Studies of New Options using Compton Backscattered Photons

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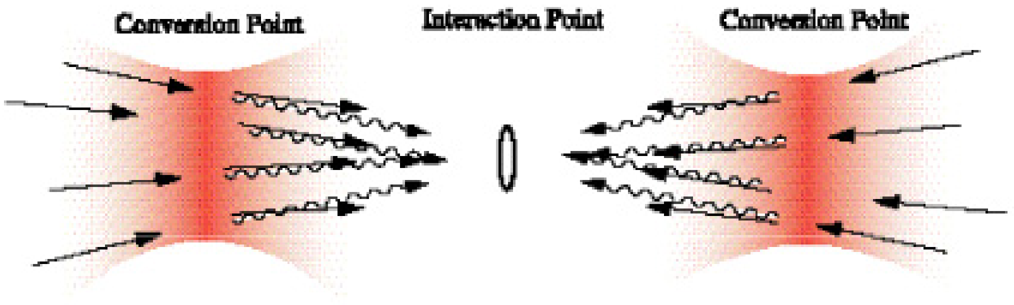
High Energy Photon Applications

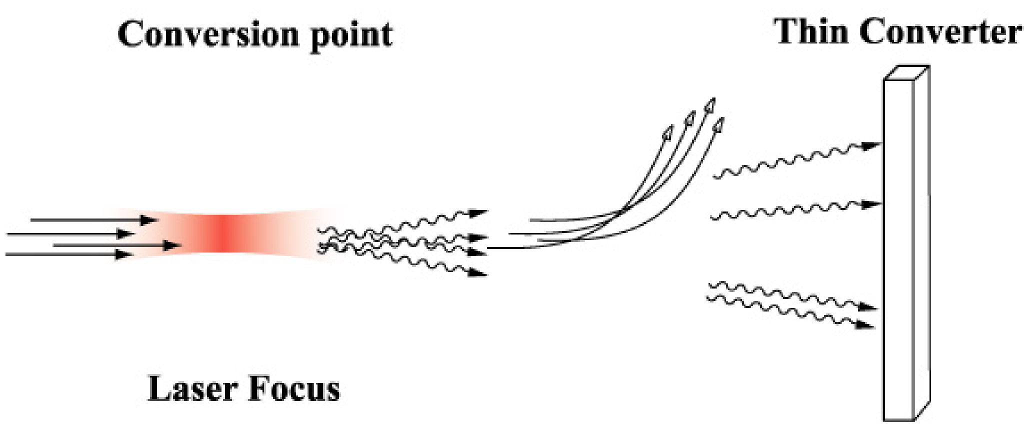
Photon Collider

$E_{beam} = 250$ GeV
$E_{\gamma} = 200$ GeV



Polarized Positron Source

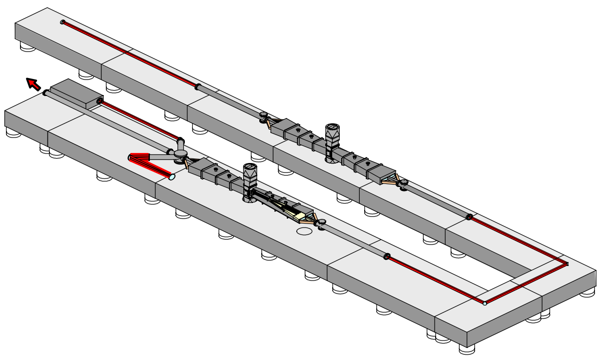
$E_{beam} = \sim 3$ GeV
$E_{\gamma} = 60$ MeV



Both based on Compton backscattering of a high average power laser from an electron beam

