Polarized e- source
Drive Laser system

A. Brachmann

Choice of Medium

- Wavelength determined by photocathodes
- Bandgap of GaAs based photocathodes is ~ 800 nm

Criteria	Choices			
	CW/QCW Laser Diodes	Fiber lasers (Er – doped)	OPA (See TTF laser)	Ti:Sapphire
Wavelength	Yes (limited)	Yes (frequency doubled)	Yes	Yes
Tunability	No	No	Limited	Yes
Bandwidth (pulse shaping)	No	No	Limited	Yes
Power	No	Yes	Yes	Yes
Complexity/Cost	Low	Medium	Very High	Medium
Commercial availability/interest	Yes	Yes	No	Yes (w R&D)

Laser Pulse Energy

- Determined by QE of cathode and number of required electrons
- Charge at Source: 5 nC
- Wavelength: ~ 800 nm
- Typical QE: ~ 0.5%
- Laser (pulse) energy: $E = \frac{n_e * h * c}{QE * \lambda}$
- Therefore the required laser energy is ~ 1.6 μJ per micropulse + overhead (transport losses, QE decay) → 3 – 5 μJ

ILC pulse train generation

- Pulse train generation requires mode-locked oscillator (synchronization to external RF oscillator)
- 3 MHz pulse train can be generated with cavity dumping or external pulse selection
- Ti:Sapphire guaranties sufficient bandwidth for wavelength tuning, pulse stretching and shaping

Amplification of Pulse Train (I)

Pump Laser

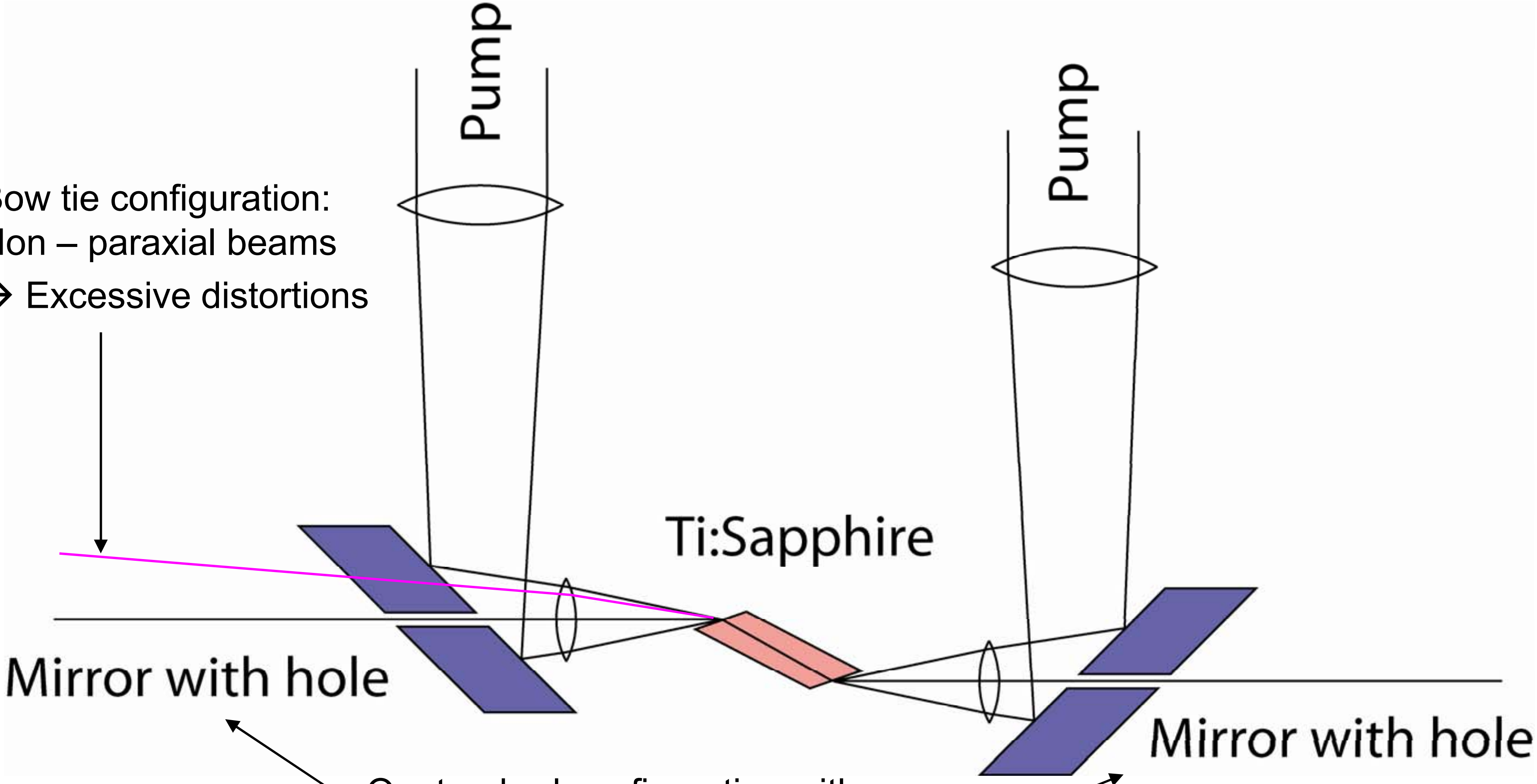
- Ideal would be high pulse energy laser with 3 MHz repetition rate at correct pump wavelength
- But no reasonable pulsed pump at 3 MHz is available
  - Due to switching technology limitations
  - Highest commercial rep rate is ~ 200 kHz
- Second option is CW Amplifier pump
  - diode pumped solid state laser
  - Nd:YAG, Nd:Vanadate, Nd:YLF, Yb:YAG
  - Highest power suitable cw lasers deliver 40 W
    - Thin disk technology – advantageous heat transfer solution

