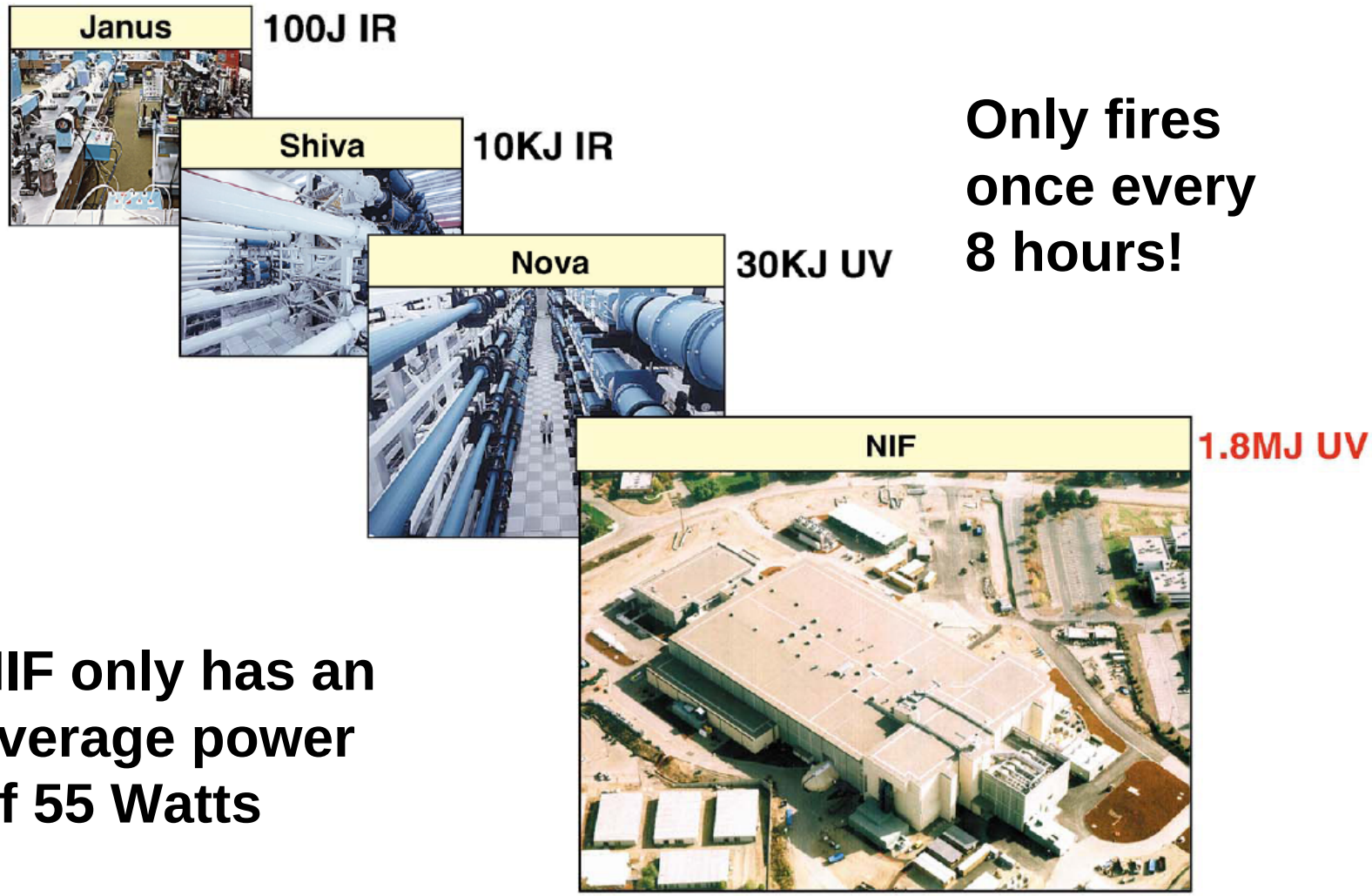
- Laser Compton interaction produces beam of high energy photons
  - **Eγ <= 0.8 E_{beam}**
- Peak has high circular polarization
  - **Linear polarization is also possible**
  - **CP studies**
- Need laser pulses of 1 J in 1 ps (terawatt) to make this work

