Gamma-gamma Working Group Summary

Jeff Gronberg, LLNL

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ALCPG09

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Photon Collider Concept

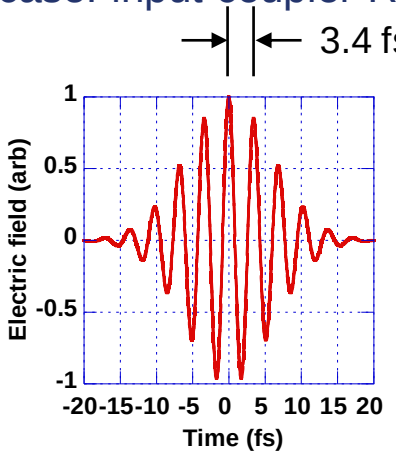
- Create real photon-photon collisions by adding lasers to the IP for Compton scattering

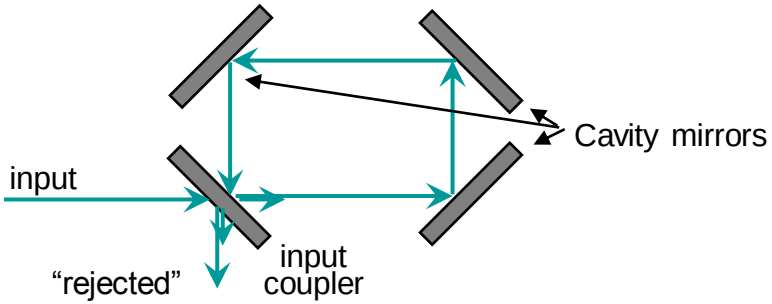
- Requires every electron bunch to have a laser pulse
  - **Very large amount of laser power required ~70kW**
  - **But only 1 in 10^9 photons used in each collision**
  - **Laser light recirculation using resonant stacking cavities explored to reduce required laser power**

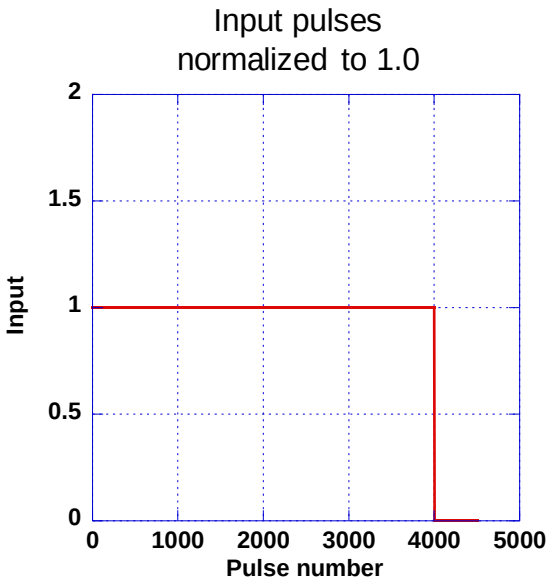
- This conference reports from:
  - **T. Takahashi (Hiroshima) on experience with resonant stacking cavities for X-ray production**
  - **B. Stuart (LLNL) on design studies for photon collider laser system with resonant stacking cavity**

