SLAC's Polarized Electron Source

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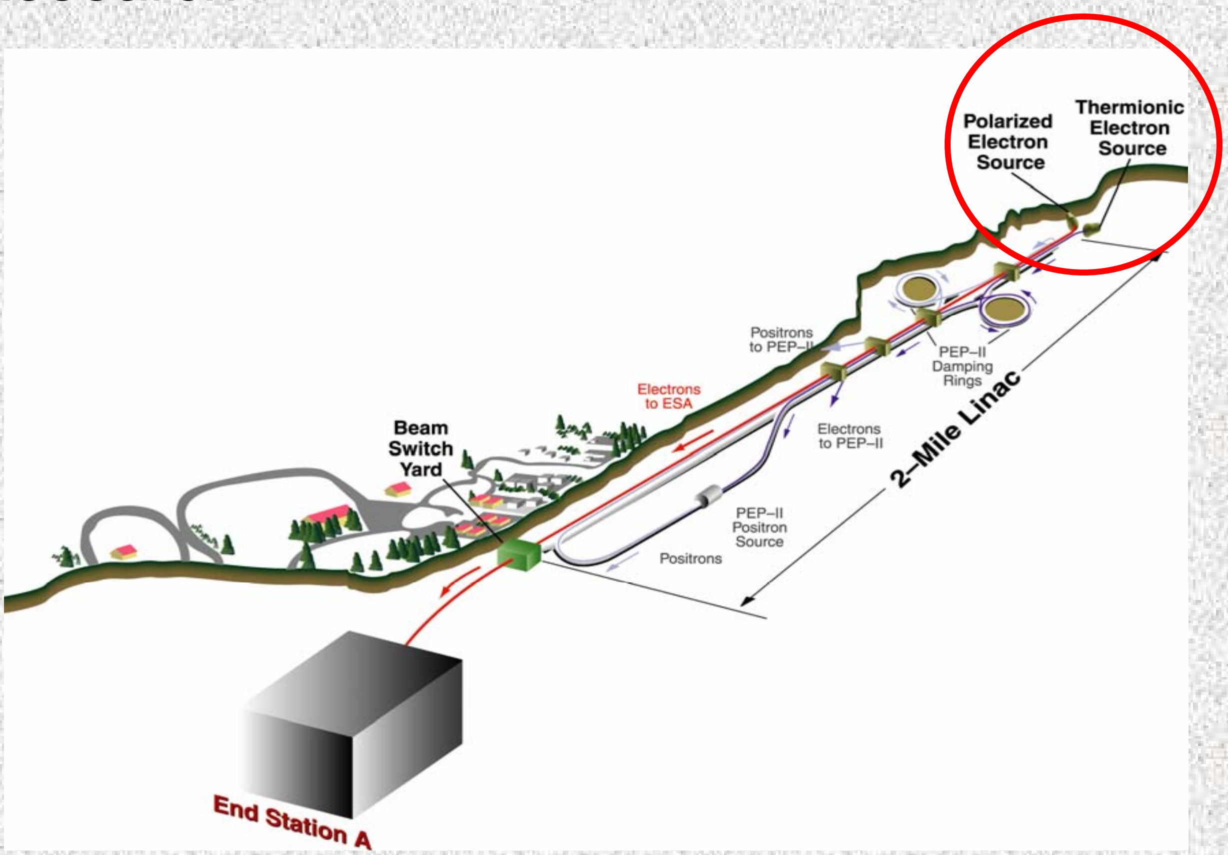
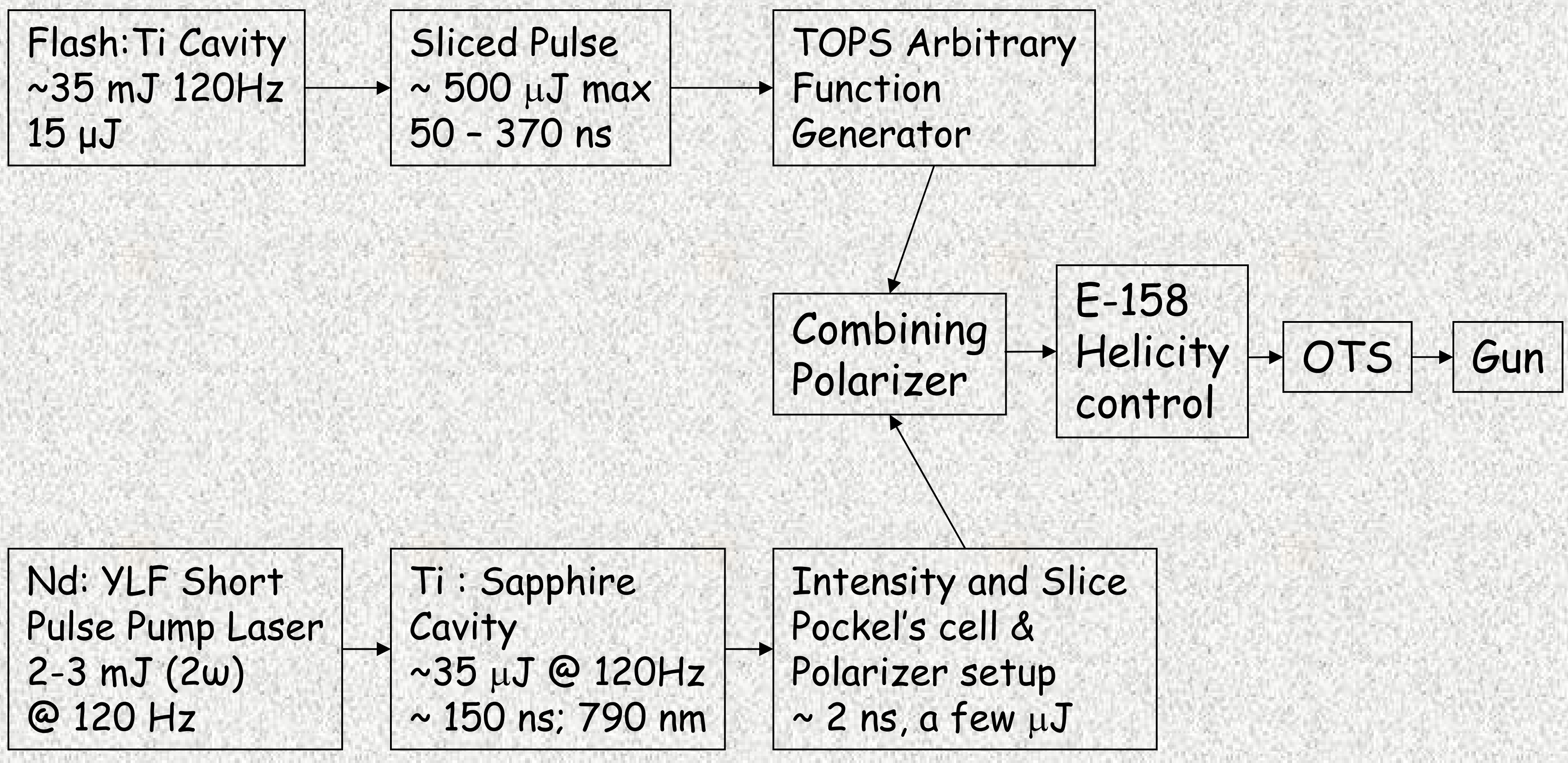
Outline

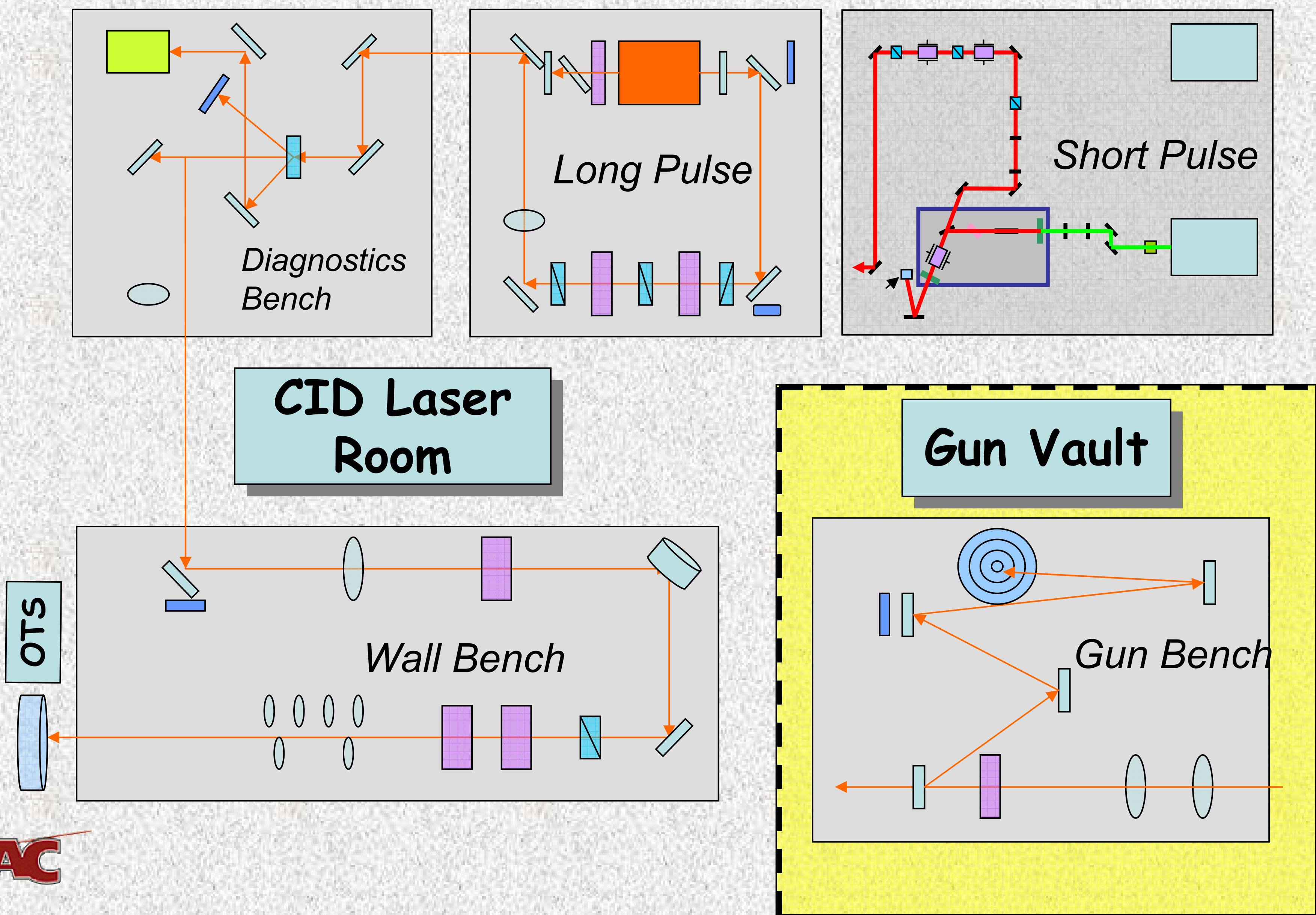
- Source Overview
- Lasers
- Photocathode Research
- Electron Gun
- Future Plans