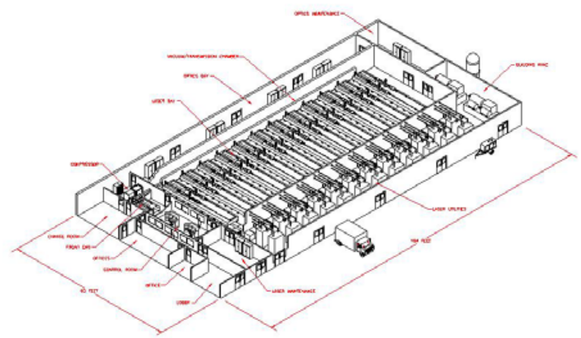
Photon Collider Hardware

MERCURY Laser



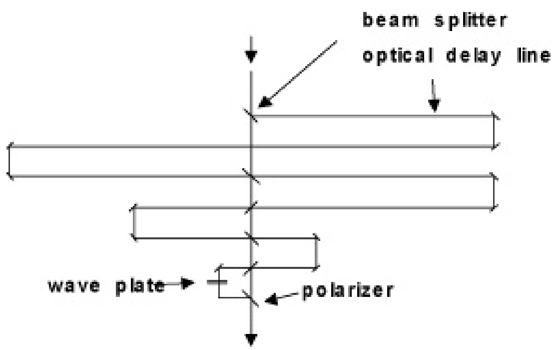
1 pulse = 100 Joules = 1 train

Laser Plant



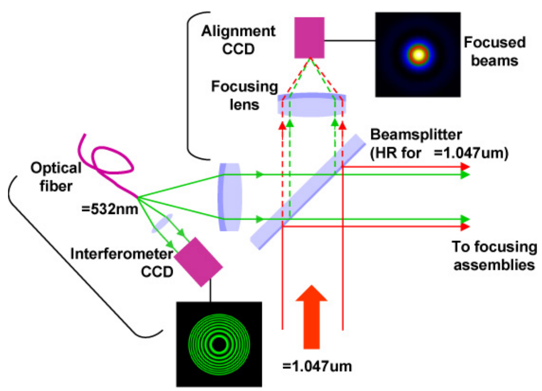
12 Lasers x 10Hz = 120Hz

Beam Splitter

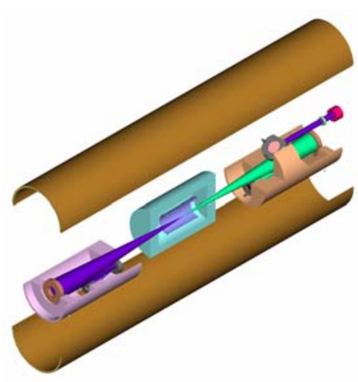


1, 100 Joule pulse -> 100, 1 Joule pulses

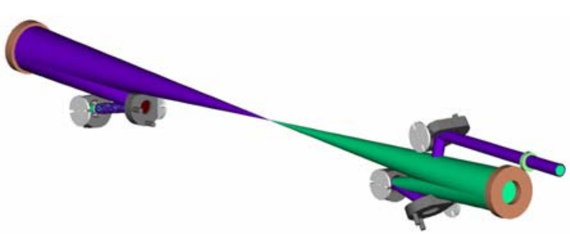
Interferometric Alignment System



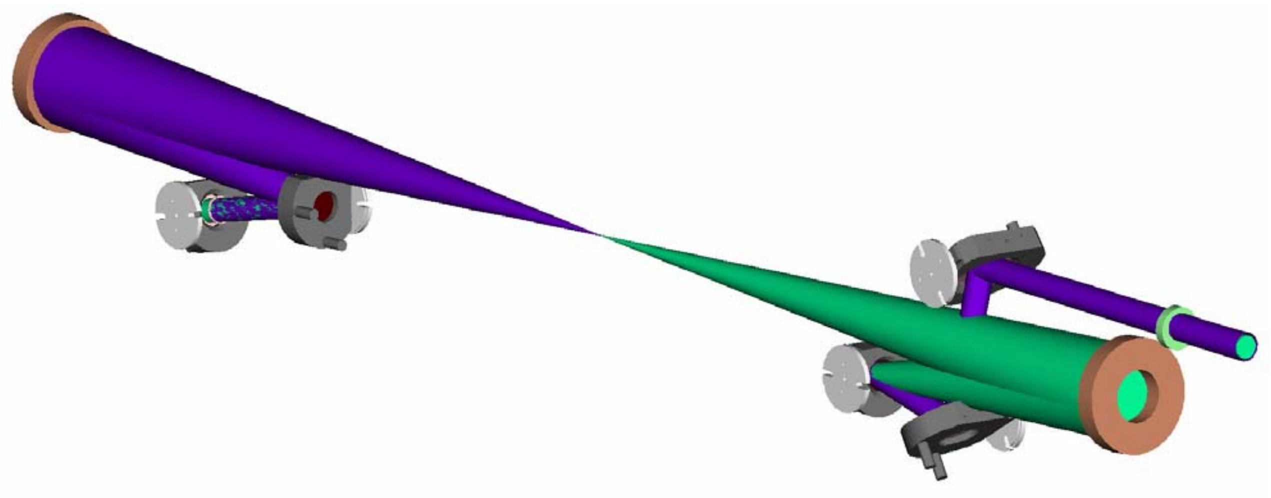
Beam Pipe