Amplification of Pulse Train (II)

Multi - Pass Amplifier Design

- – Bow tie amplifier configuration
  - Passive system (+)
  - Relatively few passes (~10) (-)
  - Imperfect overlap of pump and amplified beam (-)
    - → Beam distortion
- – → Regenerative Amplifier ←
  - Requires switching at 3 MHz
    - – loss at optical surfaces → fundamentally less efficient as bow tie amplifier
  - Many (few hundred) passes
  - Pump and amplified beam overlap

Amplifier Geometry

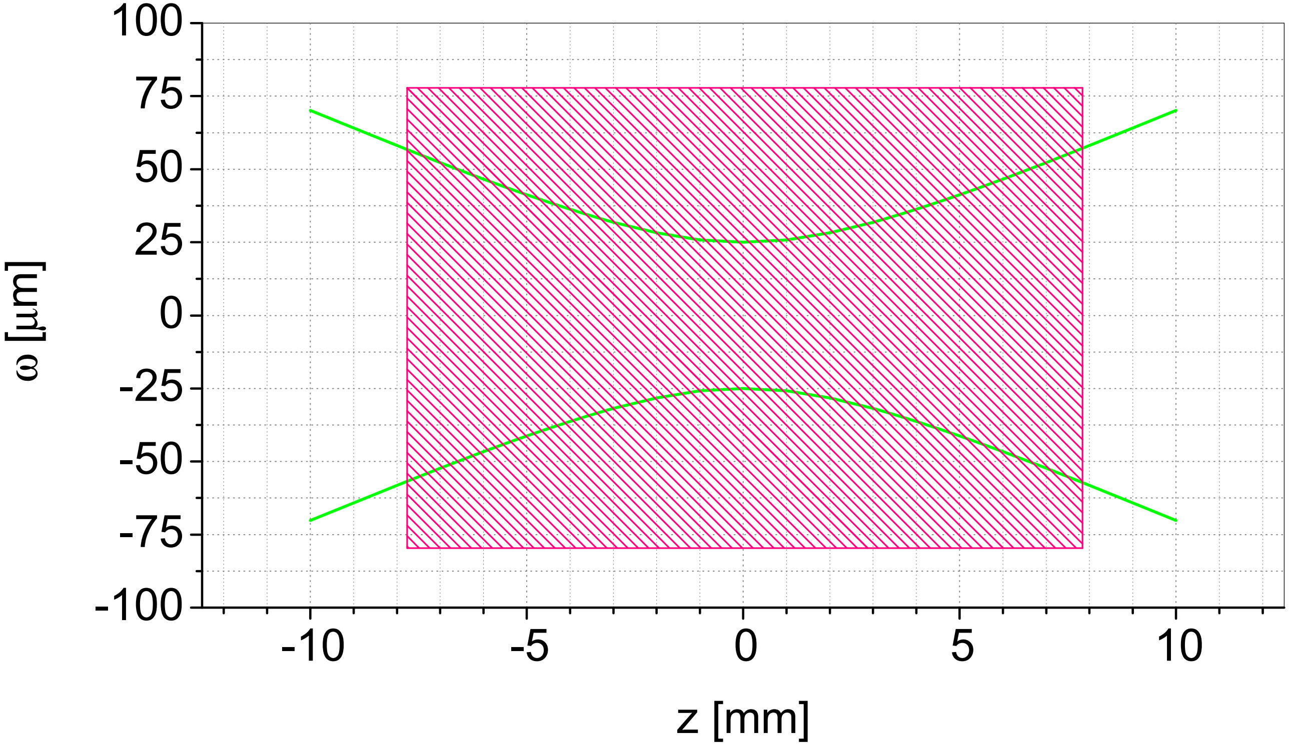


Bow tie configuration:
Non – paraxial beams
→ Excessive distortions

Or standard configuration with
pump coupled in through end mirror

Amplifier Crystal Length

Rayleigh Range: $b = \frac{2\pi\omega_0^2}{\lambda}$ $\omega = \sqrt{2}\omega_0$



Cryogenic cooling of Amplifier Cell

- Issue is thermal lensing
  - 5 W pump maximum for un-cooled crystal
- Strong thermal lensing can not be compensated optically because of astigmatism ($n_e \neq n_o$)
- Solution is a cryogenically cooled amplifier cell to suppress thermal lens
  - Cryostat
  - Vacuum
  - Liquid He cooling

Pockel’s Cell Technology

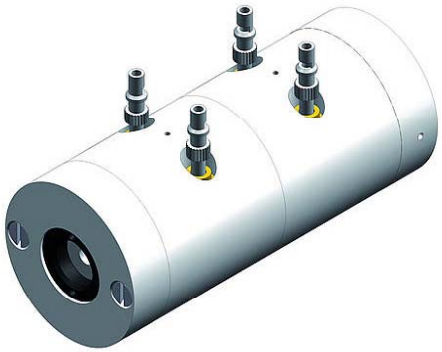
- Electro optical crystals also are piezo - electric crystals!

$$\Delta\phi = \left(\frac{2\pi L}{d} / \lambda\right)[-n^3 \underbrace{r_3}_{\text{electro-optic coefficient}} / 2 + (n-1)\underbrace{d_{13}}_{\text{inverse piezo-electric coefficient}}]E_3$$

- At high kHz to MHz rates, piezo electric resonances occur
  - – Unusable electro-optic properties
  - – Catastrophic damage of crystal itself

Pockel’s Cell Technology (II)

- The solution is damping of the cell
- Maintain low switching voltage by using small crystals (transverse crystal) and multiple crystals in one cell
  - Double, tripple BBO
  - 2- 3 mm diameter aperture



- Limited commercial availability – custom cells and drivers

Ti:Sapphire laser physics (I)