V. Telnov

Chirped pulse amplification was the breakthrough that allowed terawatt pulses



LLNL has been working on high power lasers for Inertial Confinement Fusion

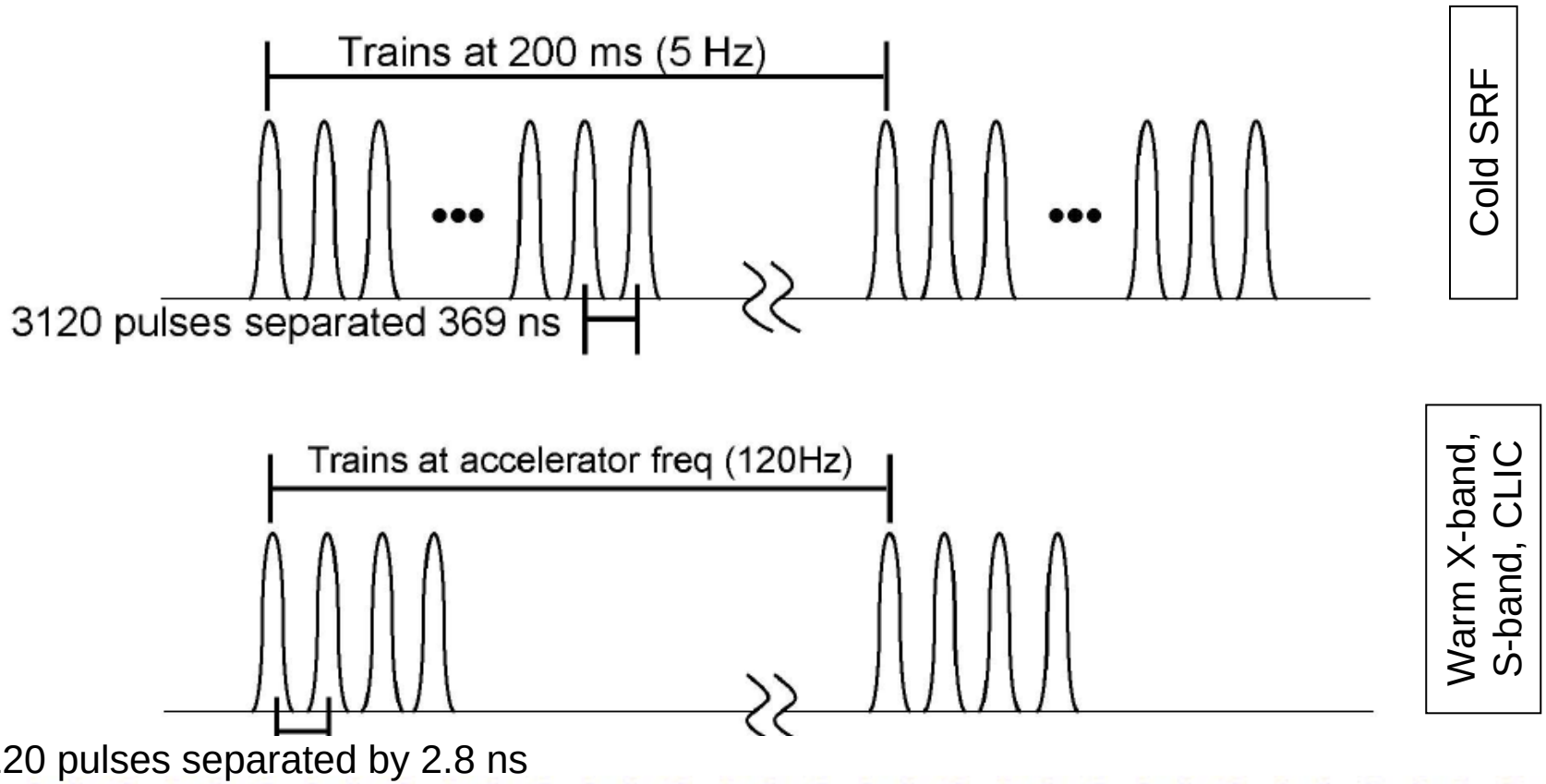


Only fires once every 8 hours!

NIF only has an average power of 55 Watts

The photon collider needs a laser pulse for every electron bunch

- Average power ~15kW / beam
- Formatted in time to match the electron time structure

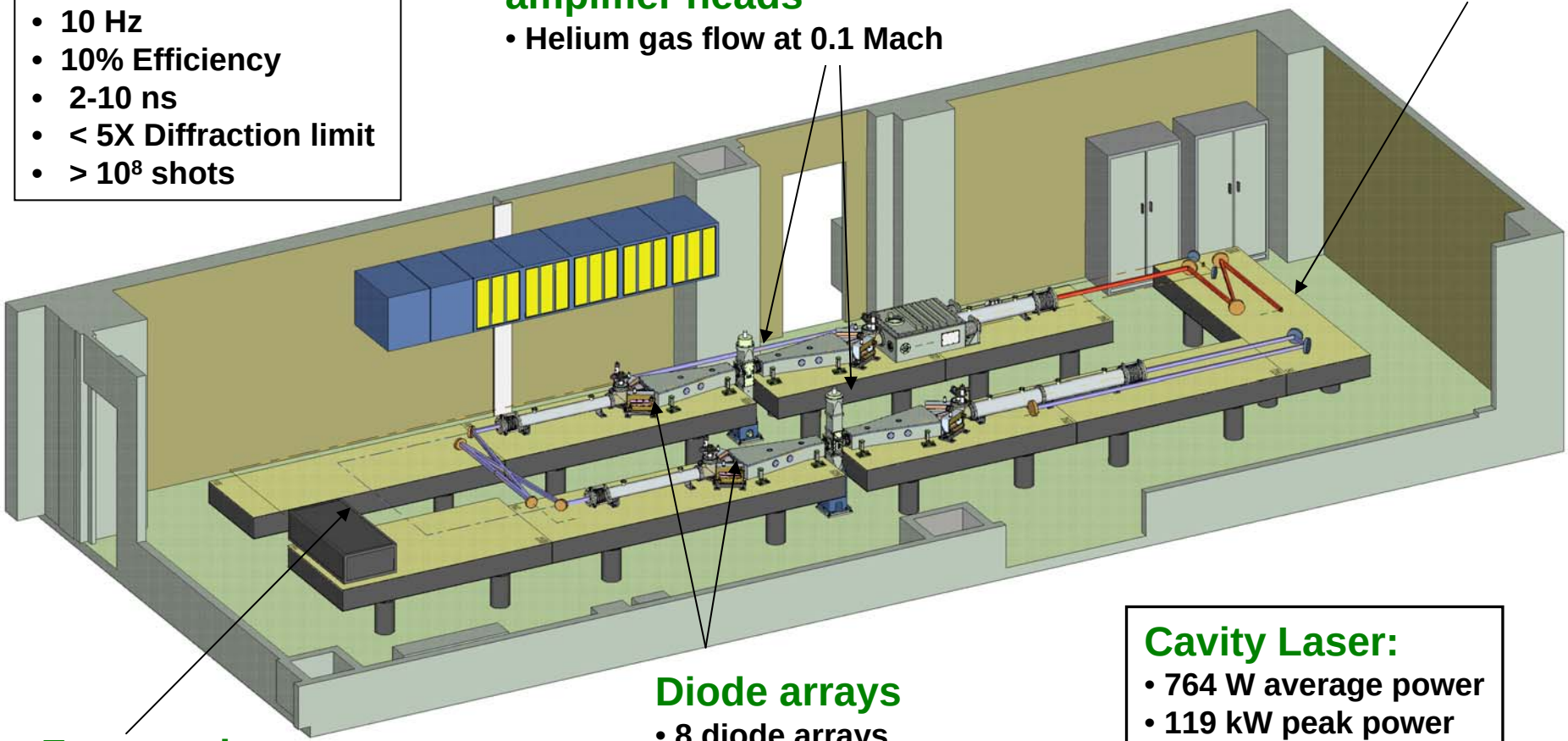


The MERCURY laser is an attempt to create high average power with good efficiency

Goal:
- **100 J**
- **10 Hz**
- **10% Efficiency**
- **2-10 ns**
- **< 5X Diffraction limit**
- **> 10^8 shots**