Optics Assembly

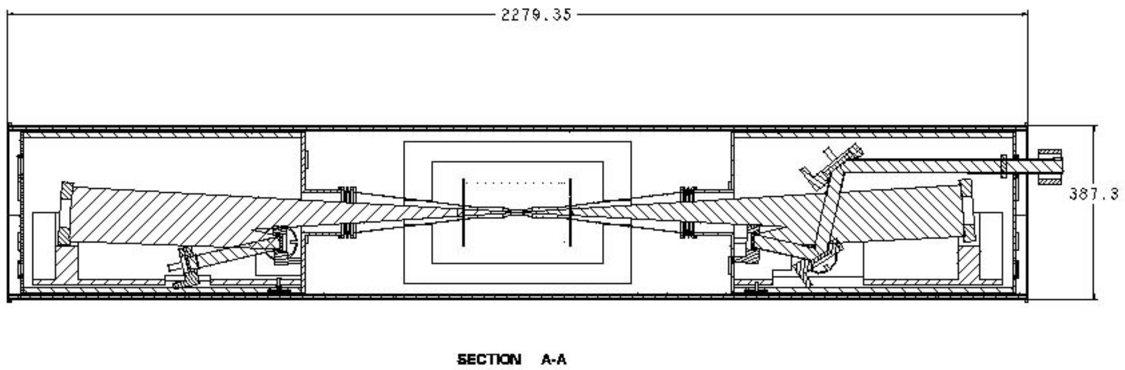


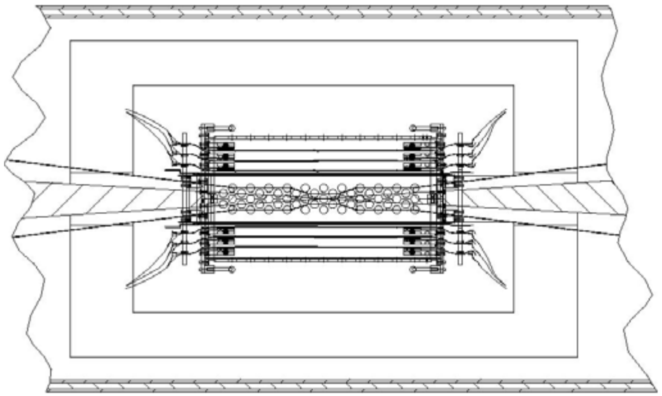
Optics Design



- Outstanding technical issues:
  - Survivability of mirrors in vacuum and radiation environment
  - Operation of optical mount movers in vacuum and high magnetic field
  - Feedback system to keep laser spot and beams overlapped
- Risk mitigation plan:
  - Characterize mirror coupons before and after radiation exposure
  - Procure and test mount movers in UHV