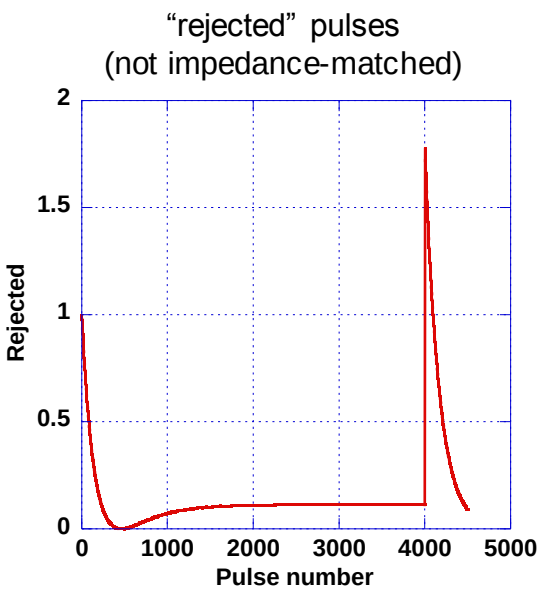
Resonant stacking cavity

- Baseline case: input coupler R=0.996, cavity mirrors R=0.998









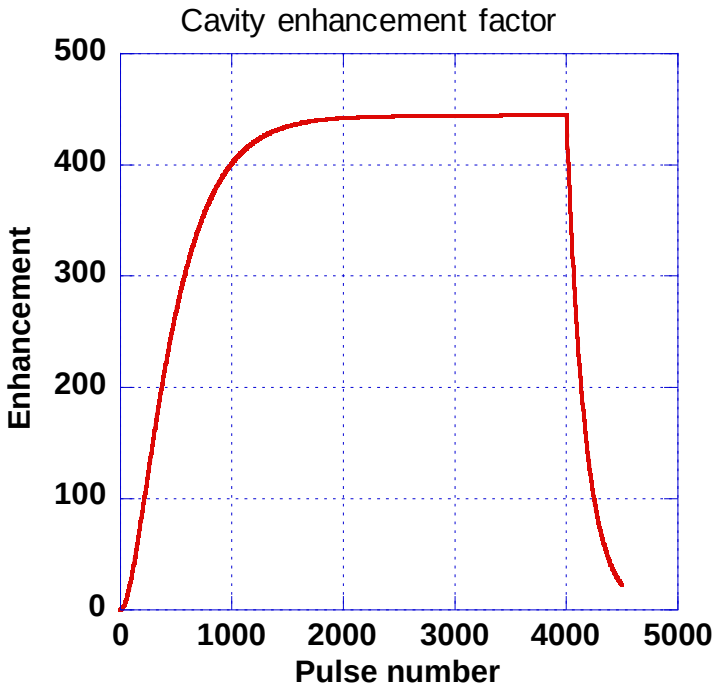
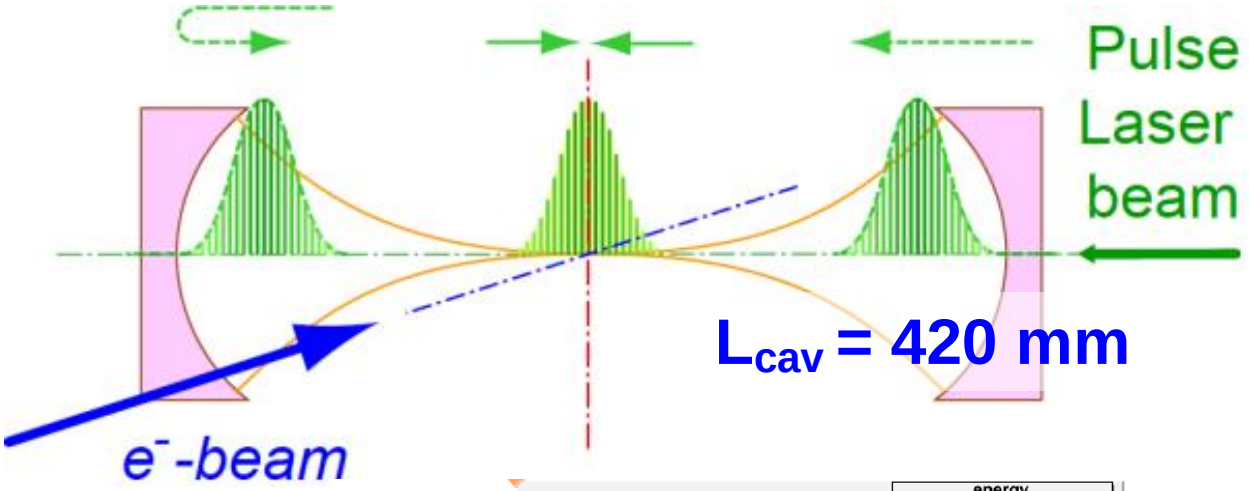