Gas-cooled amplifier heads
- **Helium gas flow at 0.1 Mach**

Output



Front-end
- **300 mJ**

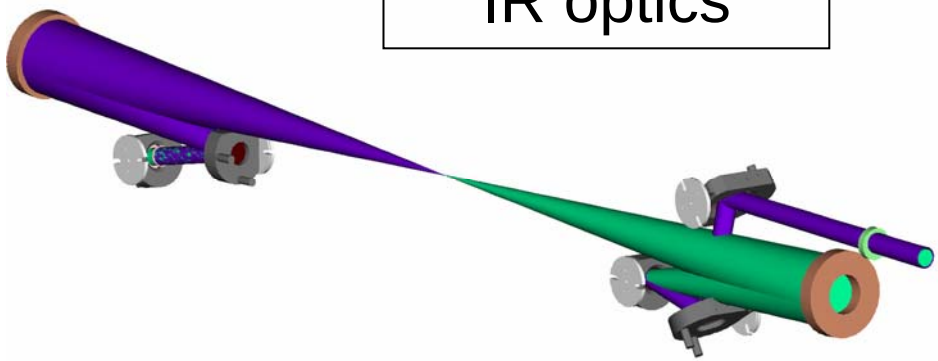
Diode arrays
- **8 diode arrays**
- **6624 diodes total**
- **730 kW peak power**

Cavity Laser:
- **764 W average power**
- **119 kW peak power**

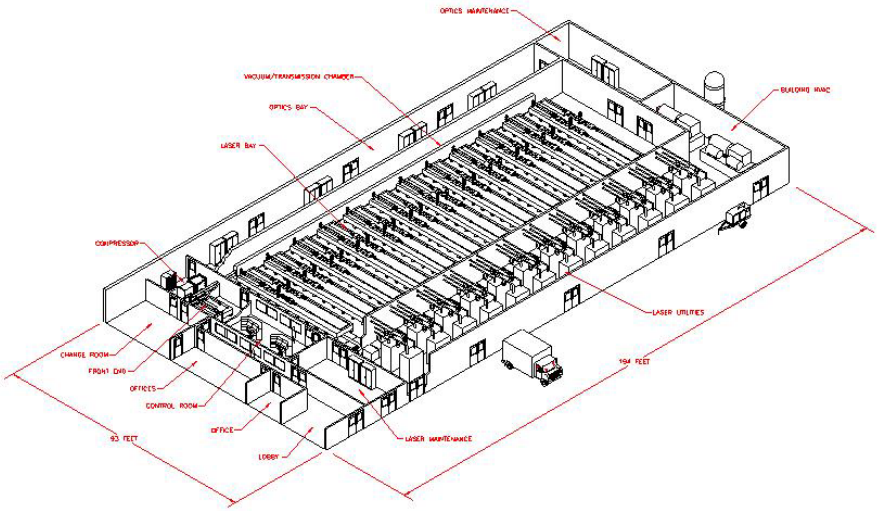
Straw-man laser for NLC presented at Snowmass 2001

- **120 hz of 100 J macro-pulses from 12 MERCURY lasers**
- **100 J laser macro-pulse converted to train of 1 J subpulses**

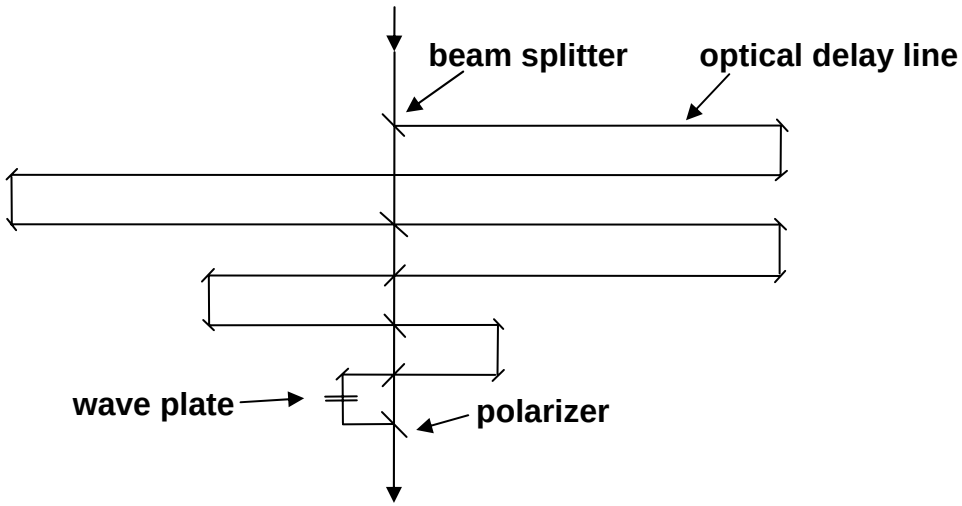
IR optics



MERCURY laser plant

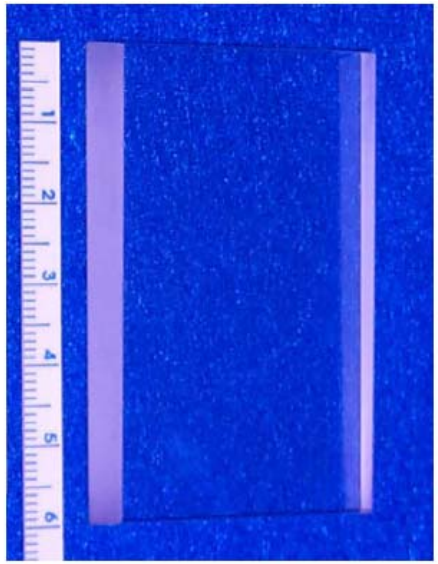


Single pulse to pulse train "hall of mirrors"