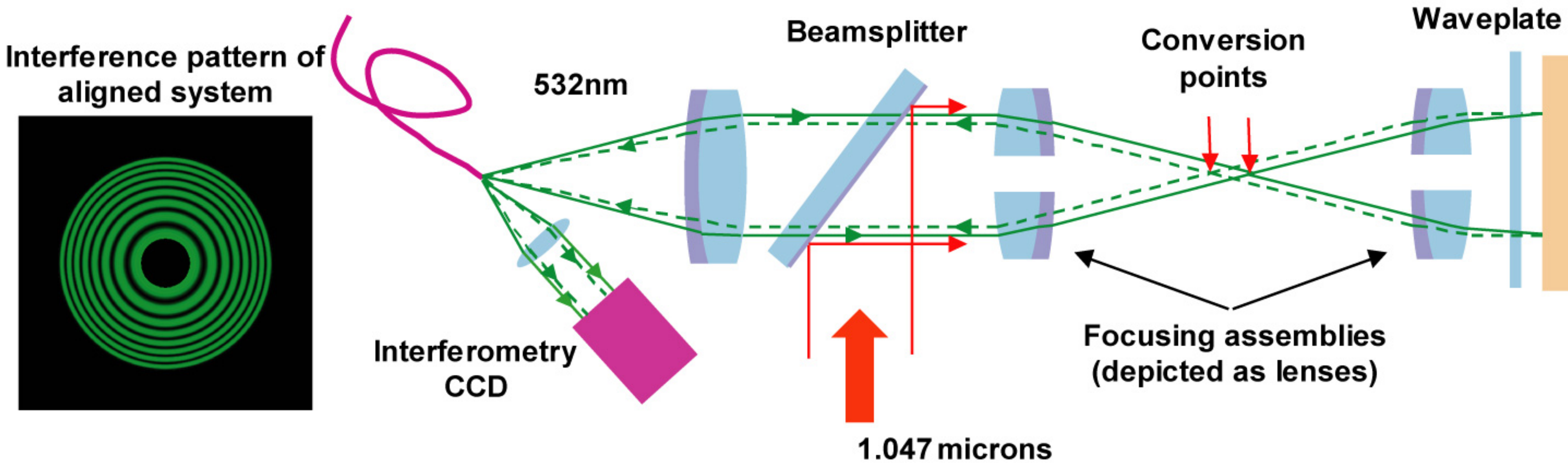
Beampipe





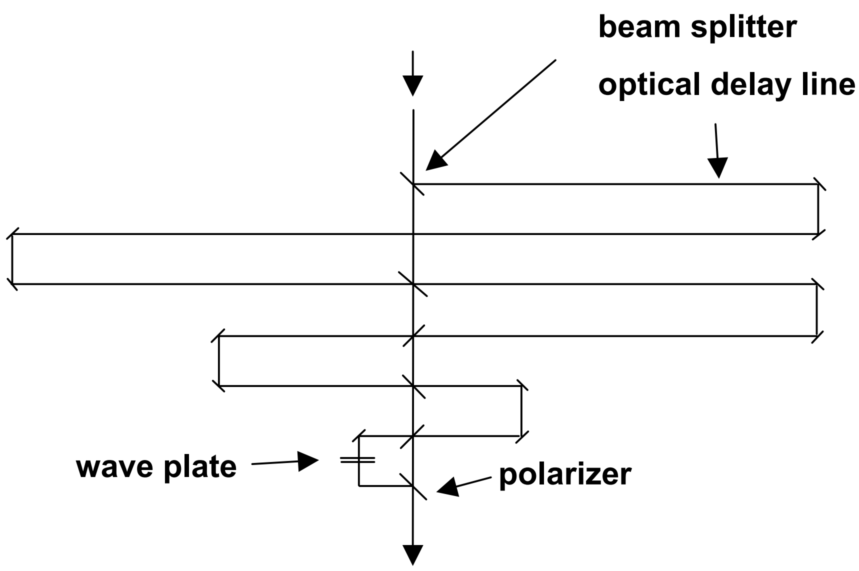
- Outstanding technical issues:
  - Interference with the final focus stabilization
- Risk mitigation plan:
  - Participate in Final Focus Girder project

Alignment System



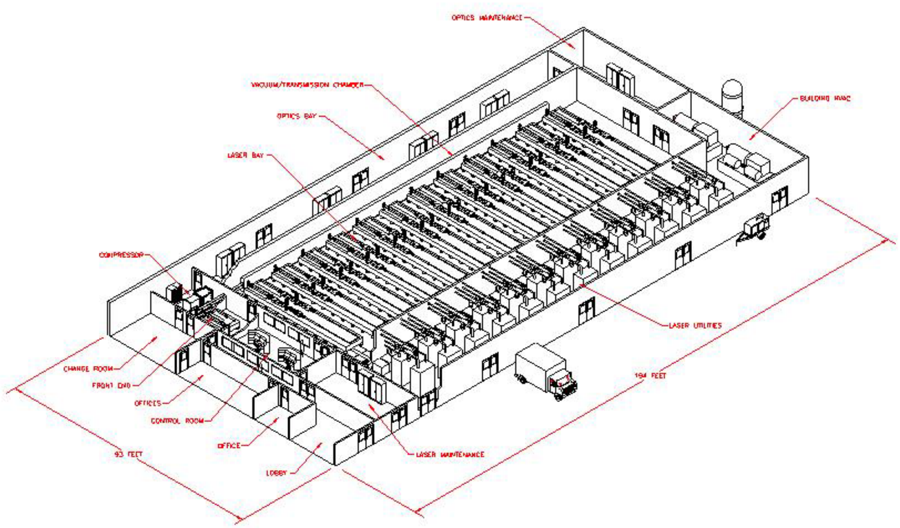
- Outstanding technical issues:
  – Conceptual design is complete
- Risk Mitigation Plan:
  – ½ Scale prototype of optics / alignment system is currently under construction
  – Operation in end of FY02
  – Demonstration of alignment tolerances

"Hall of Mirrors" - Beamsplitter



- Outstanding technical issues:
  - Does multiple mirror passes destroy the wavefront quality
  - Do pulses emerge on a common axis
- Risk mitigation plan:
  - Short term: Computer simulation of wavefront quality
  - Long term: Prototyping