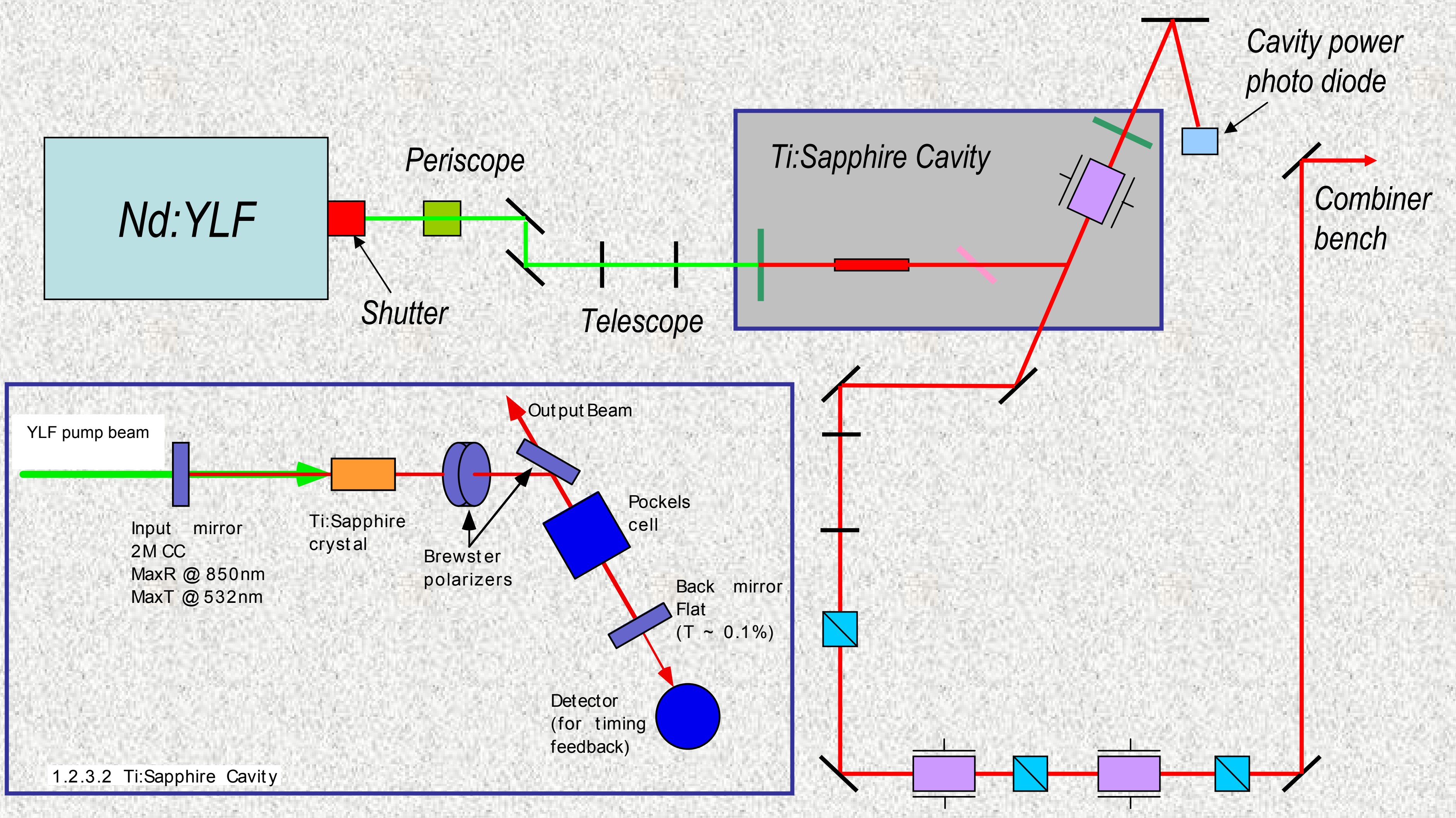
General Source Layout



Polarized Source Laser Systems

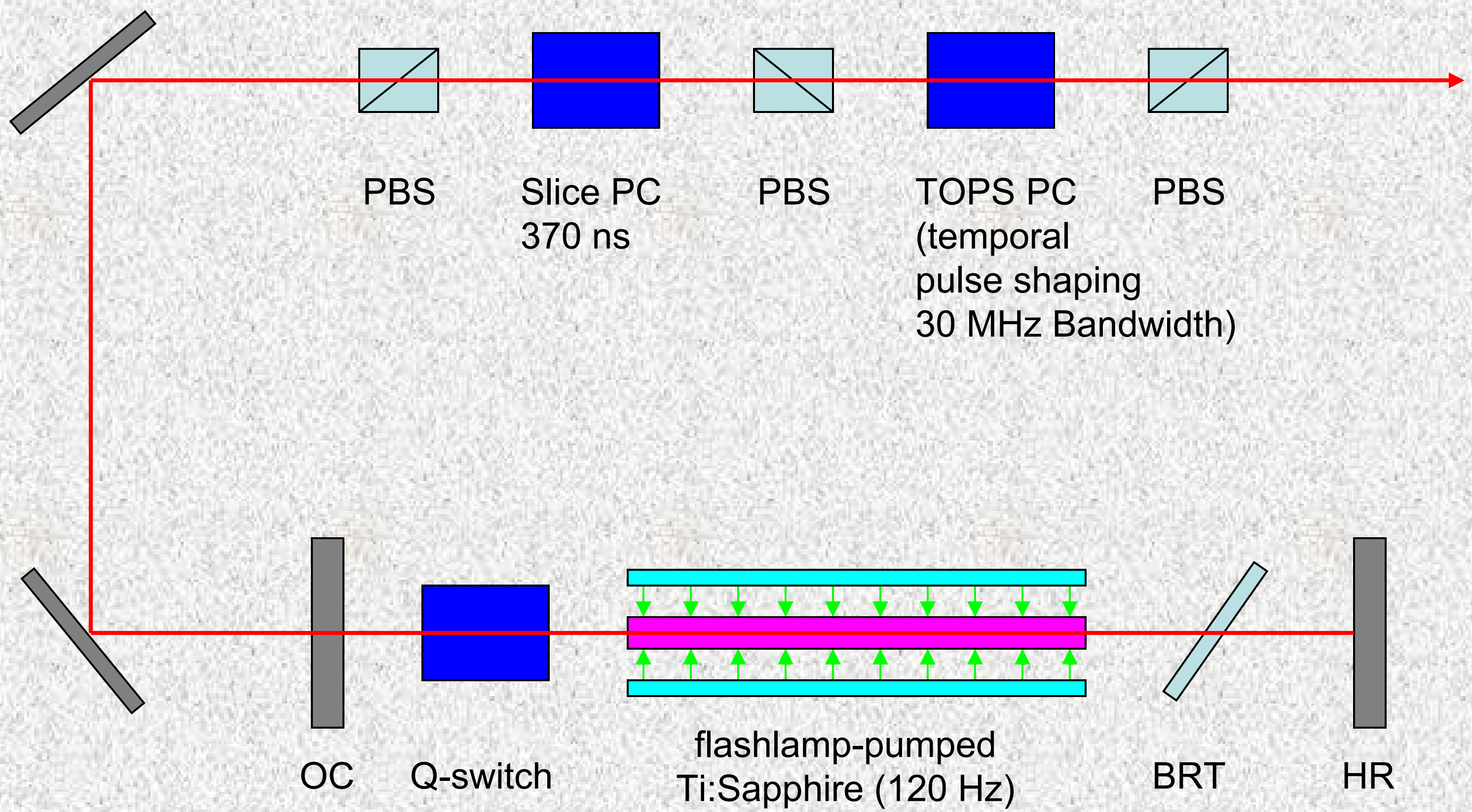


Short Pulse Ti:Sapphire System

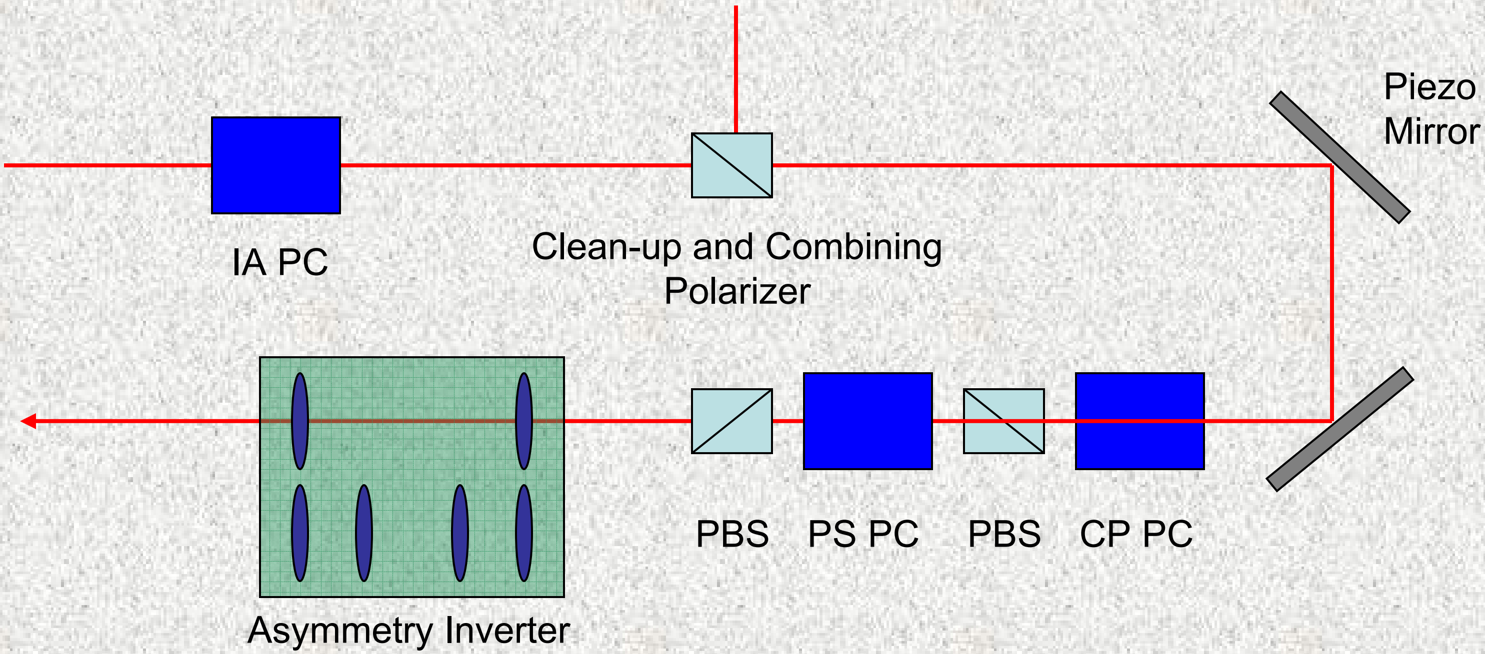


Time 2 ns /Amplitude

Flashlamp pumped Ti:Sapphire laser system
Cavity and Pulse Shaping

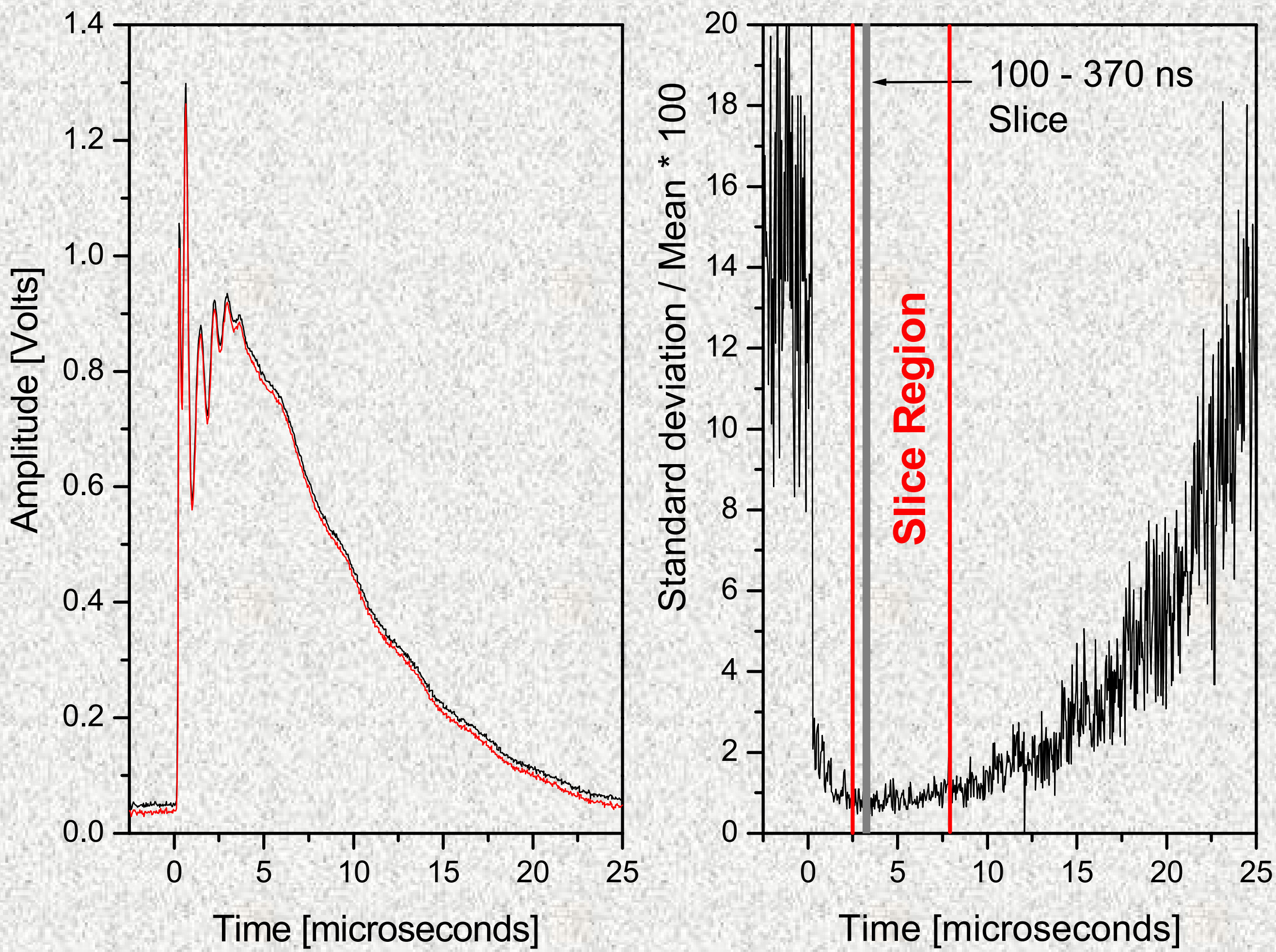


Flashlamp pumped Ti:Sapphire laser system: Helicity Control



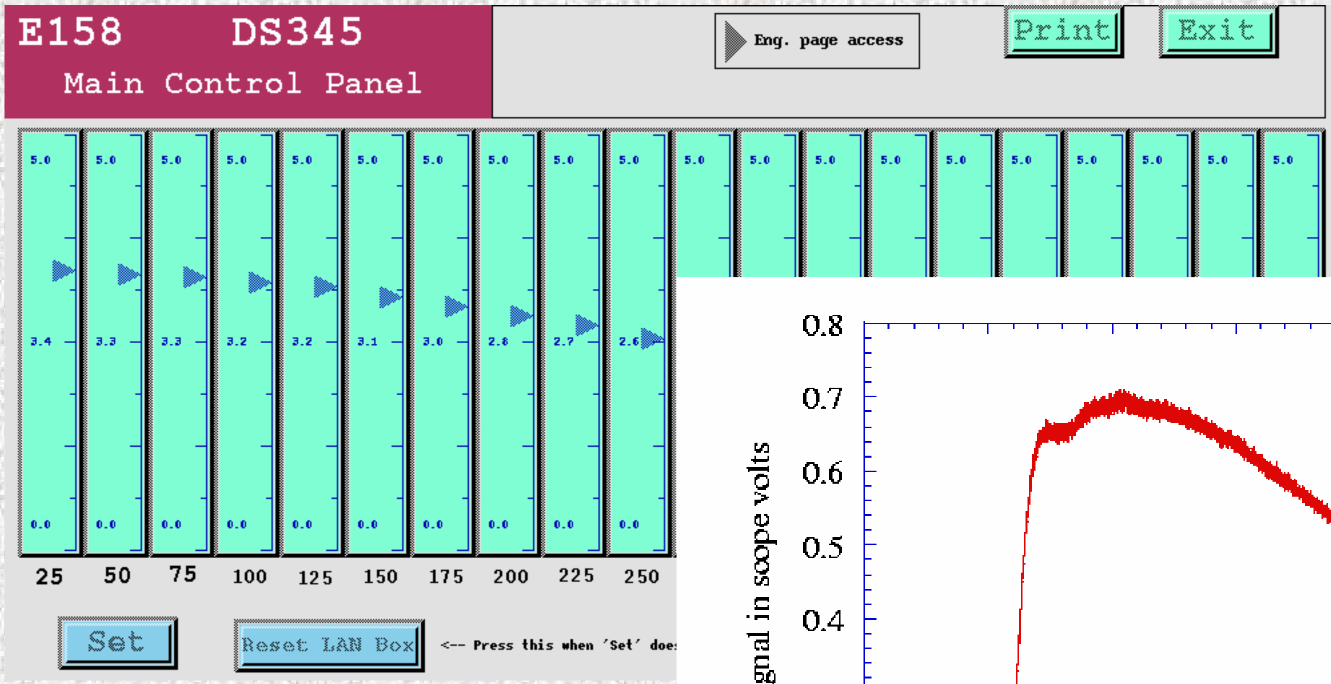
Circularly Polarizing (CP) Pockel's Cell: λ/4 wave PC with fast axis 45° from horizontal, either helicity can be chosen on a pulse by pulse basis	Phase Shift (PS) Pockel's Cell: fast axis vertical, compensates for residual linear polarization along the axis at ±45°	Intensity Asymmetry (IA) Pockel's Cell: Balances the intensity asymmetry between the two helicity states, introduces helicity correlated phase shift, clean-up polarizer transform this into desired intensity asymmetry (feedback loop)	Piezo mirror: Compensates for helicity correlated position differences (feedback loop)	Asymmetry Inverter: Flips transverse spatial profile of beam (horizontal or vertical)

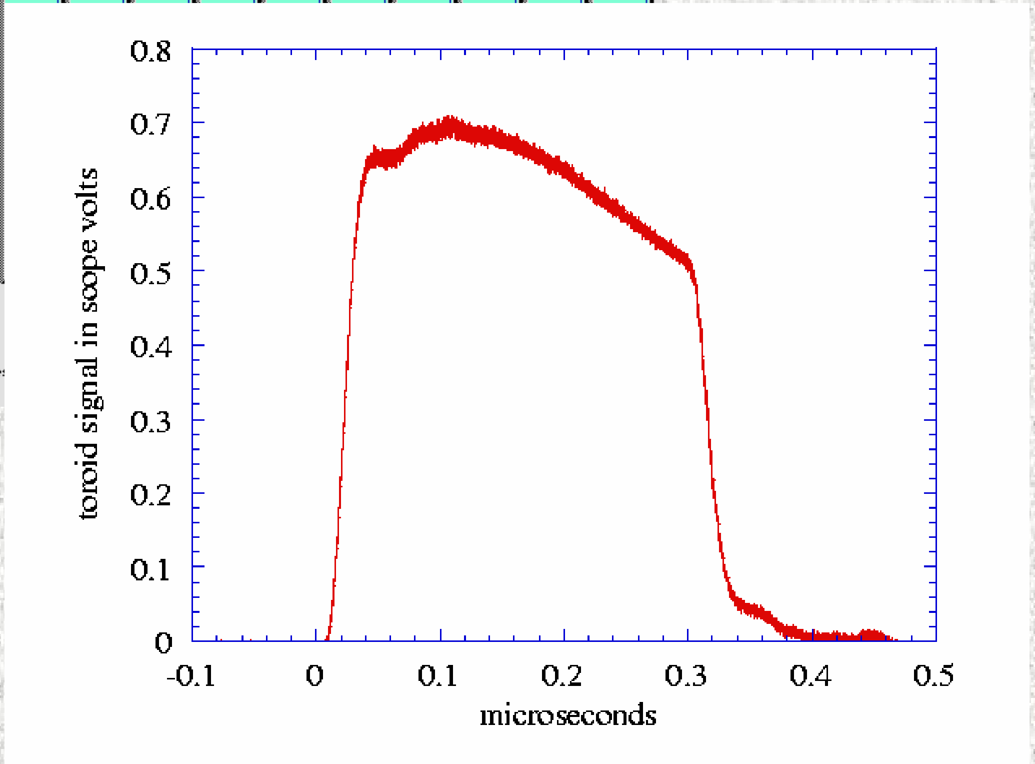
Flashlamp pumped Ti:Sapphire laser pulse shape