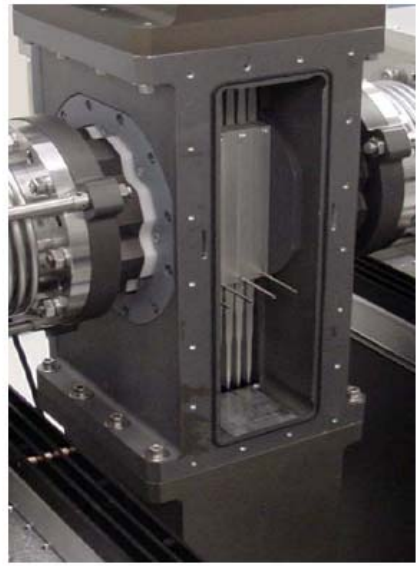


Efficiently producing laser light depends on three key technologies

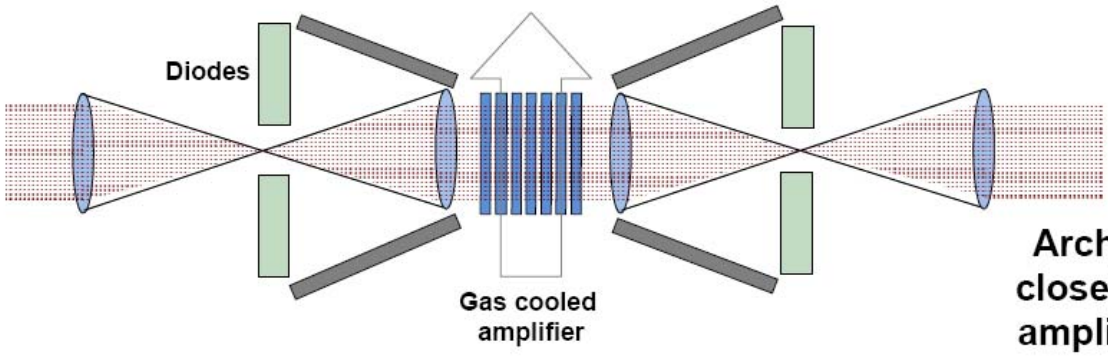
Diode pump arrays



Yb-crystalline amplifiers



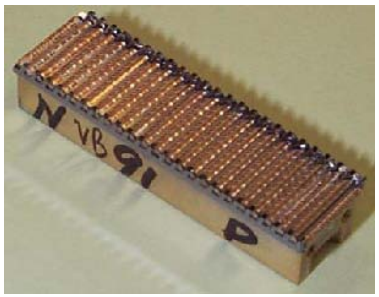
Helium gas cooling

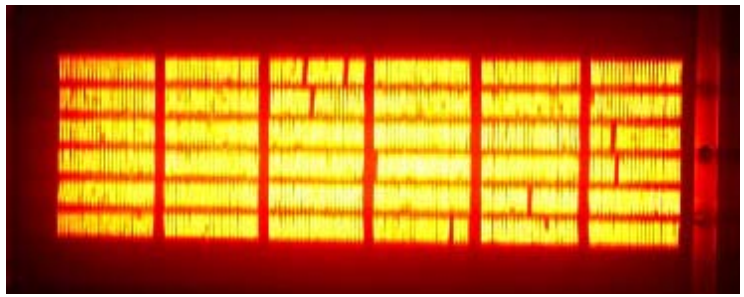


Architecture: closely-spaced amplifier slabs

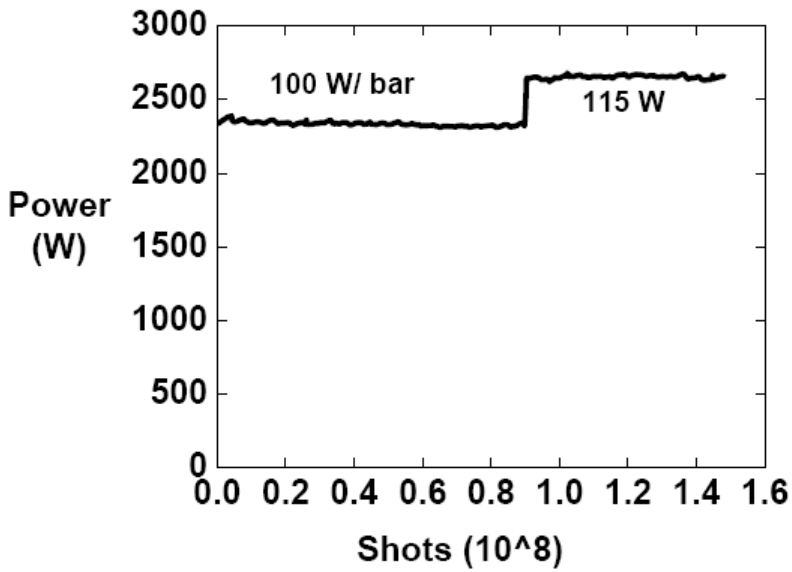
Diode arrays are mature and industrialized