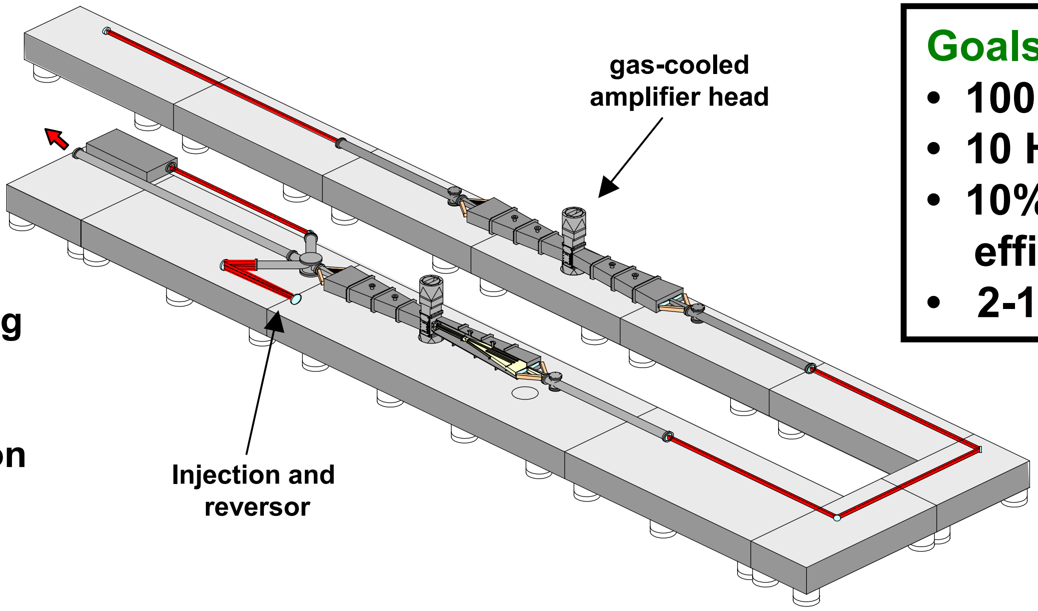
Laser Plant



- Outstanding technical issues:
  - Combining the output of multiple lasers
  - Two possible solutions:
    - Rotating mirror: Simple but tight angular tolerances
    - High Power Pockels cell: 20kW is beyond state of the art
- Risk mitigation plan:
  - Short term: No action
  - Long term: Rotating mirror prototype, possibly Pockels cell development