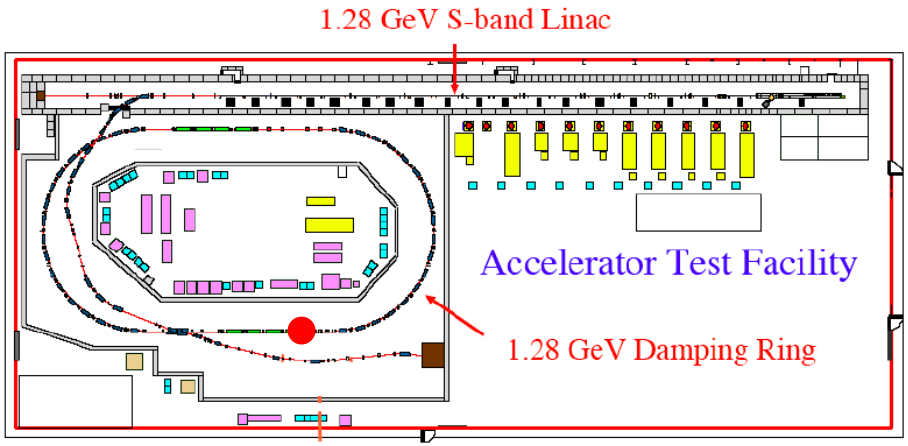
Figure from B. Stuart

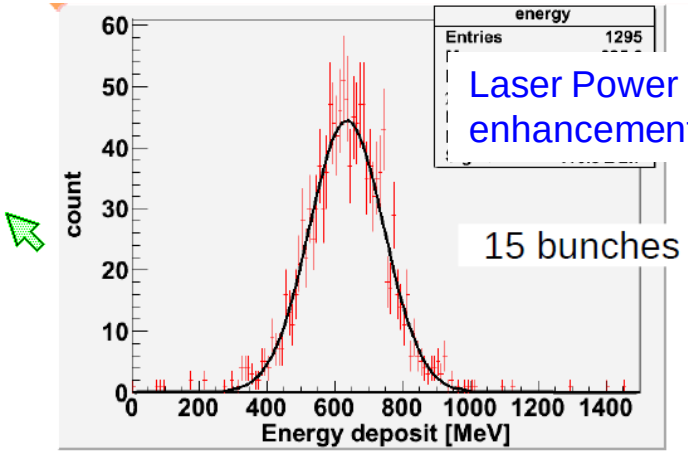
Compton stacking cavities have been demonstrated at ATF

- R&D driven by:
  - **X-ray sources**
  - **Compton positron source**
- Currently:
  - **Small cavities**
  - **Low laser power**