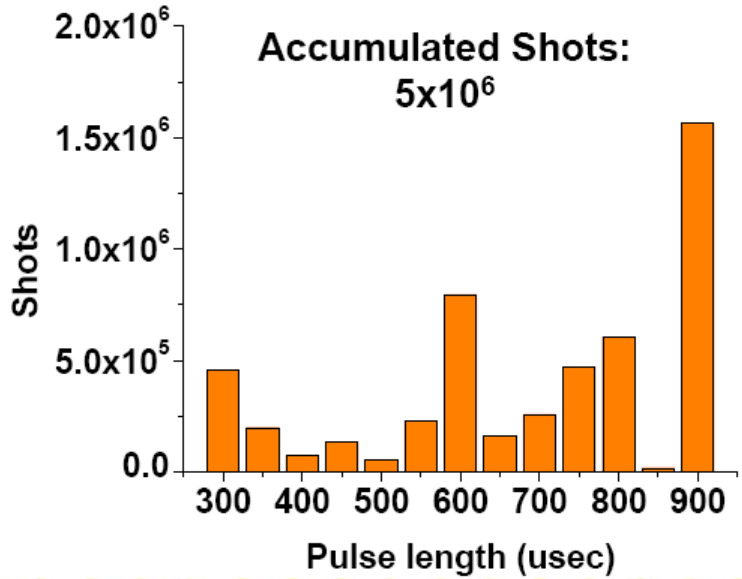
Offline tile tests:
1.5×10^8 shots



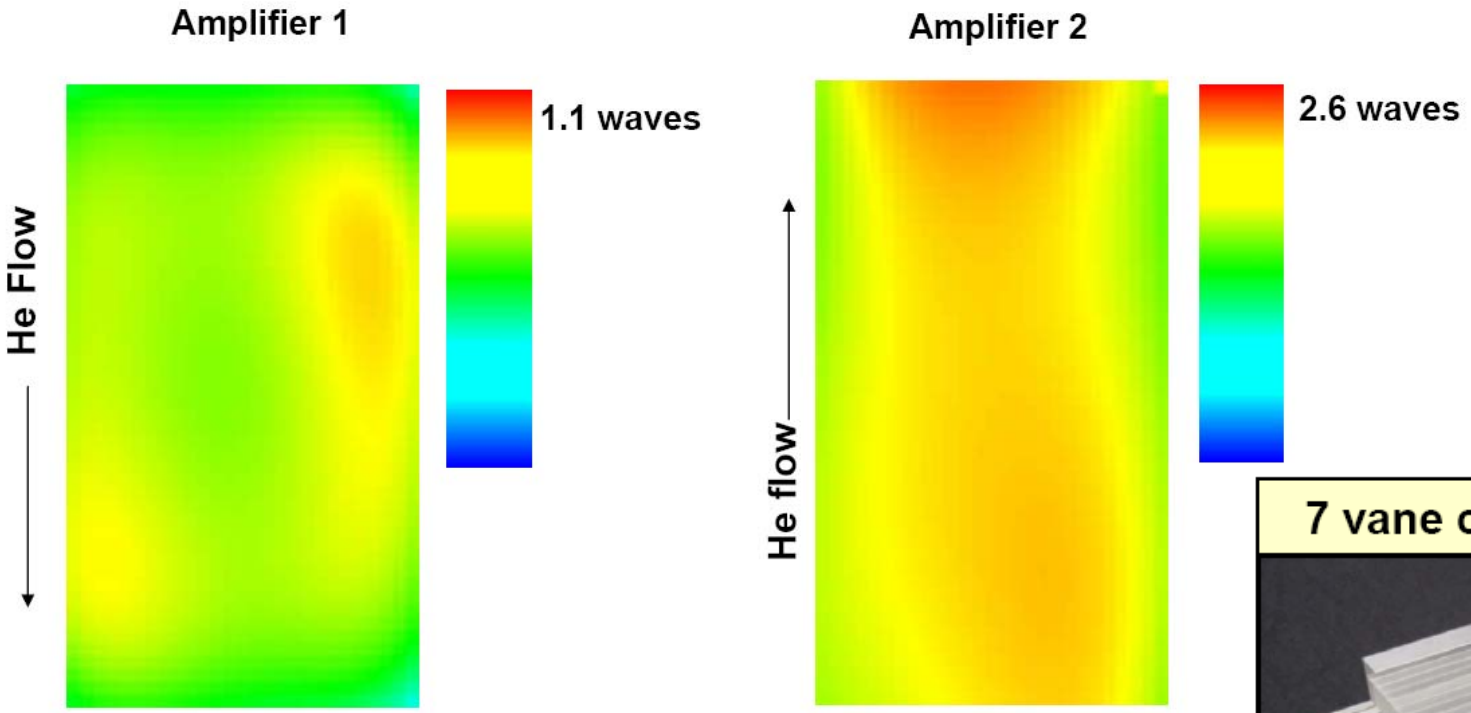


Mercury diode arrays:
5×10^6 shots

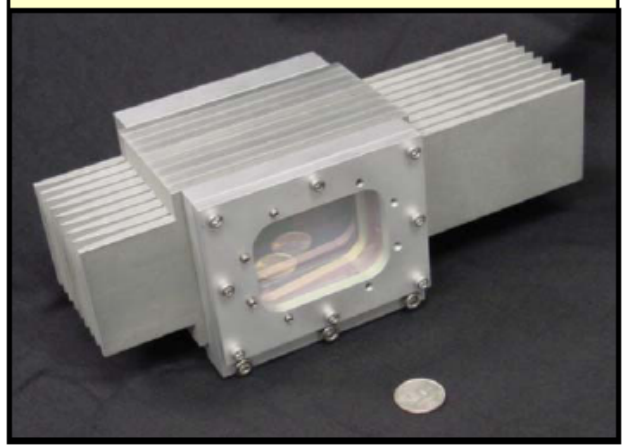




Helium flow cooling manages the heat load in the crystals

