SYNCHRONIZABLE HIGH VOLTAGE PULSER WITH LASER-PHOTOCATHODE TRIGGER

P. Chen, M. Lundquist, R. Yi, D. Yu
DULY Research Inc., California, USA

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1. Introduction

High Gradient Electron Gun Requires a synchronizable Pulser

![Graph showing electric field breakdown limit (GV/m) versus pulse length (ns) for copper electrodes.]

- Electric field breakdown limit (GV/m) versus pulse length (ns) for copper electrodes.
1. Introduction

High Gradient Electron Gun Requirements for a synchronizable Pulser

- Low jitter (< 500 ps)
- Fast rise time (<500 ps)
- Short pulse width (< 2 ns, 1~1.5 ns)
- Fall time (<1 ns)
- Pulse amplitude (~ hundreds of kV, MV)
- Repetition rate (Low: 1~5 Hz)
1. Introduction

Critical issues in a Pulser: reducing jitter, caused mainly by switch devices

- **Fast switch in accelerators**: semiconductor switch, spark gap (electrical or laser trigger), etc.

- **Limitations**: technical problems, cost, size, complications, etc.
  - Short pulse, high voltage: spark gap is often used (simple structure)
  - To improve jitter: laser-triggered spark gap
1. Introduction

Conventional laser-triggered switch

- **Jitter relatively low:** Compared with gas gap switch

- **Low optical energy utilization ratio**
  - For SF₆ and N₂, absorption rate < 0.002/cm
  - 30 cm gas channel, total photons absorbed < 6 %
  - Result: Cost increases greatly as high energy lasers are expensive
1. Introduction

Novel Switch designed by DULY in rf/dc electron gun project

Gas spark gap switch
- Triggered by laser photoelectrons
- Goals:
  - Minimize the jitter of the switch
  - Raise the utilization ratio of the laser beam energy
  - Make the pulser synchronizable
1. Introduction

Pulser Designed for the DC/RF Gun
2. Marx Generator

Energy storage device for dc/rf gun

- **Advantage:** Easy to realize voltage multiplication
- **Drawback:** Large jitter at erection
- **Main switch to control jitter**
3. Main Switch

Connected with Marx generator and control the pulse transmit

- **Trigger**: Laser-Photocathode sub-system
- **Connection**: main electrode 2 at low potential
  main electrode 6 at high potential
- **Properties**: A. Make use of the leftover laser optical energy; B. Input more activation energy to spark gap
3. Main Switch

High vacuum cell with a transparent wall

- **Purposes:** (1) high quantum efficiency (2) long lifetime of the photocathode
- **Triggering mode:** double triggering
- **Properties:** delay acceptable and very low jitter
3. Main Switch


- **Photocathode**: Magnesium
- **Quantum efficiency**: $5 \times 10^{-4}$ (Moderate)
3. Main Switch

Switch calculations

- **Assumptions:**
  - **UV Laser:** pulse length=100ps, pulse jitter~sub-ps, pulse energy=4 mJ
  - **Model:** radius of anode~1.5 cm, gap between photocathode and anode~1.5 cm, separation between anode and main electron adjacent > 1 cm, length of trigger electrode ~4 cm

- **Photoelectron charge:** \(-3.43 \times 10^{-7}\) Coulomb

- **Capacitance between trigger circuit and adjacent main electrode:** \(2.07 \times 10^{-12}\) F

- **Voltage across the gap between trigger and adjacent main electrode:** 165.7 kV (very high)

- **Electrical energy stored:** 28.4 mJ >> 4 mJ (laser energy)
3. Main Switch

Switch calculations (Cont’n)

- Transit time for photoelectron across the gap between photocathode and anode:

\[ t = \frac{m_0 c}{eE} \arccos\left(1 - \frac{eEl}{c^2 m_0}\right) \]

- \( t \) is the transit time; \( m_0 \): rest mass of electron; \( e \): electron’s charge; \( c \): the light speed in vacuum; \( E \): the electric field; and \( l \): distance between photocathode and anode

- Transit time: 276 ps

- Delay: Laser pulse length + transit time + photocurrent conduction time in metal wire < 609 ps (Wire length < 10 cm)
3. Main Switch

- Equal potential lines calculated by SUPERFISH /POISSON code around the electrodes
3. Main Switch

Field distortion type switch

- **Advantage:** multi-point ignition, easy adjustment of trigger gap distance
- **Drawback:** one more trigger circuit connection
4. Transmission Line and Discharger

Discharger on the transmission line:

Impedance of the coaxial transmission line 75 ohm

Discharger breakdown caused by: incident wave + reflection wave

Pulse length: adjustable
5. Summary

- Propose a new trigger mechanism
- Double triggering mode
- Switch having very low jitter
Thank you!

Questions?