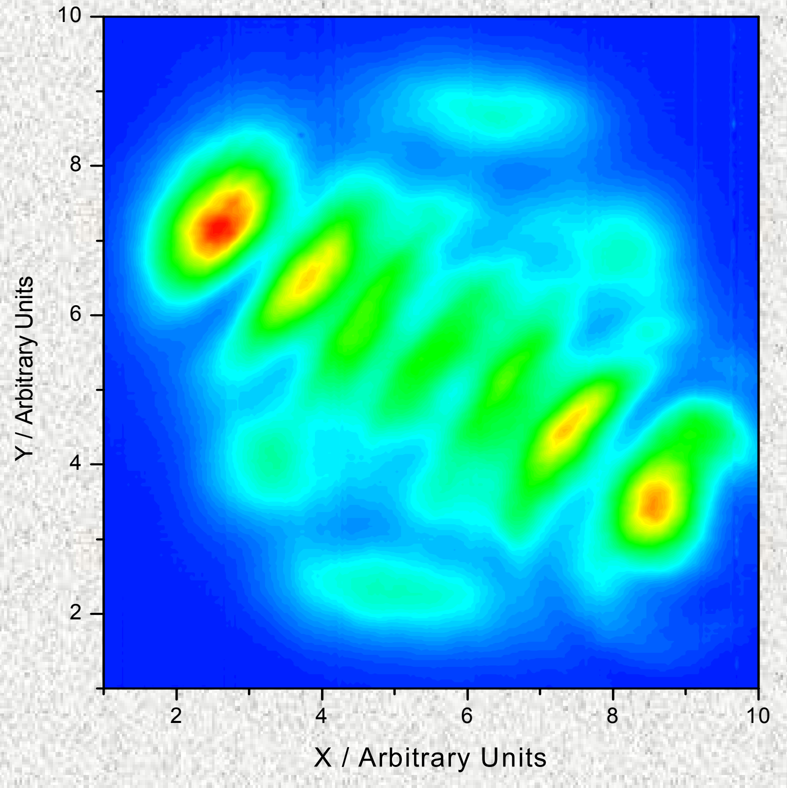
TOPS shapes e^- pulse

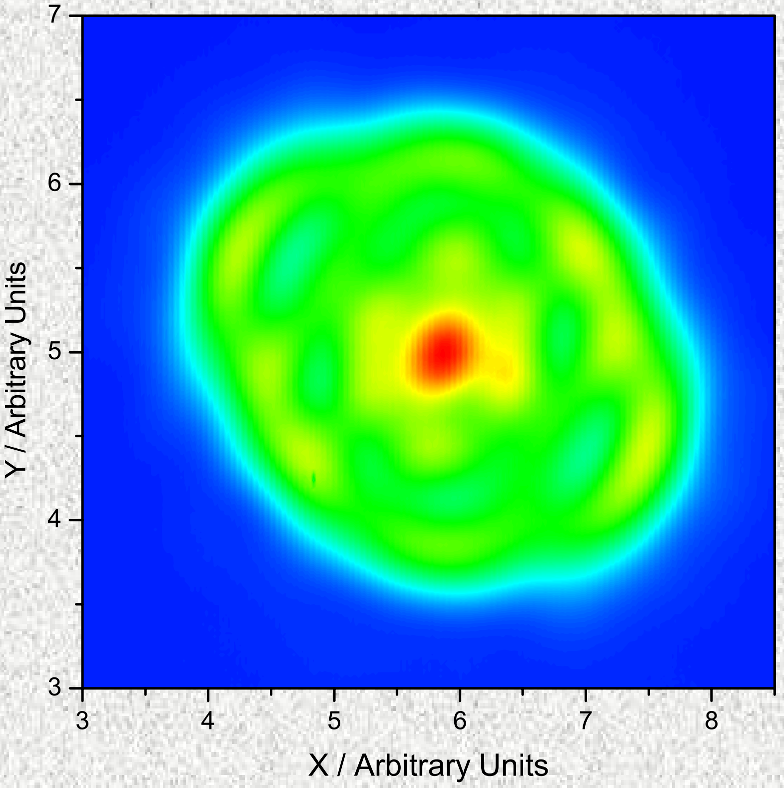
TOp hat Pulse Shaper





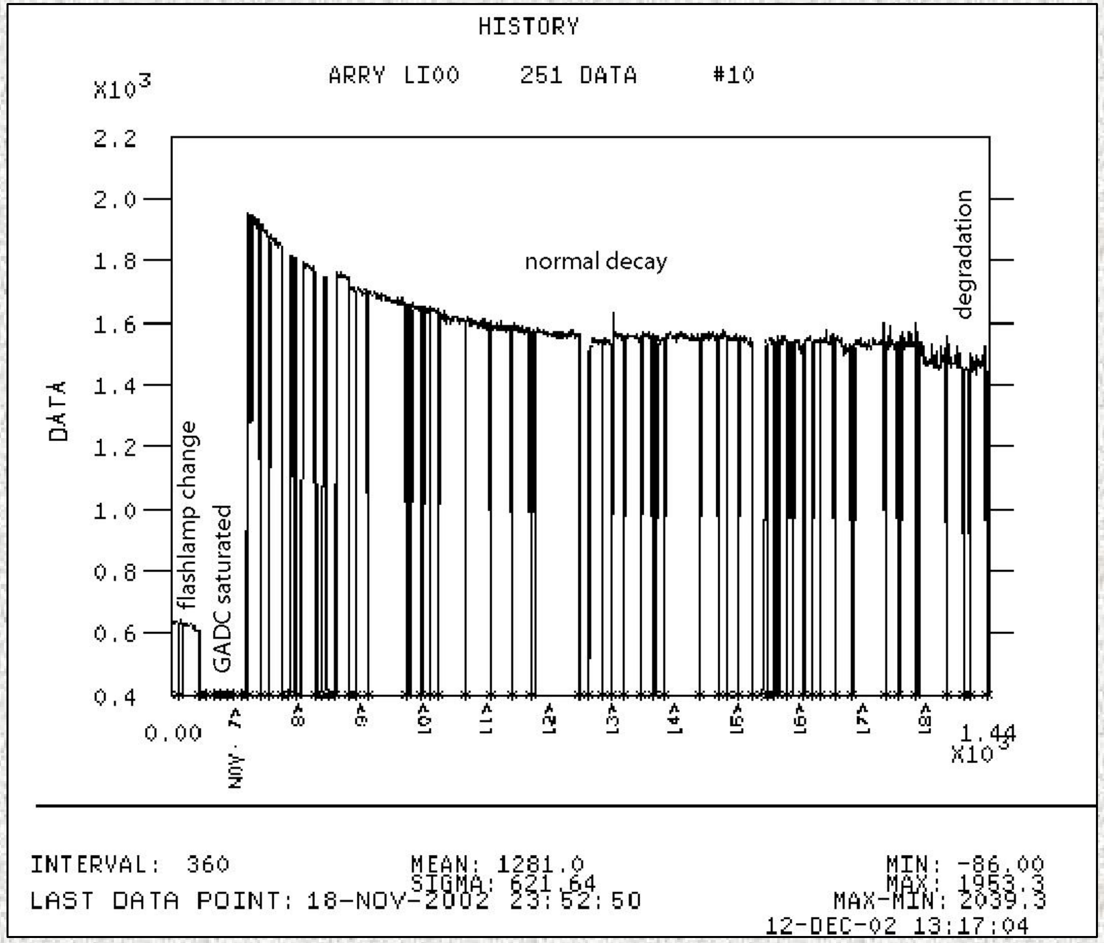
Multimodal transverse beam profile



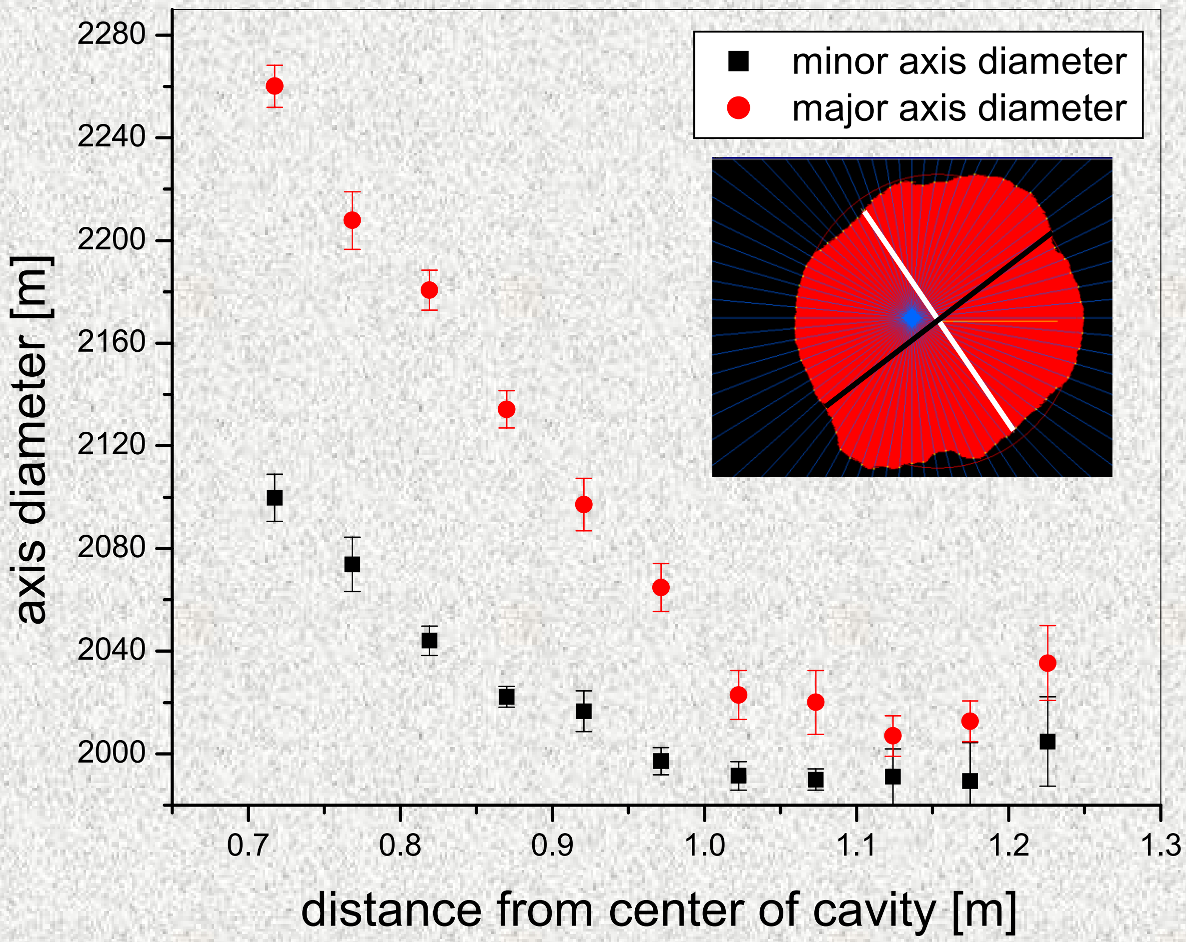


Flashlamp history

~ 145 * 10^6 shots → 2 weeks lifetime at 120 Hz