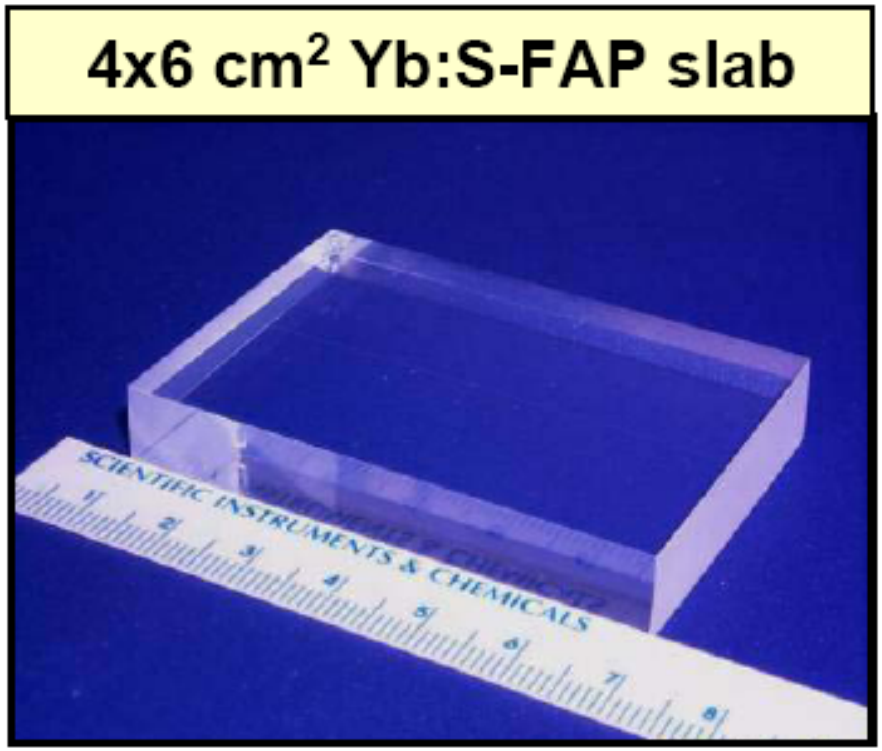


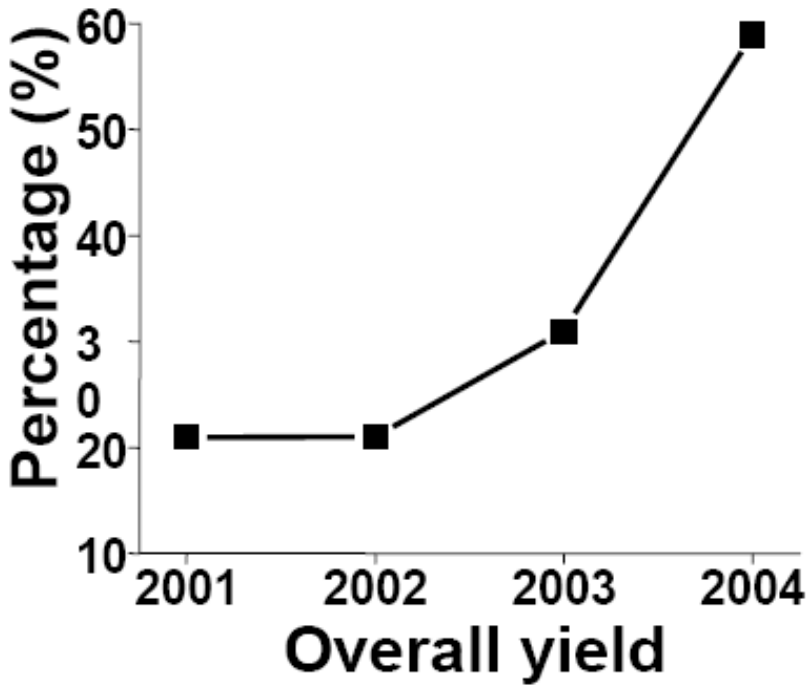
7 vane cooling elements



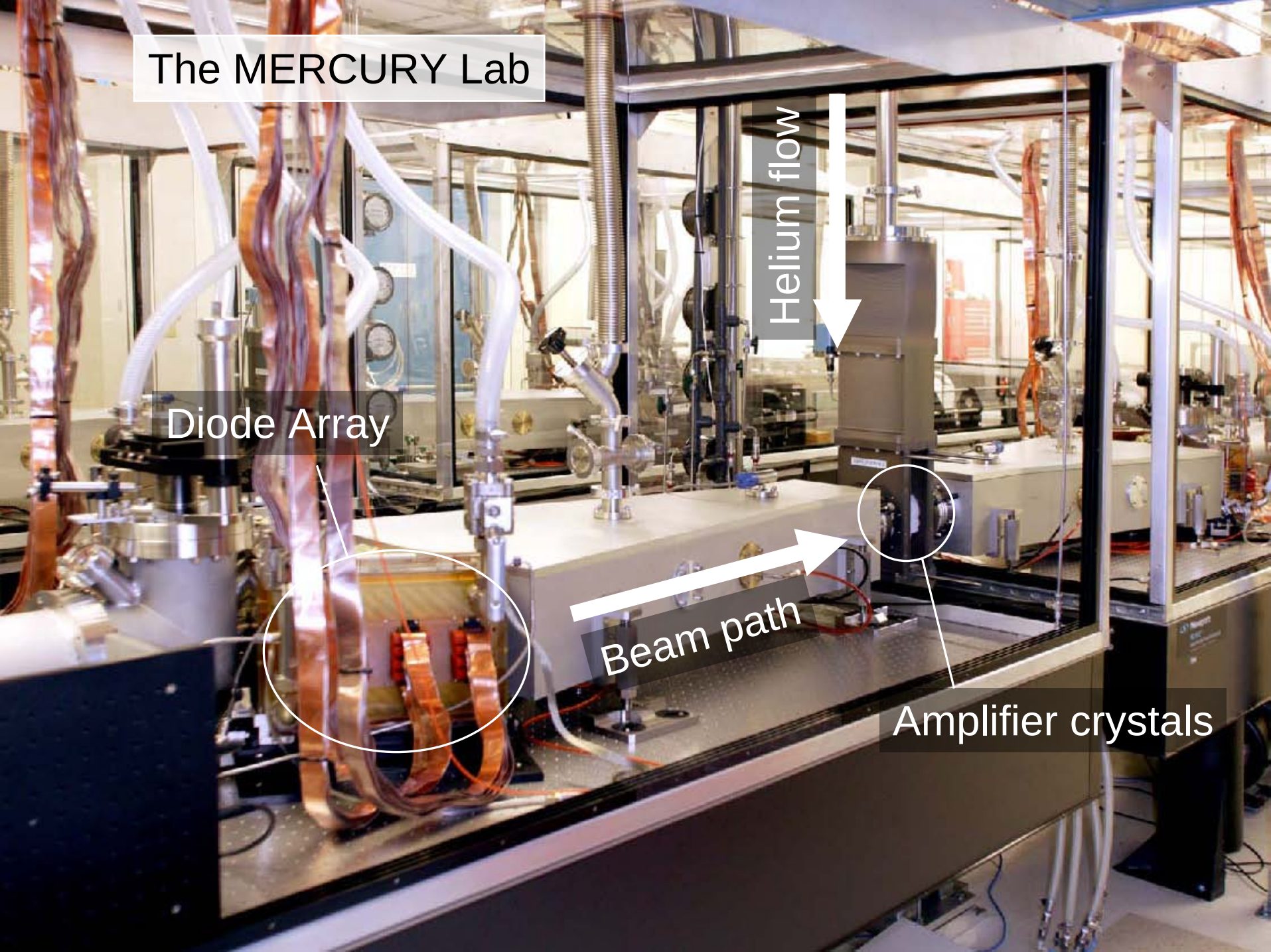
Corrector plates will remove the residual wavefront distortion once the final configuration is in place