Hiroshima-Waseda-Kyoto-IHEP-KEK







Laser Power enhancement 250

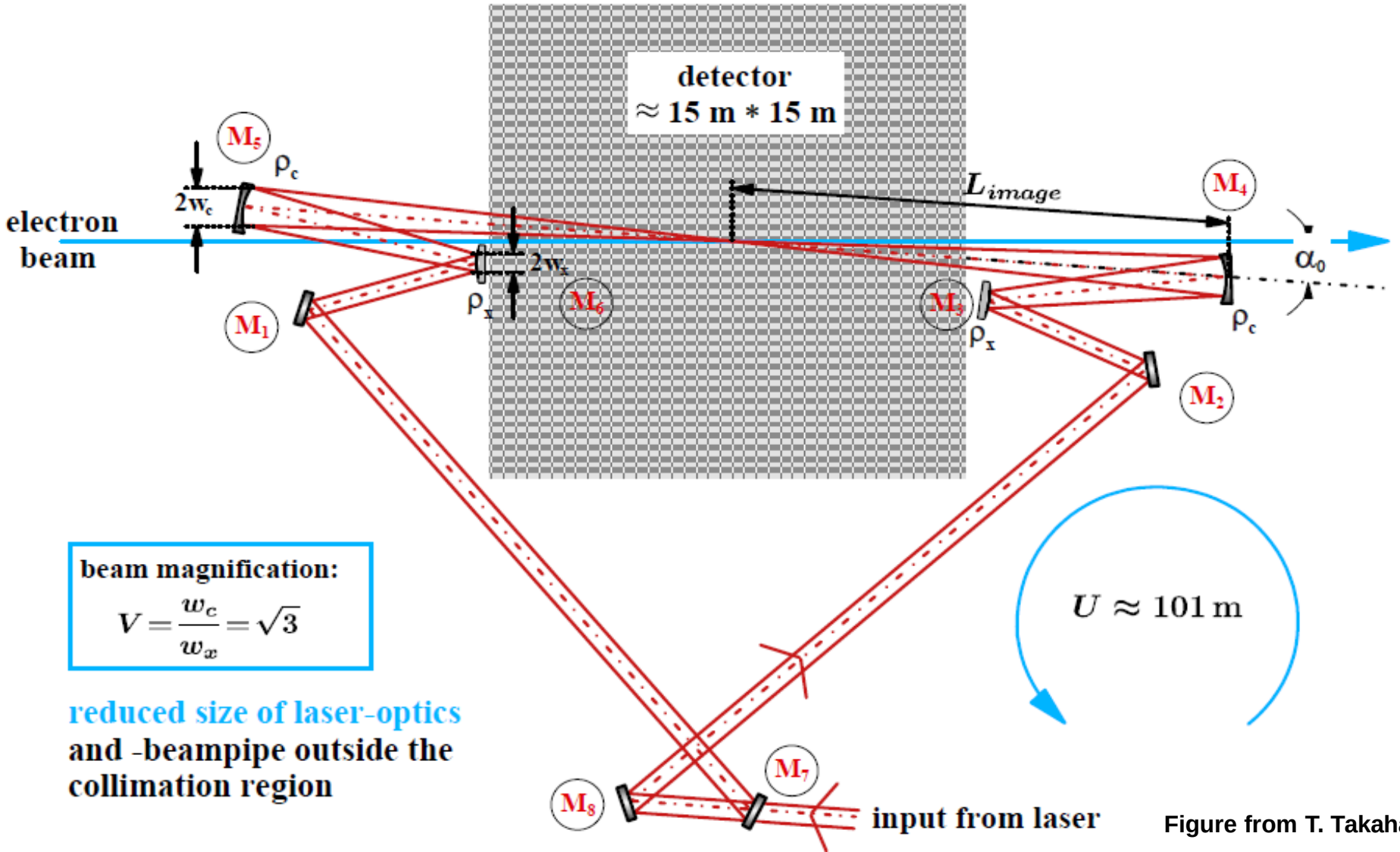
15 bunches / train

We detected 27 gamma-rays / bunch train.
generation 60 gamma-rays / train to all angle.

Figure from T. Takahashi

DESY/MBI design for photon collider stacking cavity

Proposed telescopic, passive, resonant external cavity



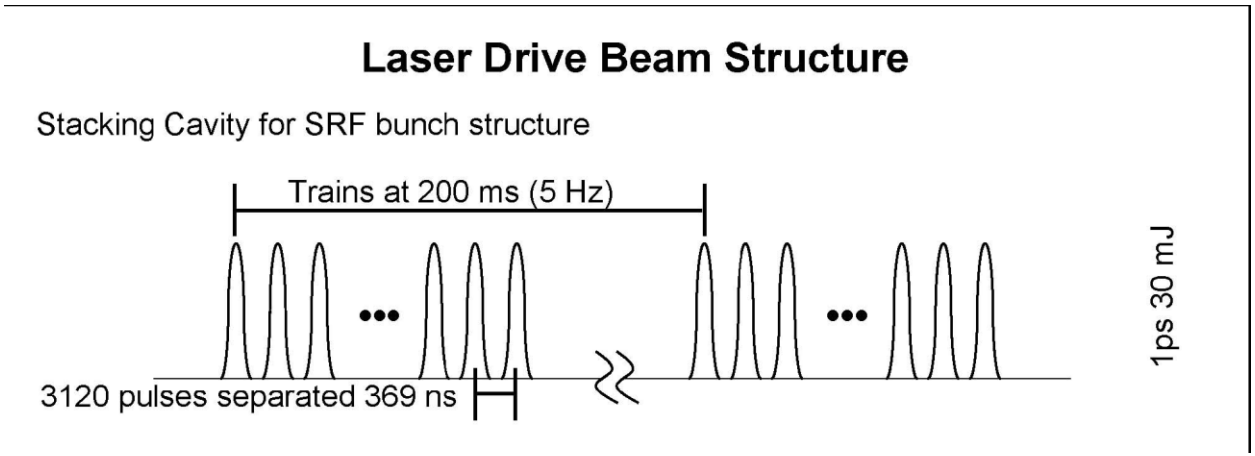
beam magnification:

$$V = \frac{w_c}{w_x} = \sqrt{3}$$

reduced size of laser-optics
and -beampipe outside the
collimation region

Figure from T. Takahashi

Laser energy and pulse structure is achievable



Requirements for cavity:

- Energy ~ 30 mJ
- Wavelength ~ 1 μm
- Pulse length ~ 2.4 ps FWHM (σ = 1 ps)
- Rep rate/pulse train for superconducting L-band accelerator:
  - **369 ns bunch spacing**
  - **2820 bunches/train + cavity filling bunches**
  - **5 Hz train repetition rate**
- Commercial technology to generate pulse train
- Custom design for final amplifier stage

400 W Yb:YAG Innoslab fs-amplifier [1],
(5.3 μJ, 76 MHz, 682 fs, ΔT=18°K, CW pump)

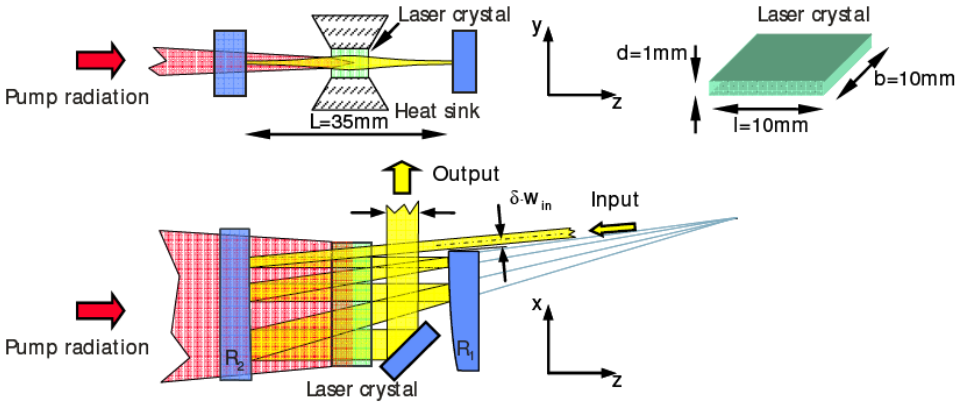
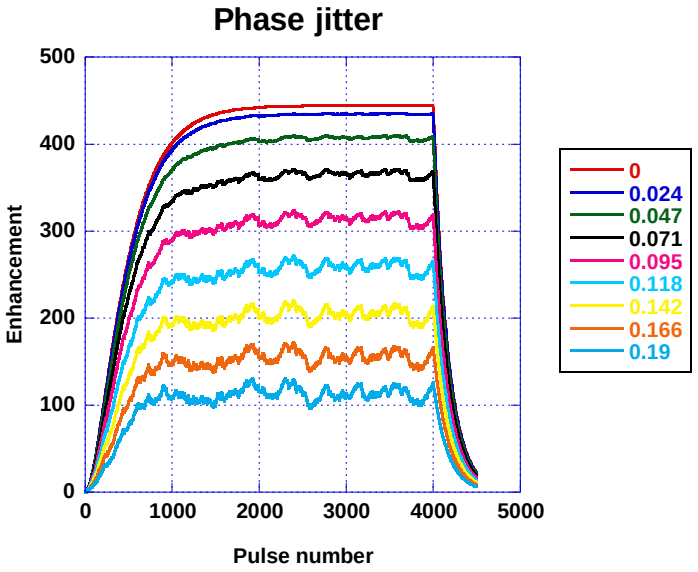