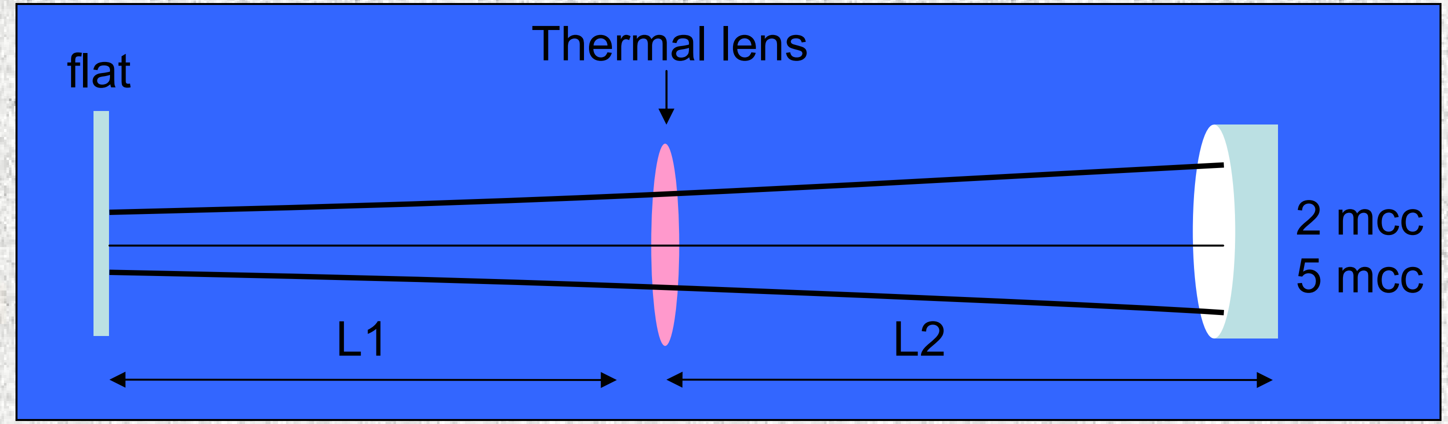


Thermal lens ~ 1.1 meter

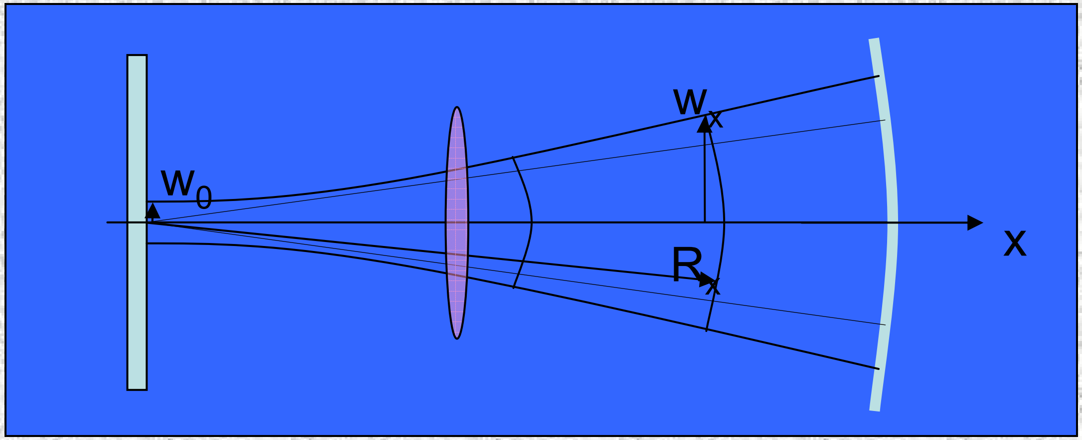


Simulation setup

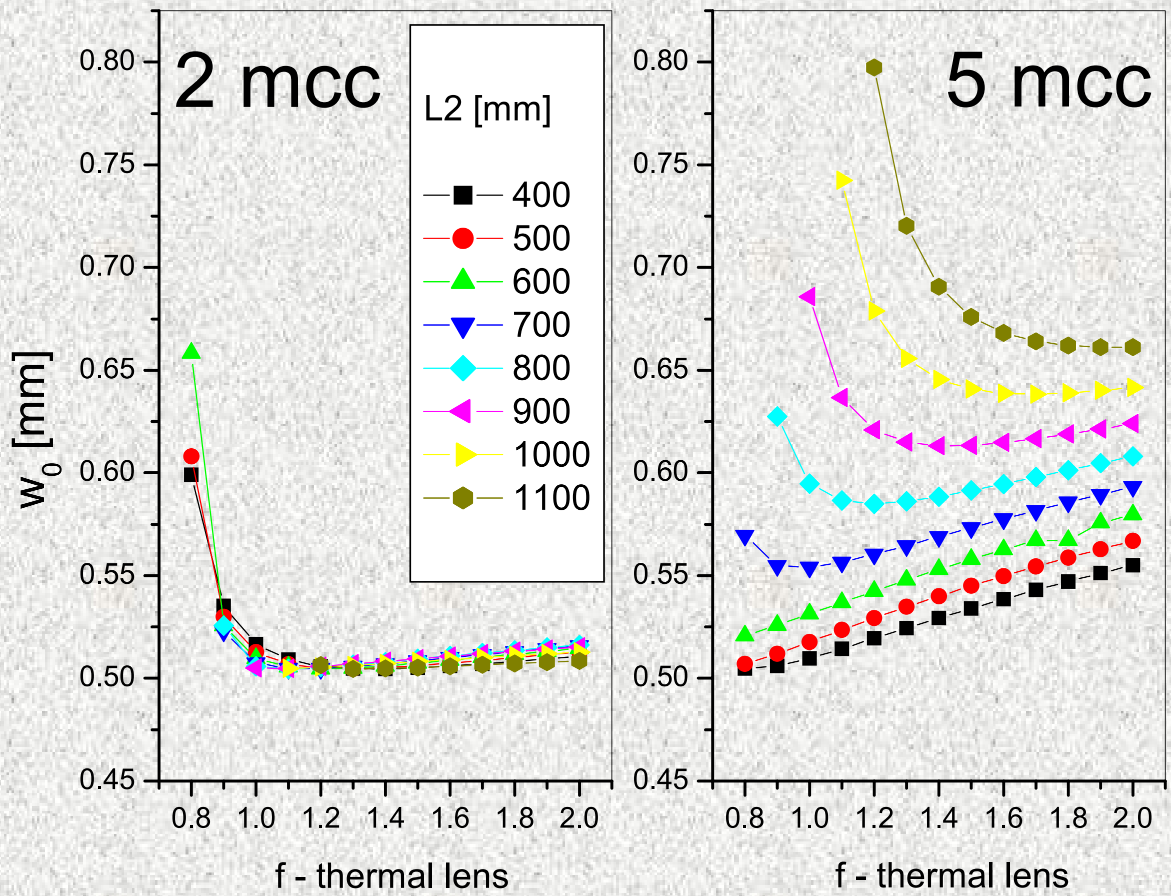
Spotsize



Wavefront



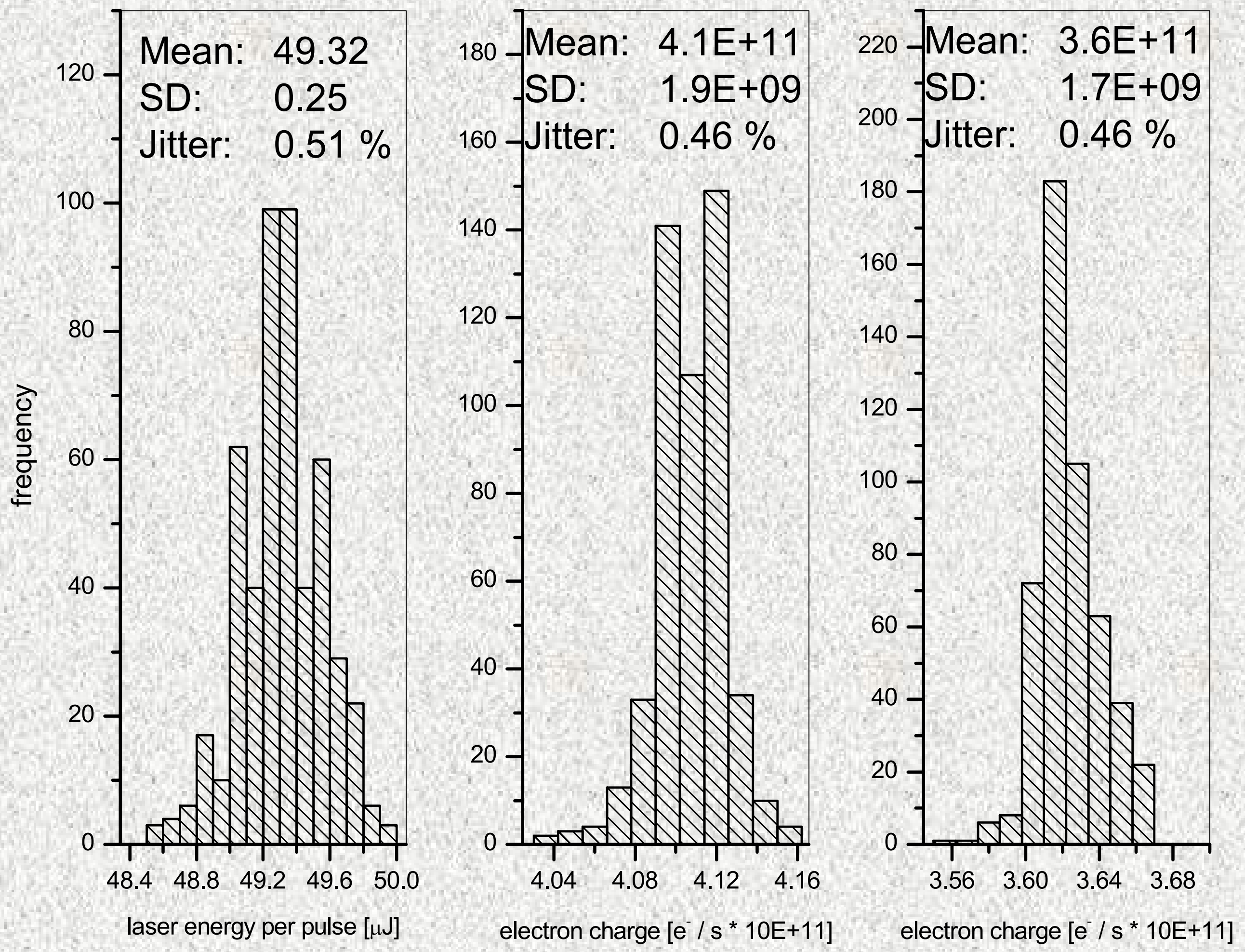
Cavity simulations



Comparison of cavity waist as function of cavity length and thermal lens.