Methodologies for growing the amplifier crystals are in place



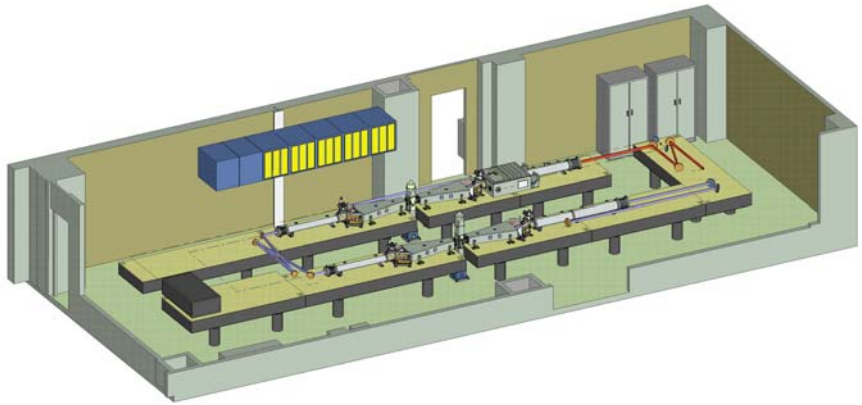


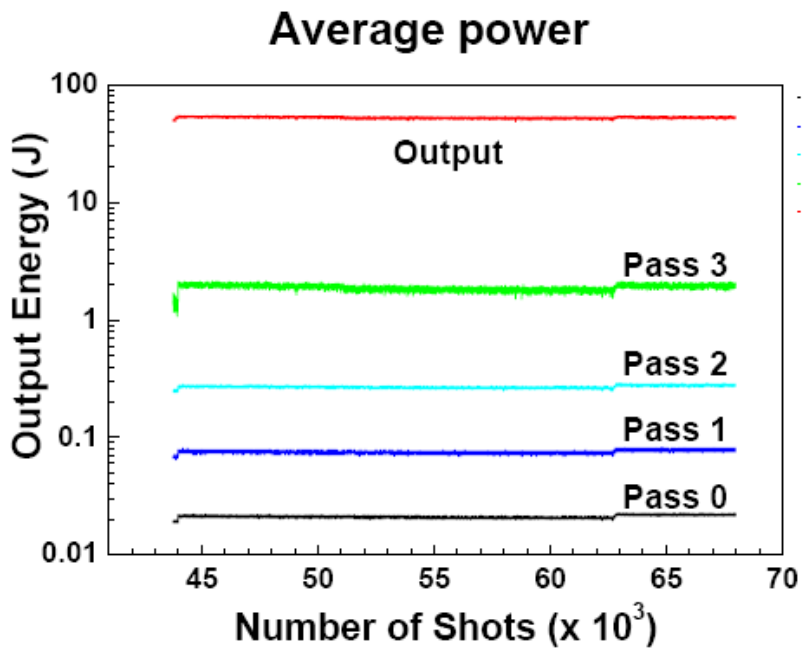
The crystals can be economically grown and processed


The MERCURY Lab
Helium flow
Diode Array
Beam path
Amplifier crystals

MERCURY technology has been under development since 2001

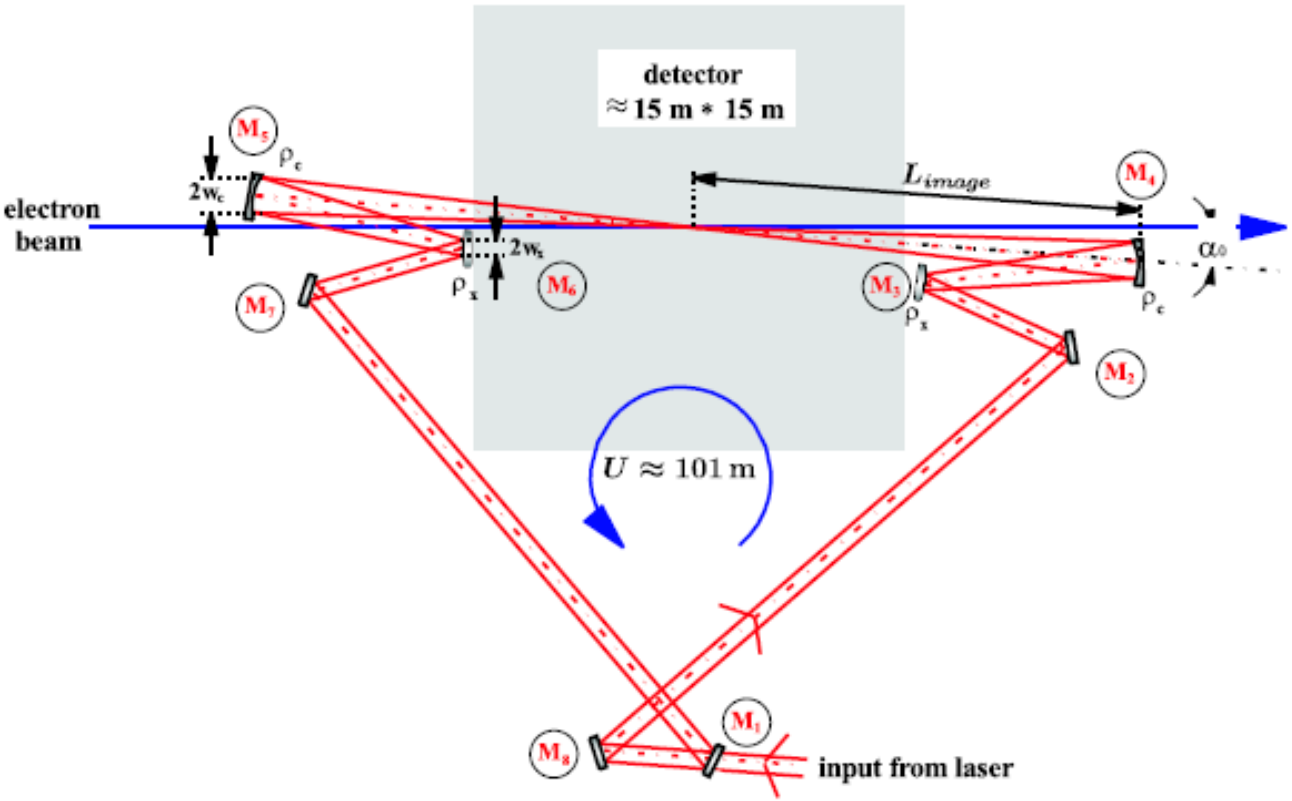
- Operation at 10 Hz with 55 Joule pulses for 8 hours
- 10 ns width pulses
  - **Has the bandwidth to support ps pulse but not demonstrated**
- 5x diffraction limit wavefront quality
  - **Final wavefront corrections not done**
- Large improvements in diode cost and crystal growth and processing





Most laser power is unused - A recirculating cavity can reduce required laser power

2004 Cold SRF technology chosen for ILC
Inter-bunch spacing allows possibility of recirculation
Stacking cavity design from MBI / DESY- Zeuthen