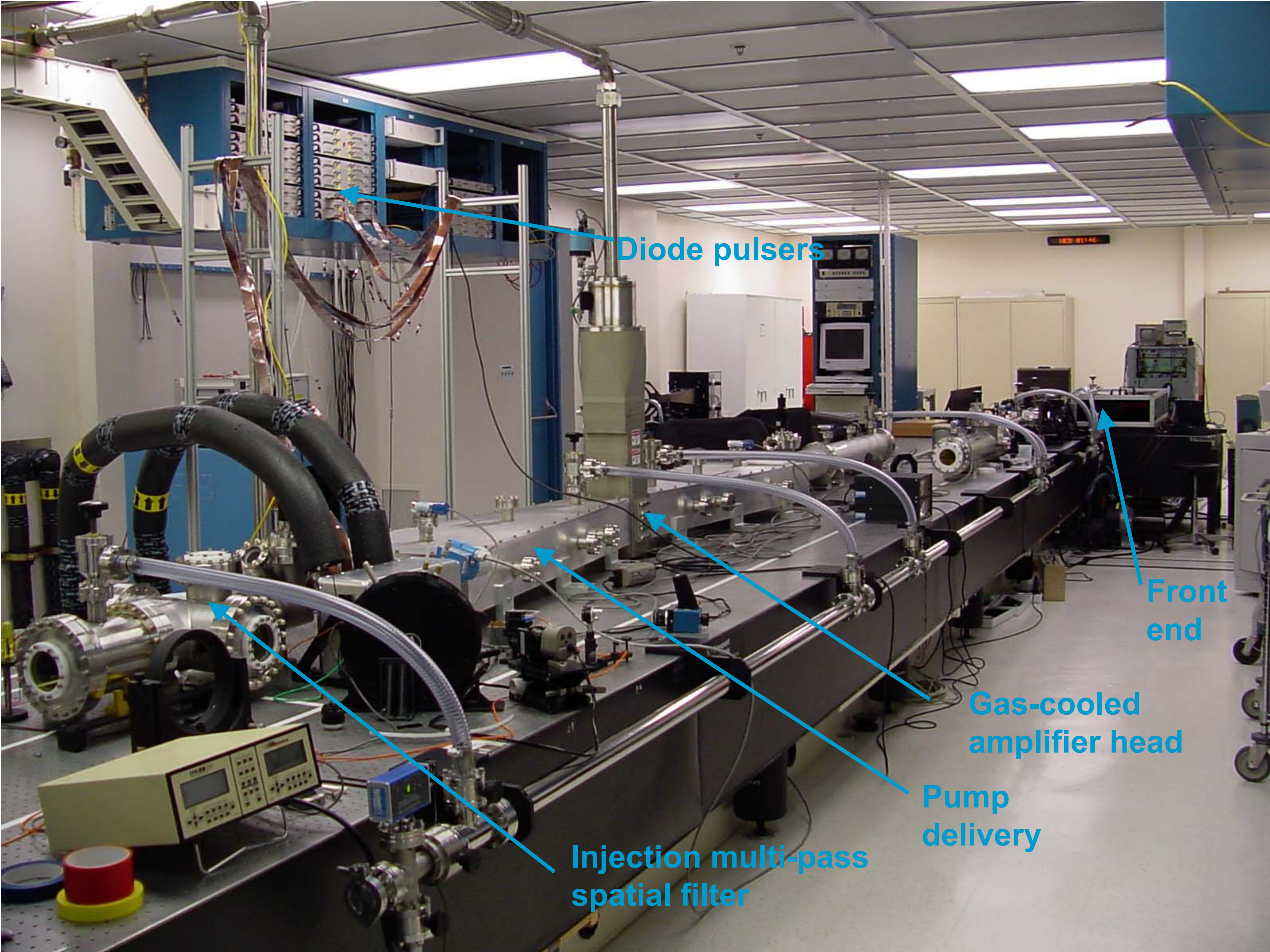
MERCURY Laser

Architecture:
- 2 amplifier heads
- angular multiplexing
- 4 pass
- relay imaging
- wavefront correction

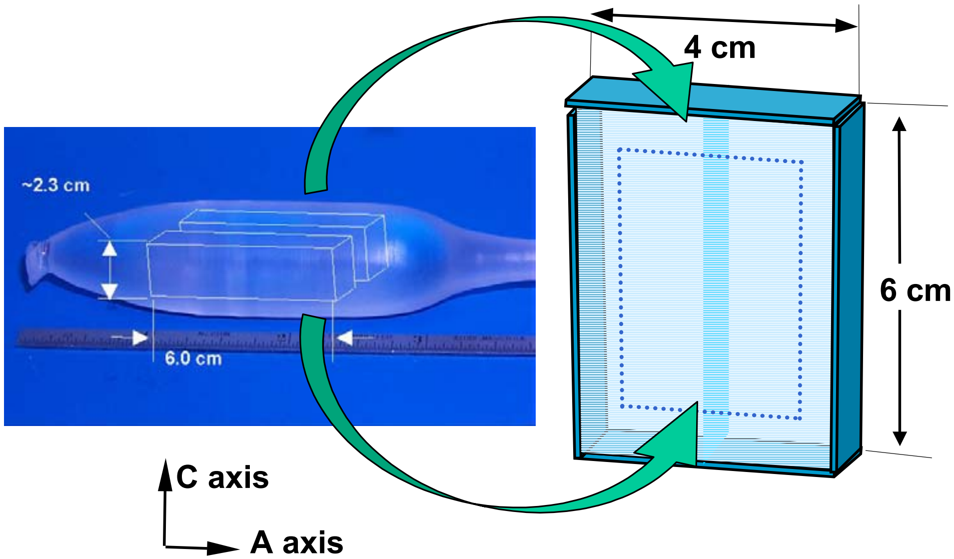


Goals:
- **100 J**
- **10 Hz**
- **10% electrical efficiency**
- **2-10 ns**

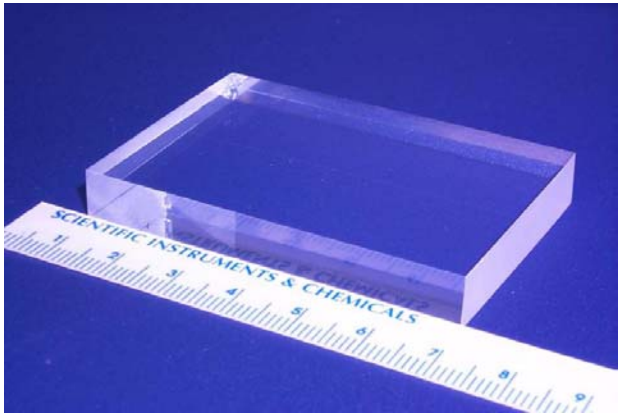
- Outstanding technical issues:
  - Demonstrate:
    - 100 Joule pulses at 10 Hz
    - Wavefront optical quality -> Achievable spot size
    - Compression to 1.8 picoseconds