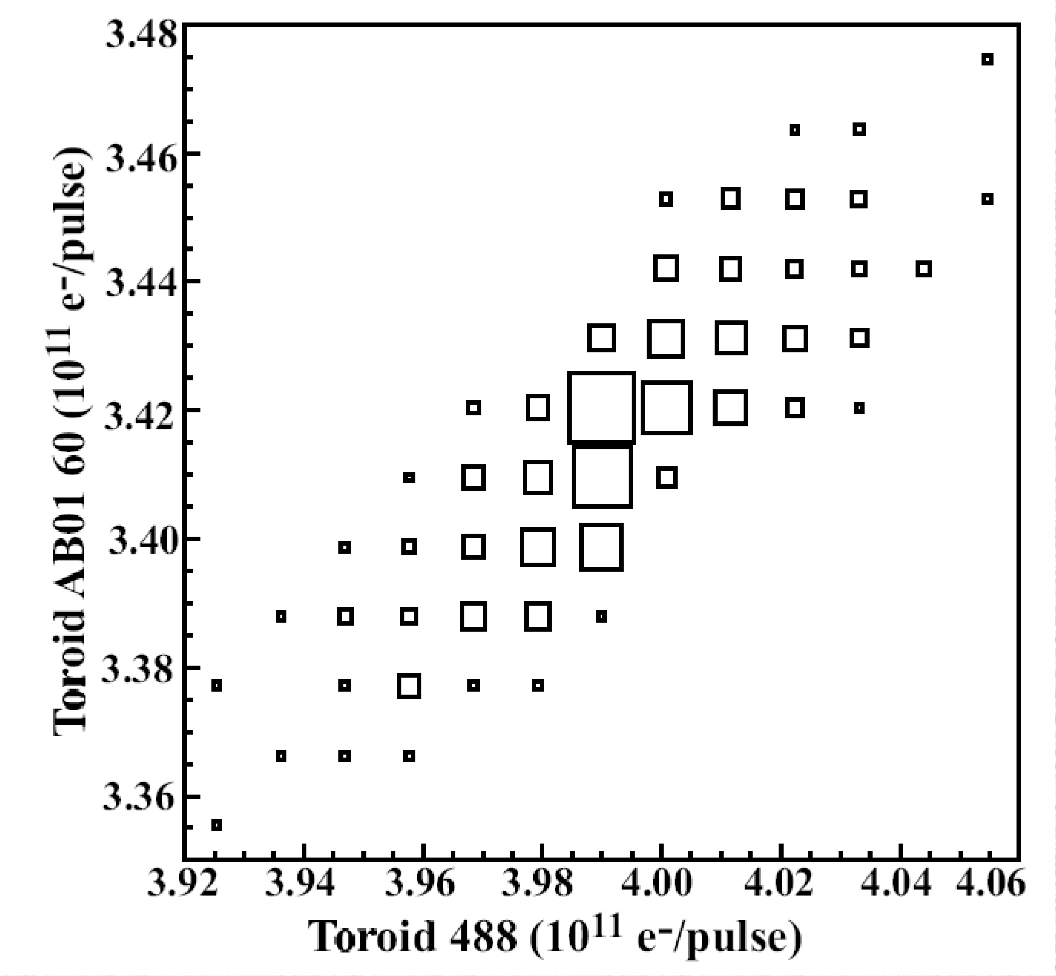
Result of ABCD Calculations show less sensitivity of cavity waist to Varying thermal lens.

Laser and electron beam stability



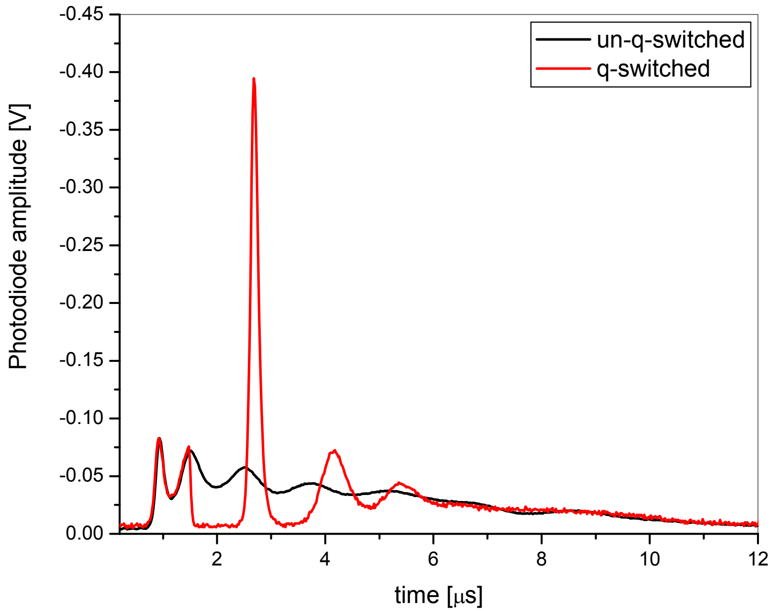
Laser Gun Endstation

Electron beam stability before and after acceleration

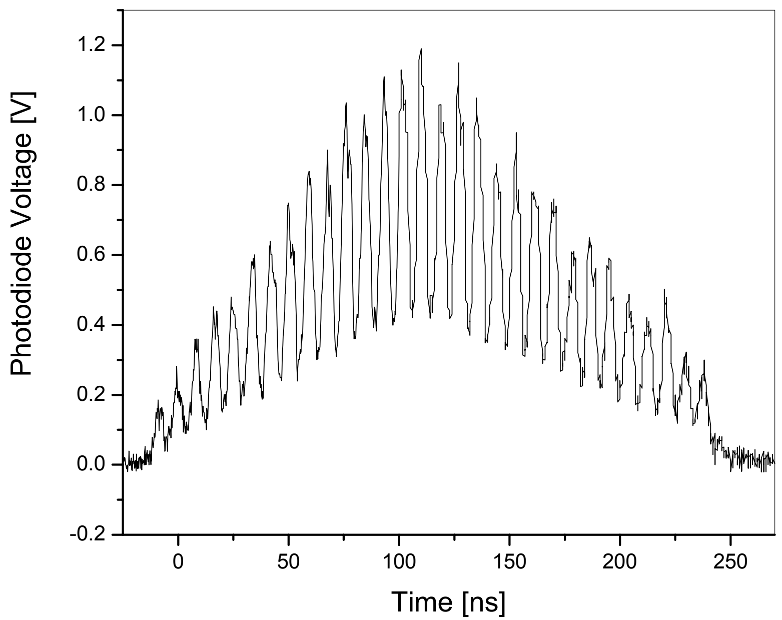


Q-switching the cavity

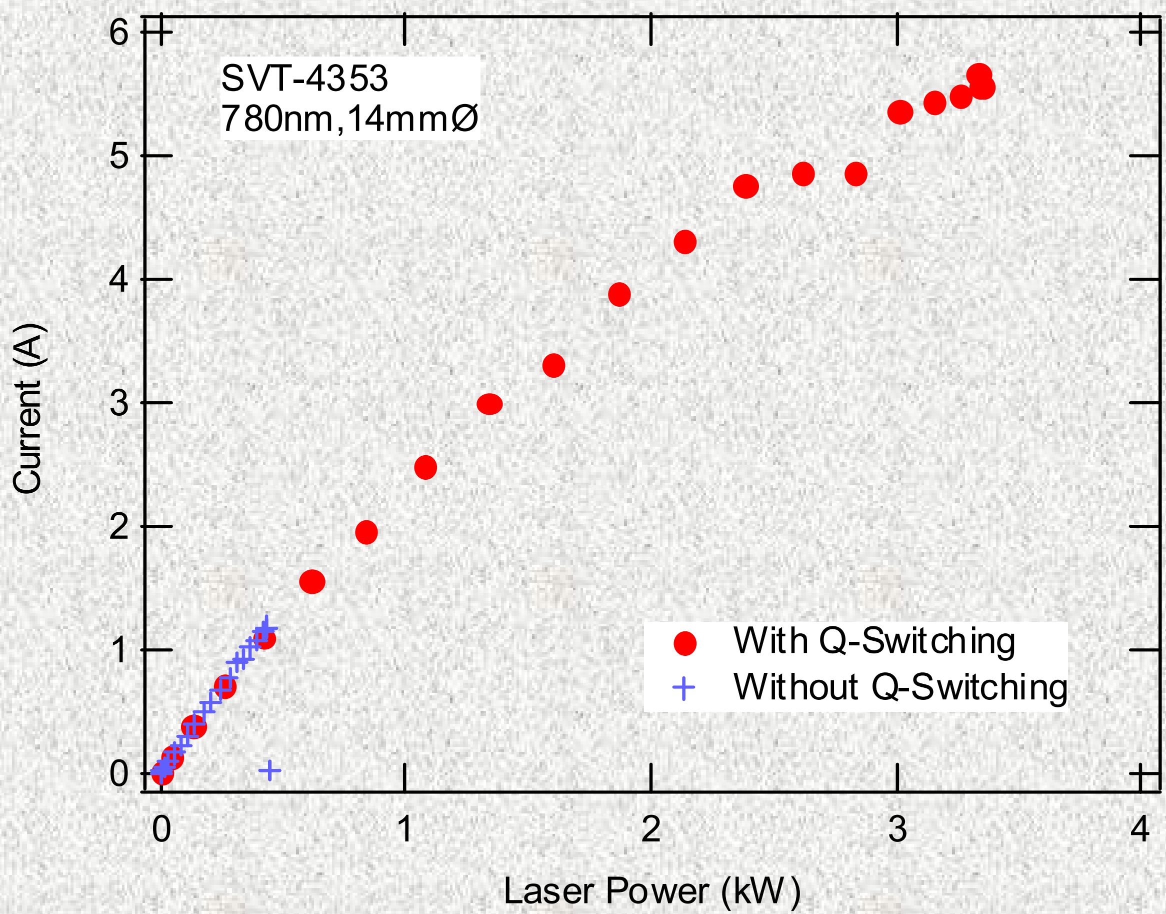
Increases peak power by an order of magnitude