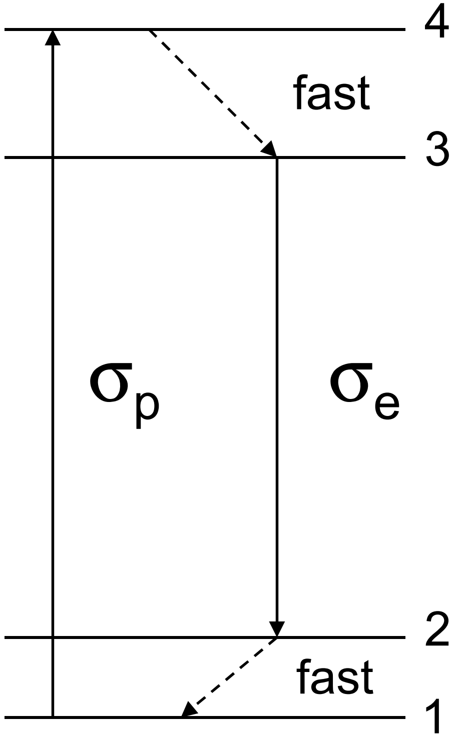
Simplified Rate Equation System

$$\frac{\partial N_1}{\partial t} = \frac{\sigma_p I_P}{h * \nu_p} \bullet N_1 - \frac{N_3}{\tau_F}$$

$$N_{total} = N_1 + N_3$$

Gain Coefficient

$$G(t) = \exp\left[\sigma_e N_3(t)\right]$$

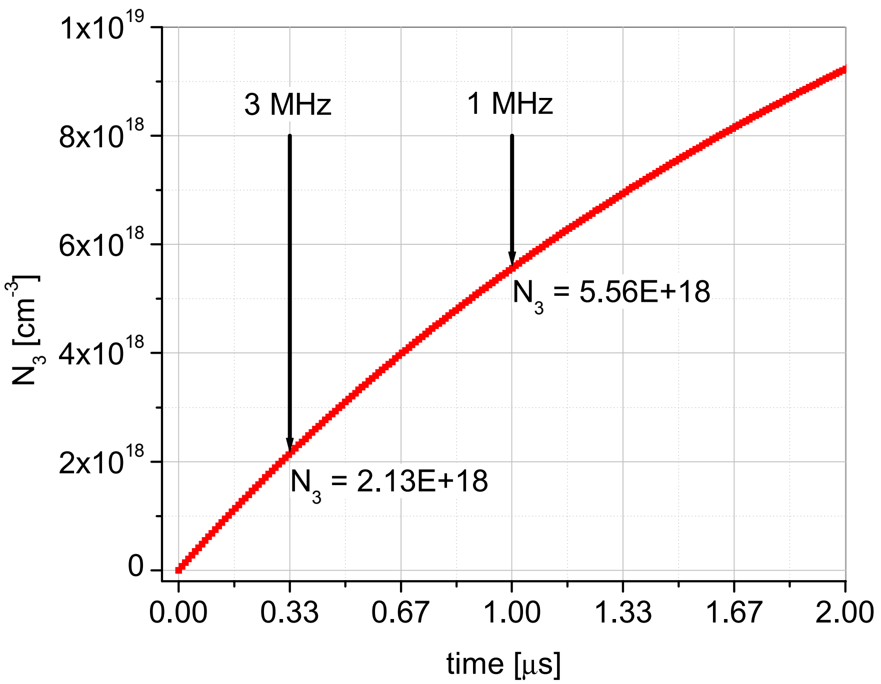


Ti:Sapphire laser physics (II)

Parameter	Value
TiO_2 Doping	0.2 wt %
N_{total}	6×10^{19} cm^{-3}
σ_p	$4.9 * 10^{-20}$ cm^2
σ_e	$28 * 10^{-20}$ cm^2
τ	$3.5 * 10^{-6}$ s
λ_p	515 nm
λ_p	800 nm
$\omega_0 = \omega_p$	25 µs
P_p	40 W
D	2 MW/cm^2
η	0.9