Diode pulsers
Front end
Gas-cooled amplifier head
Pump delivery
Injection multi-pass spatial filter

MERCURY Status – waiting on crystals



A full size 4x6 cm amplifier slab



- All Hardware available
  - Yb:S-FAP crystals are being grown, 4 of 14 are ready
- Operations commencing
  - Low power with 4 slabs now
  - Complete single head, end of FY02
  - Full system, 2003

MERCURY upgrades for $\gamma\gamma$ collider

- MERCURY must be upgraded to allow 1 ps pulses, current design produces 1 ns pulses.
  - Laser front end must be modified to support a chirped pulse.
- MERCURY needs an adaptive optics system to achieve the best beam quality.
  - Poor beam quality → larger laser spot at the focal point → more laser power required
- MERCURY pulse timing jitter needs to be < 1ps.
  - Laser pulses must match the timing of the beam

ICF deliverable:	Photon collider deliverable:
100 Joules at 10 Hz	Pulse compression, adaptive optics, timing system

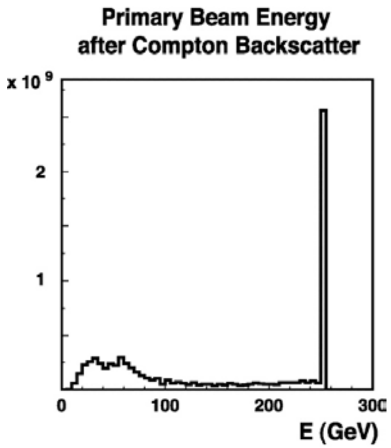
Work toward the CDR

- MERCURY demonstration
  - 100 Joules at 10 Hz
    - Funded by ICF program, ~$10M / year
  - Front end modifications, adaptive optics, timing system
    - ~ $1.3M
- Optics survivability
  - Coupon tests of optics under radiation, vacuum and laser power
  - Hard data on MTBF for the optics system in the IR
- Wavefront preservation
  - Complete simulation of wavefront from laser to IP
  - Determine beam quality delivered to the IP.

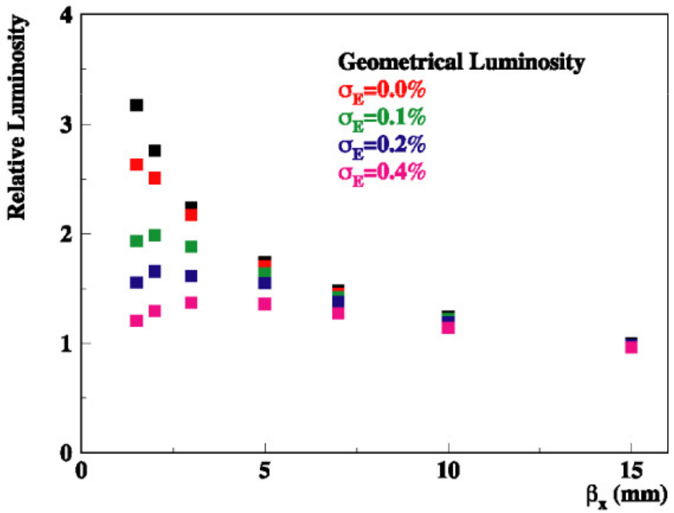
Needed for a baseline design and costing to be ready for the CDR

Accelerator Impact

- Outgoing beam
  - Compton backscattering leaves a large energy spread
    - On-energy peak (30% of particles)
    - Low-energy tail (Multiple backscatters)
    - Hard cutoff at 5 GeV
- Solution: Zero field extraction line to the dump

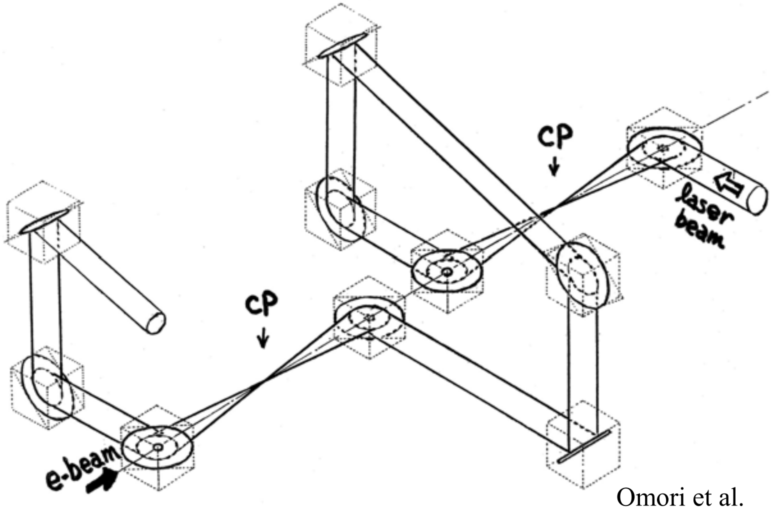


- Final Focus
  - No beam-beam interaction constraint
  - Final Focus can be tuned to reduce β_x to achieve higher luminosity
  - Limited by accelerator energy spread