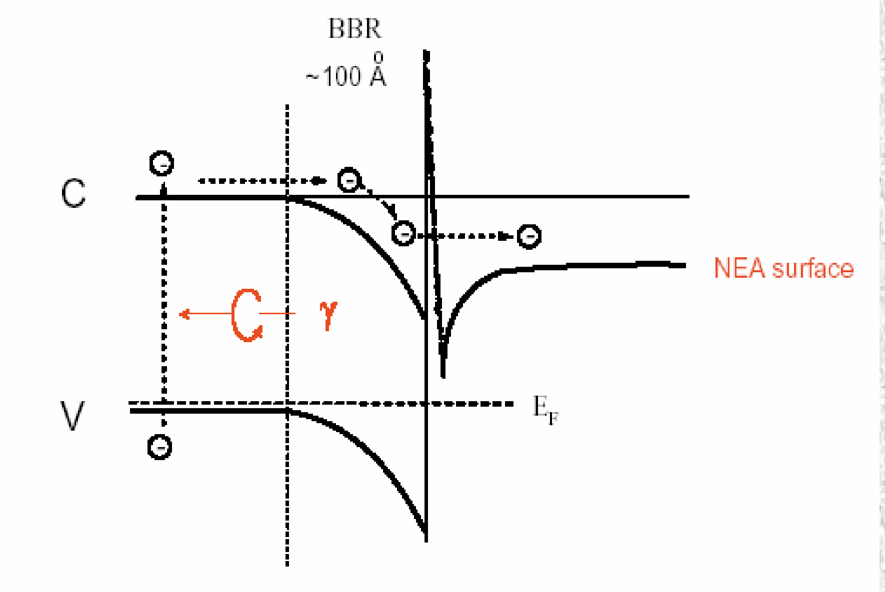
Microstructure of Q-switched pulse is interpreted as partial modelocking (Ti:Sapphire – Kerr lens)



Probing surface charge limits with Q - switched pulse



Polarized photoemission from GaAs Photocacthodes

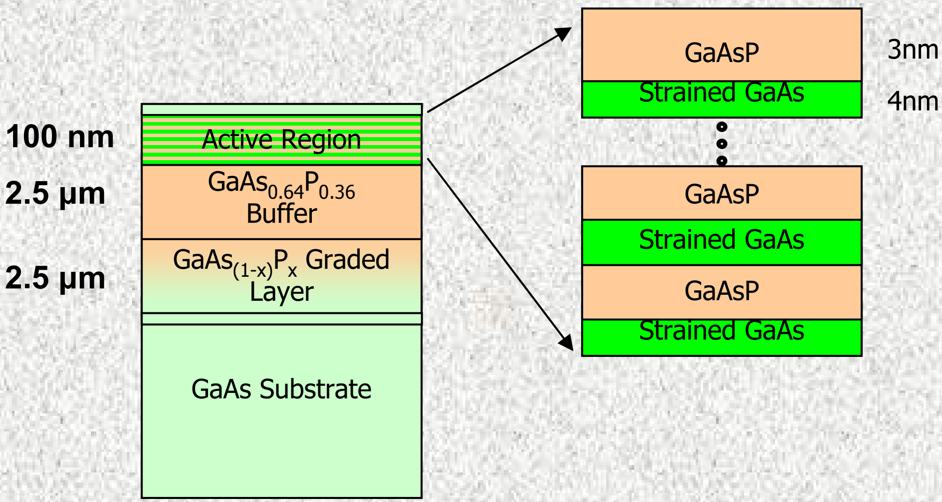


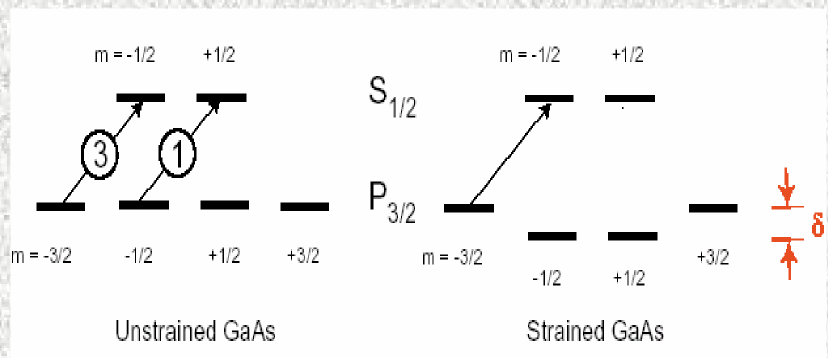
NEA Surface – Cathode "Activation"

- Ultra-High-Vacuum < 10^{-11} Torr
- Heat treatment at 600° C
- Application of Cesium and NF_3/O_2

- Circularly polarized light excites Electron from valence band to conduction band
- Electrons drift to surface
  L < 100 nm to avoid depolarization
- Electron emission to vacuum from Negative-Electron-Affinity (NEA) surface
- Surface photovoltaic effect (surface charge limit) limits photoemission
- Gradient doping of first few nm solves surface charge limit

GaAs/GaAsP Strained-Superlattice[*]



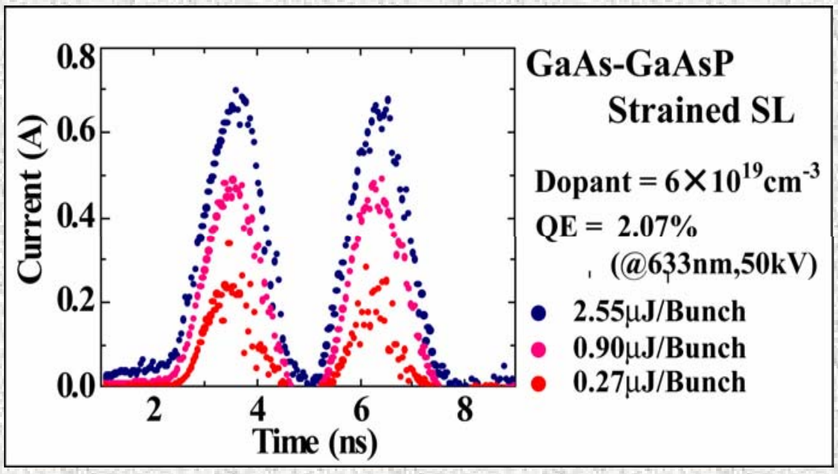


- **HH – LH splitting from two sources: quantum size effect and strain**
  → High polarization, 85 - 90% routine
- **GaAs/GaAsP has a larger band gap**
  → Higher QE (1%)
- **High gradient p-doping: Be $5\times10^{19}/cm^3$ In the 5 nm surface layer and $5\times10^{17}/cm^3$ in the rest**
  → No surface charge limit
- **Superlattice layer thickness**
  → GaAs layers are highly strained

[*] Maruyama et al. SPIN 2004 proceedings

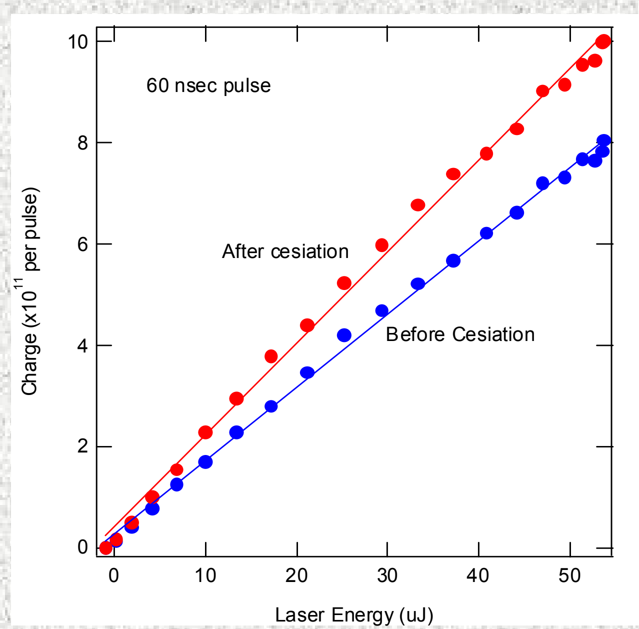
Surface charge limit is overcome by doping

Nagoya



p-p : 2.8ns,
bunch-width : 0.7ns
Charge: 1nC/bunch

SLAC

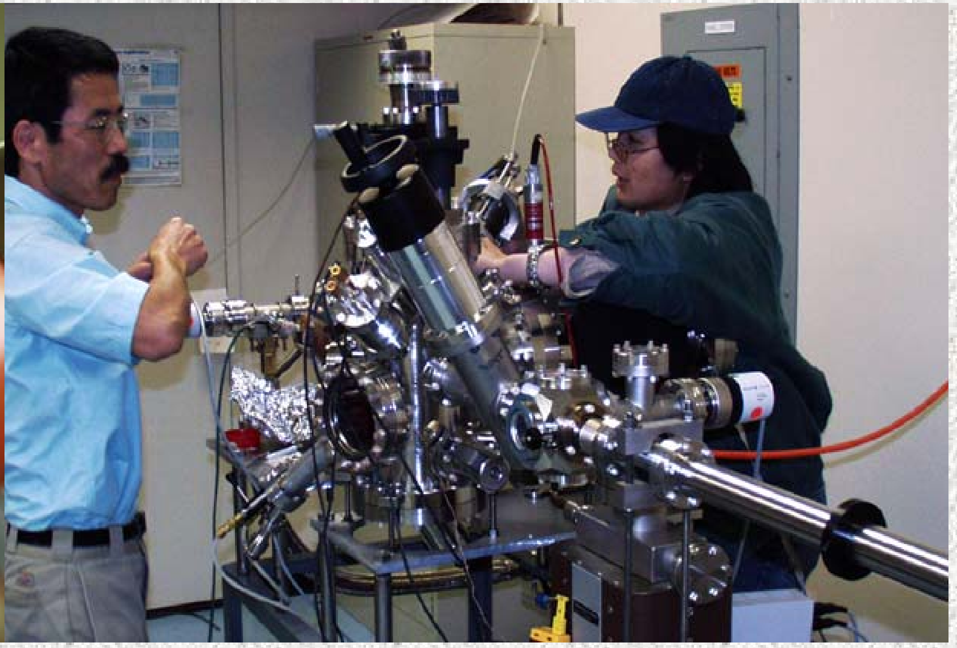


e.g. 4.5 $*10^{12}$ e^- in 270 ns pulse
3 x NLC bunch train

Atomic hydrogen cleaning

Cleaning of surface using atomic hydrogen

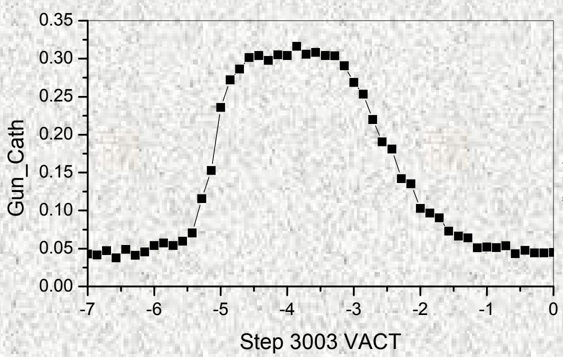
- Removal of capping material (As, Sb)
- Reduction of heat cleaning temperature to protect dopant
- Ideal case have apparatus and gun integrated