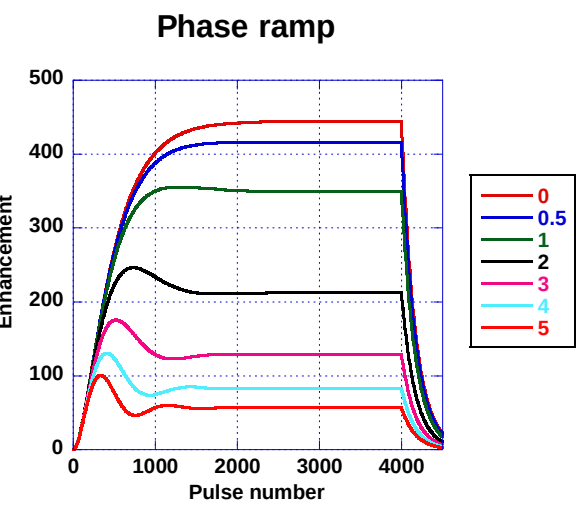
Fig. 2. Schematic setup of an Innoslab amplifier

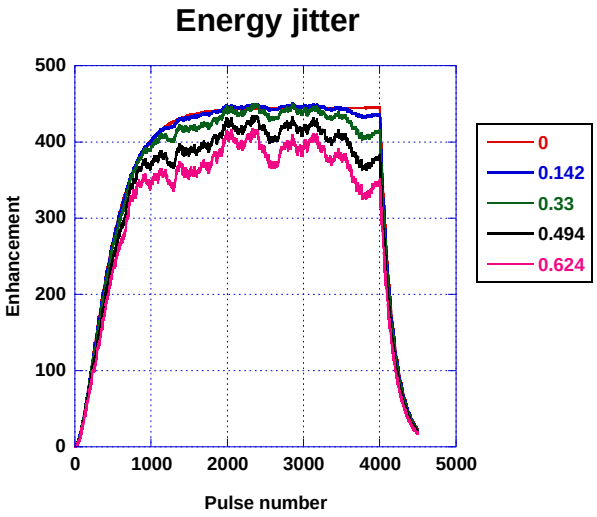
Figure from B. Stuart

Resonant cavity enhancement puts stringent requirements on the laser and optics phase jitter

- Phase noise
- Amplitude noise
- Thermal changes to refractive index in amplifiers/optics
- Cavity length/laser repetition frequency
- Dispersion in resonant cavity
- Pointing stability