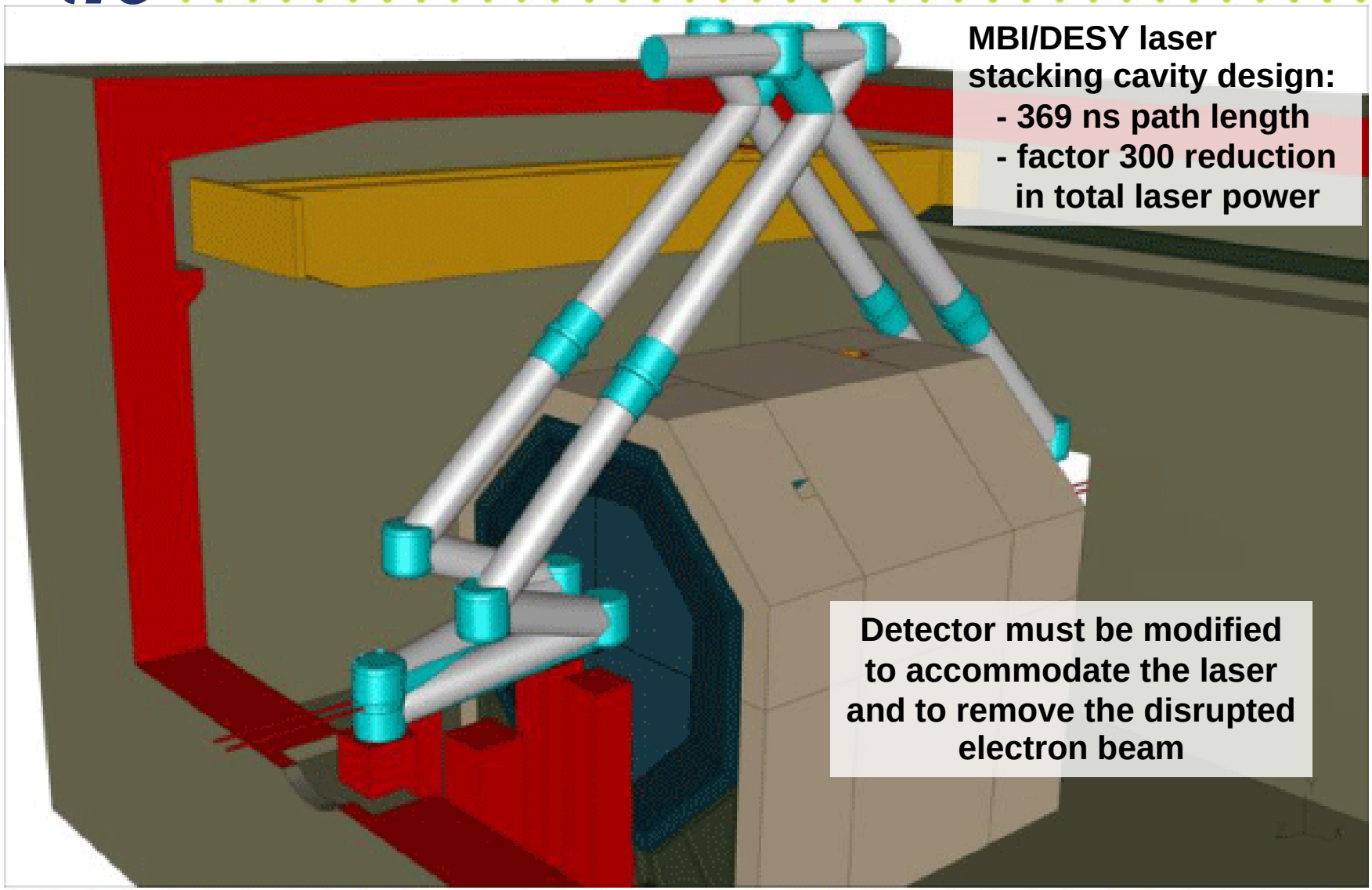


Laser requirements:

- 5 Hz operation
- 1000+2820 bunches / train
- 40mJ / pulse

- 764 W average power
- 119 kW peak diode power

A layout for integrating the laser cavity and detector and detector was proposed

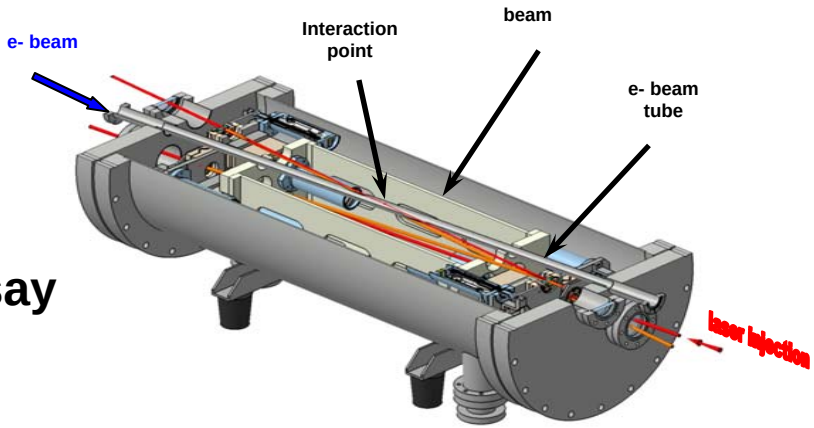


MBI/DESY laser stacking cavity design:
- **369 ns path length**
- **factor 300 reduction in total laser power**

Detector must be modified to accommodate the laser and to remove the disrupted electron beam

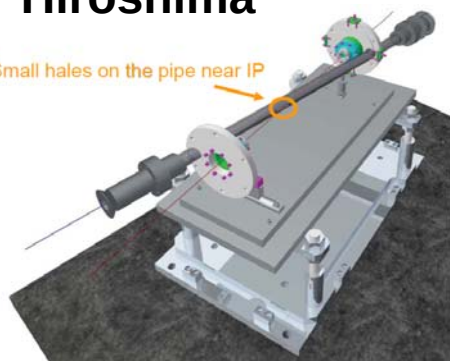
Since then smaller recirculating cavities have been developed for Compton light sources

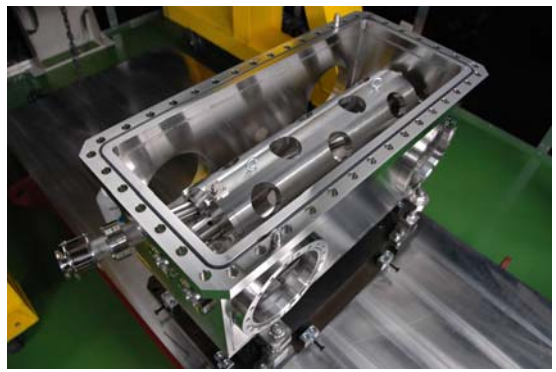
LAL - Orsay



- Resonant cavities are being developed for:
  - **Polarized positron source**
  - **Laser wire**
  - **Beam diagnostics**
  - **Medical and industrial applications**
  - **Photon collider**

KEK - Hiroshima





It is time to develop a conceptual design for a photon collider laser

- Average power of ~500W
  - **Been done before**
  - **But not with**
    - ps pulse
    - Good wavefront quality
    - Time formatting
- In 2009 we will create a conceptual design for the laser system
  - **Identify any technology limitations**
  - **Understand the R&D path to demonstrating a workable system**