Polarized Positron Production

- Capture efficiency of the system means that multiple photons must be produced for every captured positron
- Enormous amount of work has gone on in conceptual studies
  - Omori et al. have produced a conceptual design presented at conferences
  - http://www-conf.slac.stanford.edu/lc02/wg1/WG1_Omori,T_PositronSources.pdf
  - Based on CO_2 gas laser technology (Pogorelsky et al. BNL)
- Key element is an optical system that allows each produced laser pulse to be used 20 times.

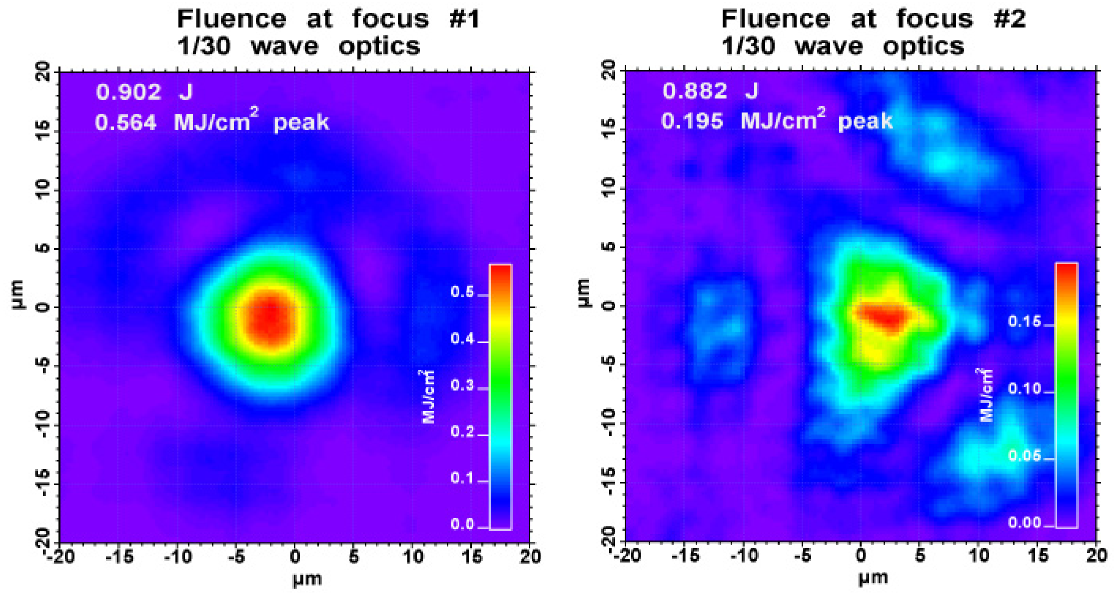


Omori et al.

Wavefront degradation

- When light bounces off a mirror it picks up wavefront errors
  - The light energy can no longer be focused to a small spot
  - This may be a limiting factor for reusing laser pulses

Simulation of the γγ optics showing the reduction in pulse quality for a two pass system with medium quality mirrors



Using 10 micron light rather than 1 micron automatically makes the mirrors 10 x better

Laser technology choice

	Advantages	Disadvantages
CO_2 Laser (10 micron)	Reusing light is easier Compton cross section is higher Less energy loss in the beam	Laser needs to be developed and demonstrated for this application
MERCURY (1 micron)	Laser is on-track for demonstration	May be limited scope for reusing laser pulses

Proposed work

- Detailed simulation of achievable spot size in a multipass system for realistic optics.
  - Analyze both a 1 micron and 10 micron system.
  - Quantify the ability to reuse light.
  - 1+ FTE, ~200K
- Would provide a better baseline to cost either system.

Conclusions

- Photon Collider:
  - MERCURY on track for demonstration
    - ~ \$1.3M needed for $\gamma\gamma$ specific modifications
  - Full simulation of the optical train is needed for wavefront quality
  - Mirror damage behavior needs to be quantified
- Polarized Positron Source
  - The potential to reuse laser light needs to be quantified before a reasonable cost estimate can be made