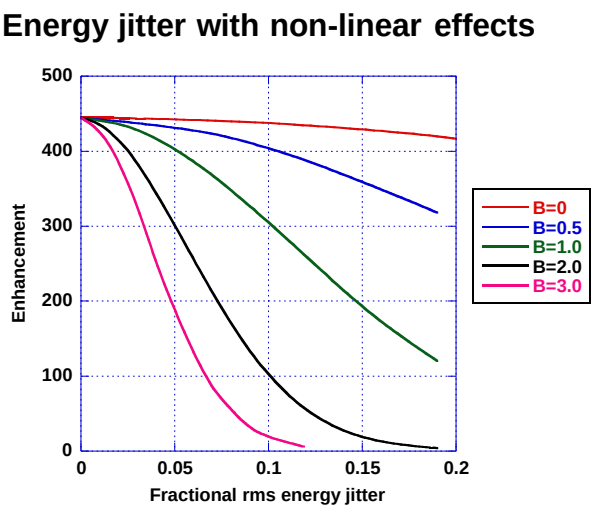
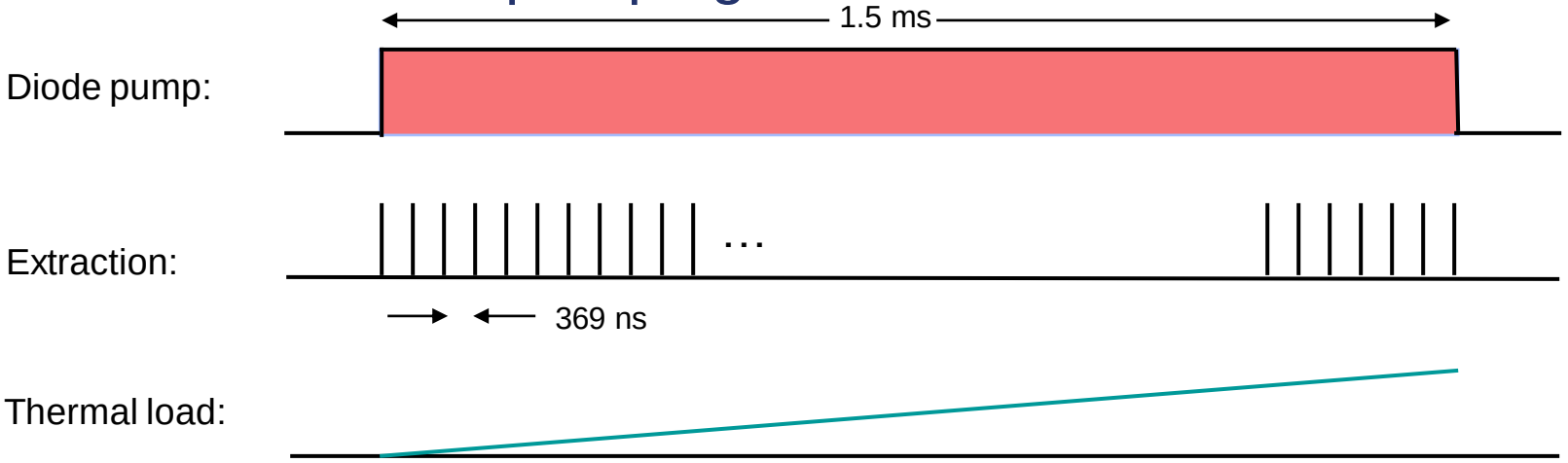


Figure from B. Stuart

Main amplifier

- Probably a slab or small-diameter rod configuration with continuous diode pumping

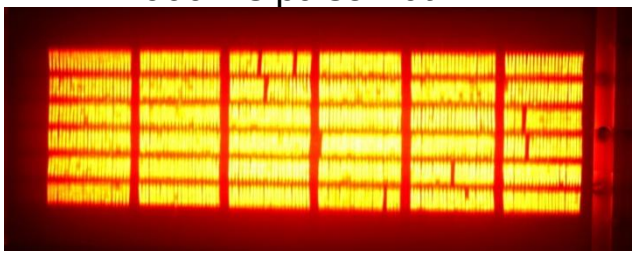


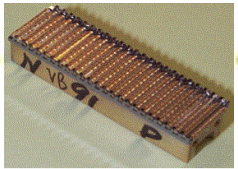
Operated at:
- 120 W/bar at 10 Hz
- 900 ms pulsewidth

Diodes:

40% eff.

50 mJ/369 ns = 136 kW peak ⇒ 339 kW peak
at $5/peak W ⇒ $1.7 M for diodes/drivers
~ 3500 bars at 100 W/bar





tile with 23 diode bars

Figure from B. Stuart

Summary

- Resonant stacking cavities can dramatically reduce required laser power
- Small cavities are already in use for X-ray production and have demonstrated >250 enhancement
- Photon collider laser power requirements are in range of currently demonstrated systems
  - **Diode costs are no longer the limiting factor ~1.7M$**
  - **Full laser cost ~20M$**
- Use of resonant stacking cavity imposes strict design constraints on the phase stability of the laser
  - **Requires a detailed engineering design of the final power amplifier**