Laser Development for NLC
Related Photocathode Research

A. Brachmann, J. Clendenin, D.-A. Luh, T. Maruyama

SLAC
Outline

• Motivation

• Flashlamp-pumped Ti:Sapphire laser modifications
  – Laser power
  – Pulse shape (micro-structure plan)

• Thoughts on NLC laser system
  – Techniques
  – Challenges
Motivation

• Explore options for laser development

• Simulate NLC beam conditions for:
  – Continuation of NLC related photocathode research
  – Diagnostics R&D (Letter of intent to SLAC’s EPAC)
Flashlamp-pumped Ti:Sapphire Laser System

- Used for polarized e- beam at SLAC since 1993
- Pulse length ~ 300 ns
- Power ~ 300 - 500 μJ
- Stability 0.5 – 0.8 % Amplitude jitter
- Operation at 120 Hz
- Last action of injector laser system was E-158 experiment
- Copy of laser system and polarized e- gun exists in Laser- and Gun Development Lab
Q-switched Cavity and Pulse Slicing Setup

Cavity

Ti:Sapphire rod

PBS PC3 PBS Diagnostic

OC PC1 BRT PC2 EM

Cavity
Successful Modification to Q-switched Operation

- Intracavity Pockels cell to generate hold-off condition for several hundreds of ns during ~15 μs long flashlamp pulse

- Slow Q-switching allows power and pulse length control

- Achieved peak power of ~ 5 mJ in ~ 200 ns (25 kW)

- External pulse slicing to select Q-switched pulse

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- Q-switched laser pulse
- Pockel’s cell pulse
- Un-q-switched laser pulse
- Flashlamp pump pulse
Pulse shape comparison

Photodiode amplitude [V]

time [µs]

-4.5
-4.0
-3.5
-3.0
-2.5
-2.0
-1.5
-1.0
-0.5
0.0

un-q-switched
q-switched
Pulse shape control using two Pockels cells

- Control of hold-off time
- Control of duration and time shape of pulse release
- Control of timing in relation to ‘long-pulse’
- Resulting Q-switched pulse length > 300 ns
Stability of Q-switched pulse meets NLC specs

Histogram of Photodiode signal (GADC counts)

- **MEAN**: 2167.43
- **STD**: 11.15
- **STD/MEAN*100%**: 0.51
Beam profile – multimodal structure

Q-switched

‘Long – Pulse’
Micro-structure of Q-switched pulse
Current increased by Q-switching the laser

SVT-4353
780nm, 14mmØ

With Q-Switching
Without Q-Switching
**Electro-optical modulation to generate micro-structure**

- **Conventional Pockels cells**
  - require kV Voltages for switching
  - Commercial pulsers do not operate in the MHz – GHz range

- **Alternative: EO modulators**
  - composed of multiple EO crystals (4-6) available up to GHz range
  - Half-wave voltage of assembly: ~ 100 V
  - Suitable RF amplifiers available (Amplify SLAC 714 MHz)
  - Sinusoidal pulse train
  - Modulation depth increases, transmission decreases with increasing crystal number
  - Small aperture (2-3 mm); damage threshold concerns
  - External of cavity \(\rightarrow\) loss of 50% of laser power
  - Intracavity \(\rightarrow\) Cavity losses
NLC source laser power requirements

- Laser power (P) is driven by required electrons/pulse and QE of Cathode

\[ P = \frac{hc}{\lambda} \frac{e^-}{pulse} \frac{e^-}{QE} \]

- For \( 1.5 \times 10^{10} \) e\(^-\) per micro-bunch and QE = 1% at 800 nm: 0.37 \( \mu \)J laser energy per micro-bunch at cathode

- Train 192 micro-bunches in 270 ns: ~ 71 \( \mu \)J

- → Laser energy overhead for pulse shaping, transmission losses etc. required
NLC source laser (I)

Micro-structure

• Mode-locked system
  – 357 MHz / 714 MHz cavity \((f = c/2L)\)
  – Double Rep.-Rate (interferometer)
  – EO selection of 270 ns pulse train
  – Pulse stretching of pulse train
  – Diode pumped multi-pass amplifier
  – Laser material: Ti:Sapphire, Cr:LiSAF

• ‘Long–pulse’ Laser
  – ‘Flat–Hat’ shaping of long pulse
  – EO modulation to generate micro-structure

Challenge (for all cases):
Rise and fall time of micro-pulses
NLC source laser (II)

**Required R&D**

- **Micro-structure**
  - Fall and rise times
  - Flexible Micro-Pulse length

- **Pulse train amplification**

- **Stability**
  - Q-switched flashlamp-pumped Ti:Sapphire laser system has been demonstrated to operate at 0.5 % rms and less intensity jitter.
  - Effort on intensity stability depends on amplifier pumps \(\rightarrow\) Flashlamps / Diodes
  - Timing
  - Stabilization Techniques
    - Feed-forward / feed-back schemes
    - Nonlinear stabilization are possible but require laser power overhead

- Some R&D might be combined with LCLS drive laser development
Laser Development for RF gun at Tesla (I)

Specifications[*]:

- Micro-pulse length at Gun: 2 ns
- # Micro-bunches: 2820
- Bunch Spacing: 337 ns
- Pulse length: 950 µs
- Repetition rate: 5 Hz
- Phase stability: 200 ps (rms)
- Energy stability: 5 % (rms)

[*] Tesla TDR
Laser Development for RF gun at Tesla (II)

• Development of two laser systems:
  – Unpolarized e\(^-\) beam using Cs\(_2\)Te Cathode – UV
  – Plans for polarized e\(^-\) beam (GaAs Cathode) – 800nm

• Much progress of UV laser system development

• Options for 800 nm laser (GaAs cathode):
  – Mode-locked Ti:Sapphire system
  – Mode-locked Cr:LiSAF or Cr:LiCAF (LiSrAlF\(_6\):Cr\(^{3+}\), LiCaAlF\(_6\):Cr\(^{3+}\))
  – OPA conversion of 2\(^{nd}\) and 3\(^{rd}\) harmonic of existing system