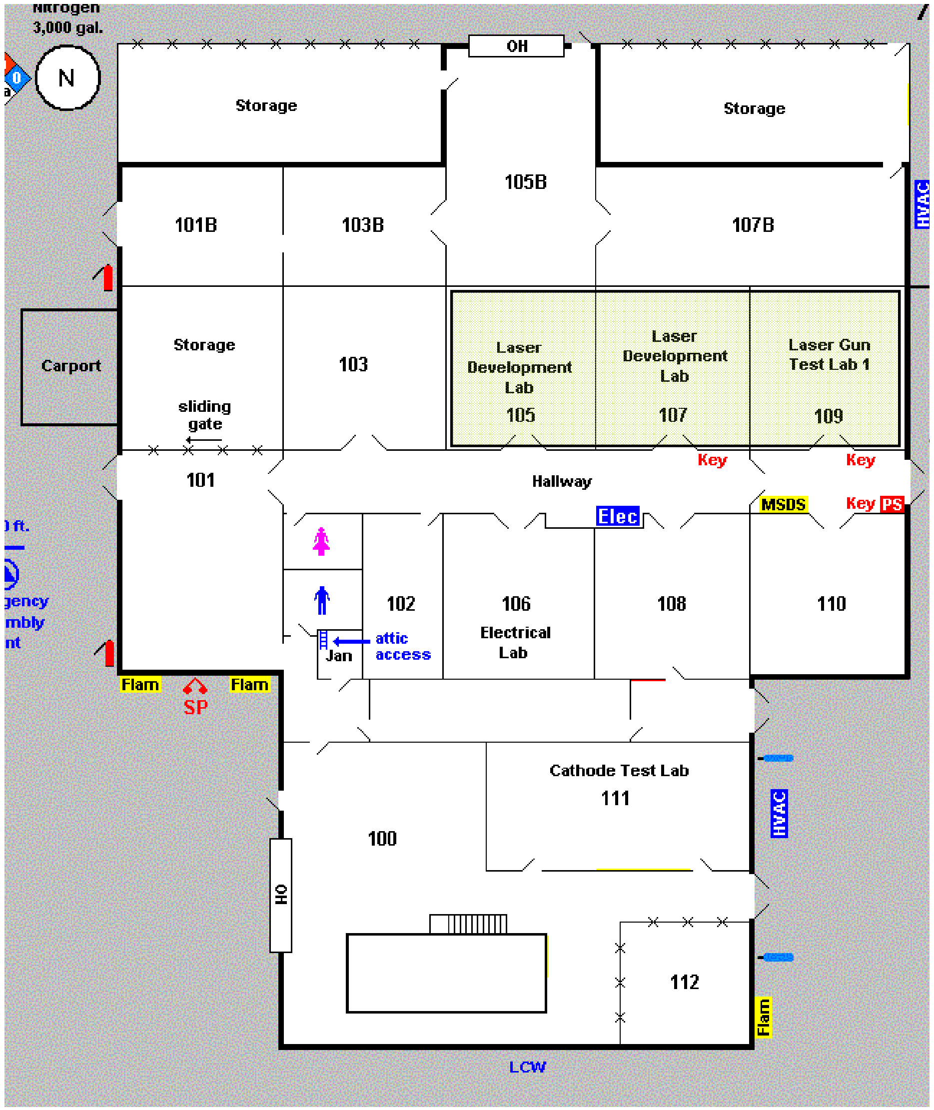
Pump Intensity

$$I_P = \eta \bullet \frac{P_p}{\pi \bullet (\omega_0^{\,2} + \omega_p^{\,2})}$$



$G_{(333ns)} = 1.81$

ILC Laser Development Lab



Investments FY05-07:

250 k$ HVAC system
175 k$ 40 W pump laser
120 k$ regenerative amplifier
(cryocooled, 3 MHz)

Current activities:

- Laser work
- Gun operation
- Photocathode development

Summary

- Laser technology suitable for the ILC source is not demonstrated or investigated in detail
- We are pushing technology in many respects
- R&D is required to confirm feasibility of our concept
- We are planning to build a ‘proof of principal’ laser system at SLAC
- Laser system will be used at SLAC’s ITF to generate e- beam
- Laser system also needed to demonstrate photocathode performance und ILC conditions
  - Concern is surface charge limitations