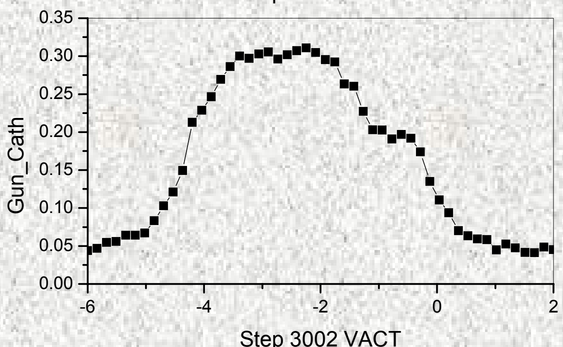


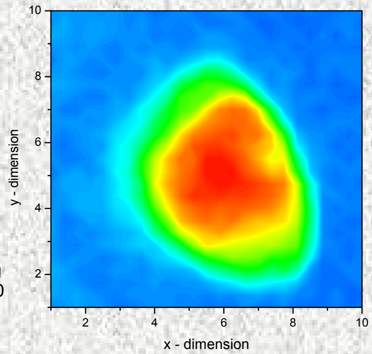
Cathode 'Lifetime' > 1 year

QE profile, D= 2 cm

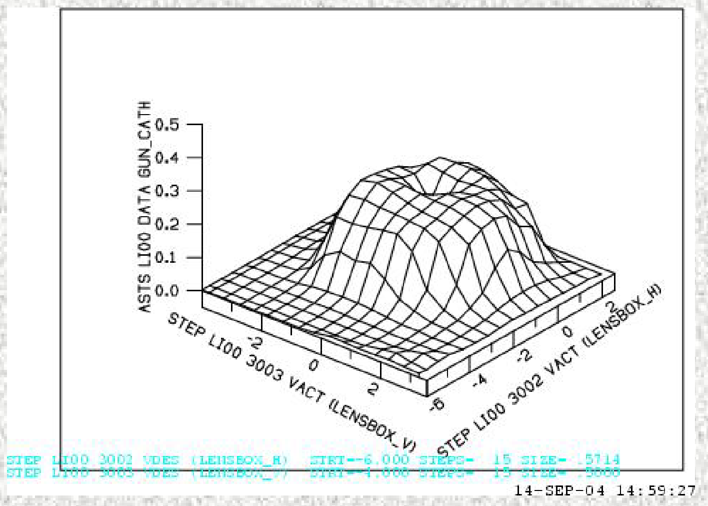
August 2003



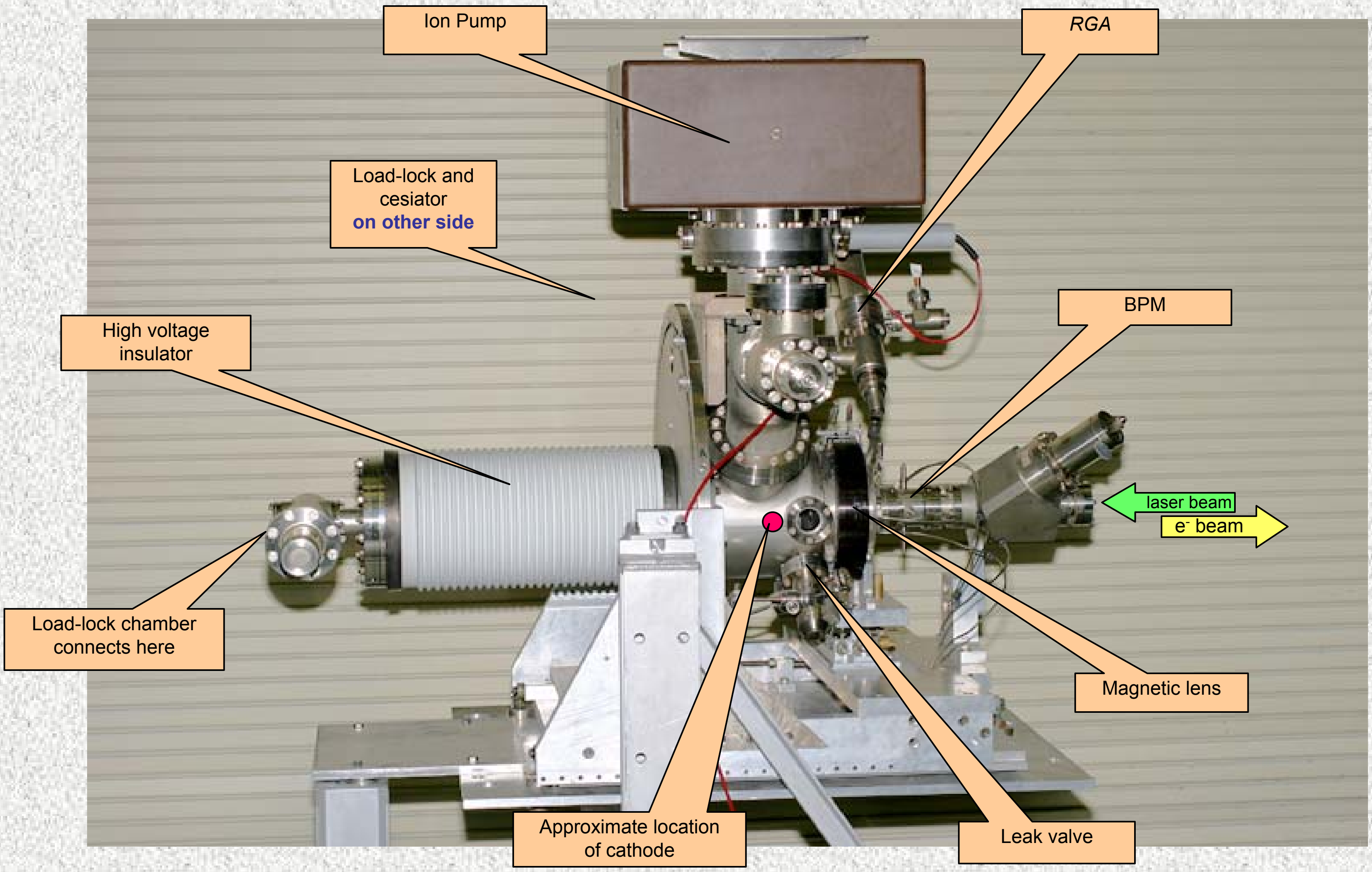




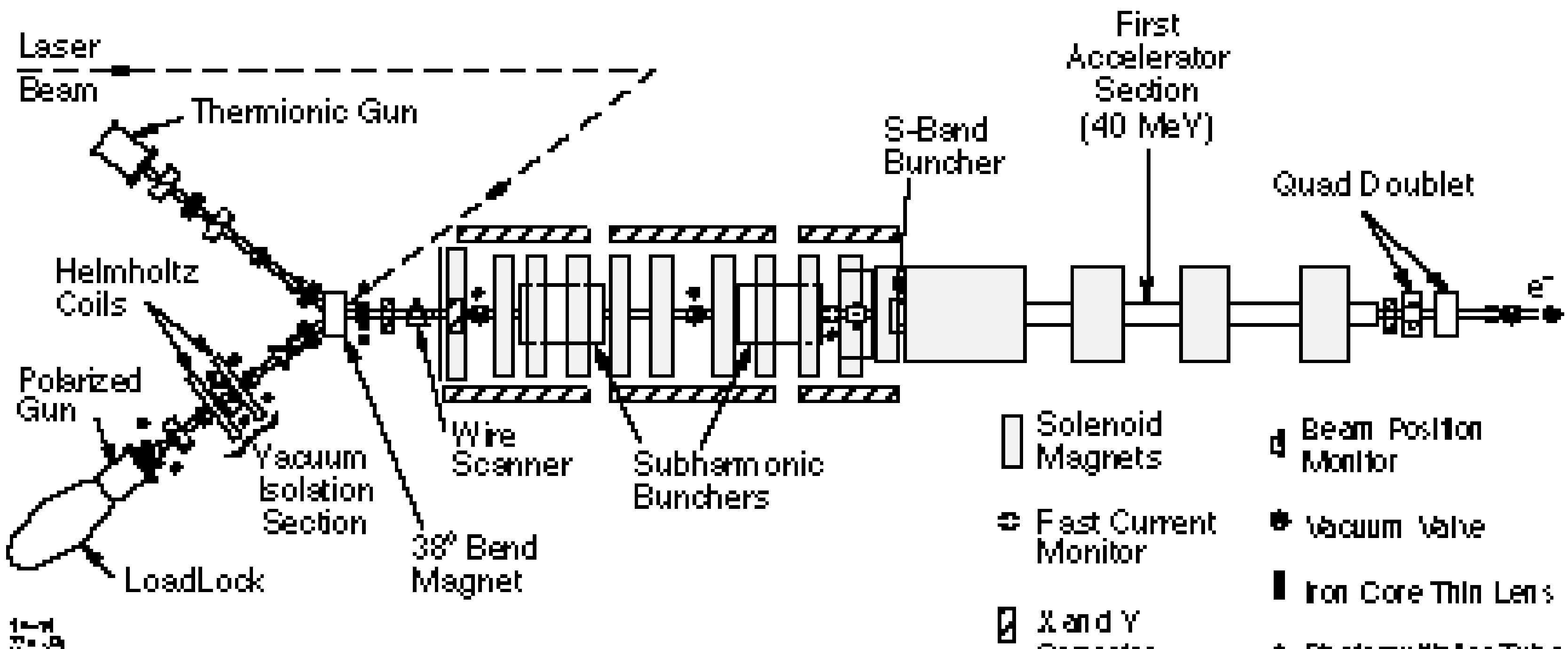
September 2004



SLC Polarized Electron Gun



SLAC Injector



SLAC’s DC gun

- Cathode bias -120 kV (-200 kV design)
- <8 MV/m, 1.8 MV/m at cathode.
- Low fields necessary to minimize the dark current (< 50 nA)
- GaAs crystal 2-cm dia. decreases space charge limit, but increases beam emittance at source
- Space Charge Limit (Child’s Law) limits max current
  $j_e, \propto V\ 3/2$
  11 A

SLC Gun for ILC Injector ?

Clendenin(SPIN2004)

Parameter at Source		**NLC NCRF S-band**	**ILC SCRF L-band**	**ILC NCRF-Inj/ SCRF-Linac**	**SLC Design (2-cm)**
ne	nC	2.4	6.4	6.4	20
Dz	ns	0.5	2	0.5	3
Impulse, avg	A	4.8	3.2	12.8	6.7
Impulse, peak	A				11 (SCL)

Conclusion: Space charge limit a problem for ILC source only if try to operate with NCRF injector S-band linac

Gun R&D

- Currently not at SLAC, possibly in the future
- 3rd generation polarized gun R&D at JLAB, Nagoya
- Nagoya – 500 kV Gun proposal
- Polarized RF – Gun ?[*]
  - Activation (NEA surface preparation)
  - Vacuum
  - HV bias, dark current, RF breakdown
  - Ion bombardment from back acceleration

[*] Clendenin et al. SLAC-Pub-8972, 2002

Future Source Activities at SLAC

→ driven by ILC collider design

- SLAC is in the process of planning future activities (Funding, Personnel)

- Continue Photocathode R&D
  - Demonstrate pulse train extraction
  - Strained GaAs/GaAsP
  - Strained InGaAs/GaAs

- Source Laser Development
  - Support Photocathode R&D
  - Towards ILC source laser