Karlsruhe Institute of Technology

Resonance Behaviour of a Pulsed Electronic Control Gear for Dielectric Barrier Discharges

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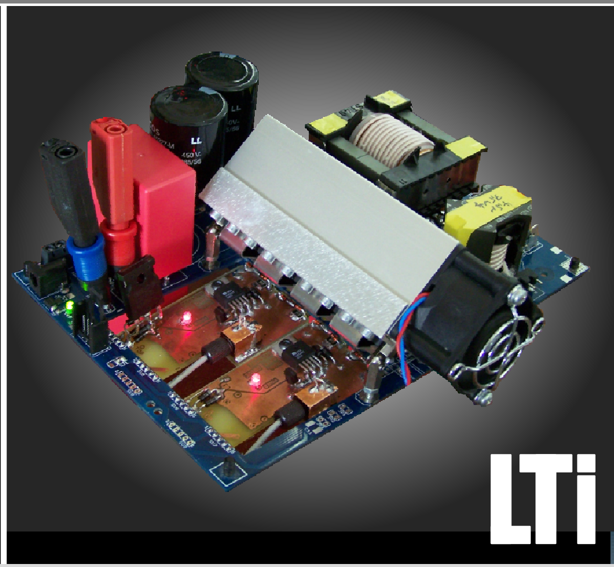
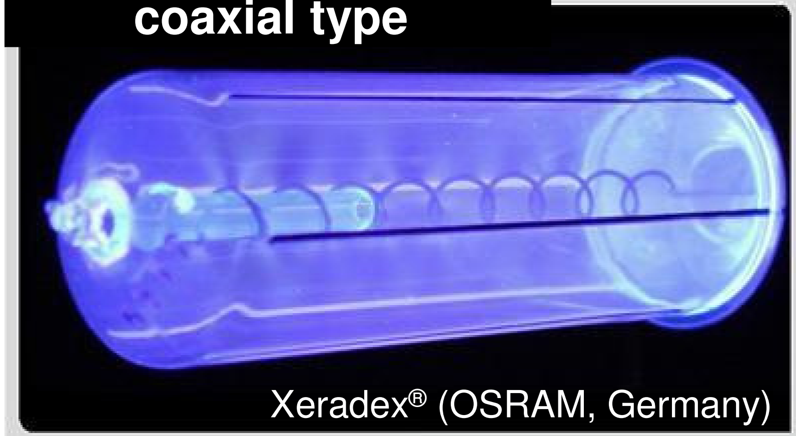


Dielectric Barrier Discharge Lamps - DBD

coaxial type



Xeradex® (OSRAM, Germany)

plane to plane type

Planilum© (Saint-Gobain Glass, France)

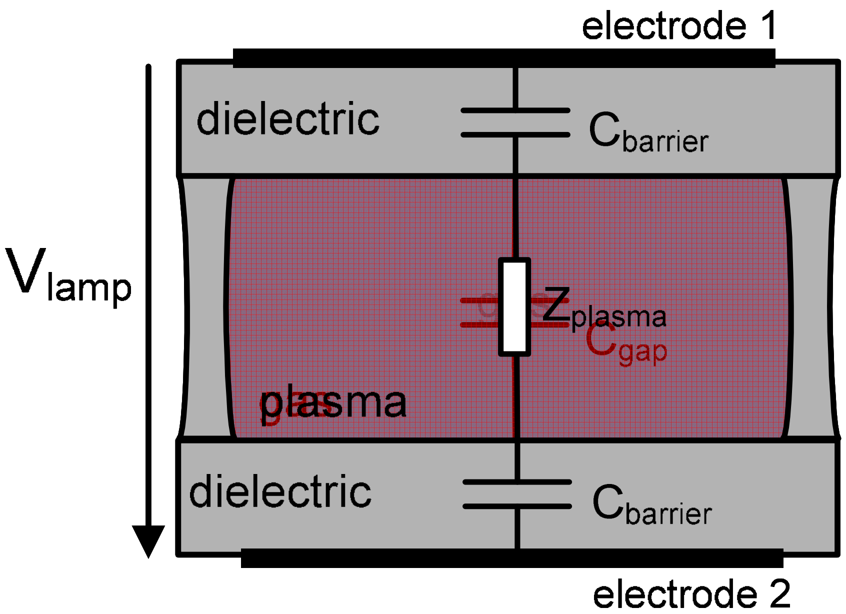
features:

- instant-on
- long lifetime
- areal radiation
- various wavelengths
- mercury free

applications:

- UV - surface modification, lacquer curing
- scanner and copying machines e.g. XeFI™ (OSRAM, Germany)
- ambient lighting

Dielectric Barrier Discharge Lamps – Set-up



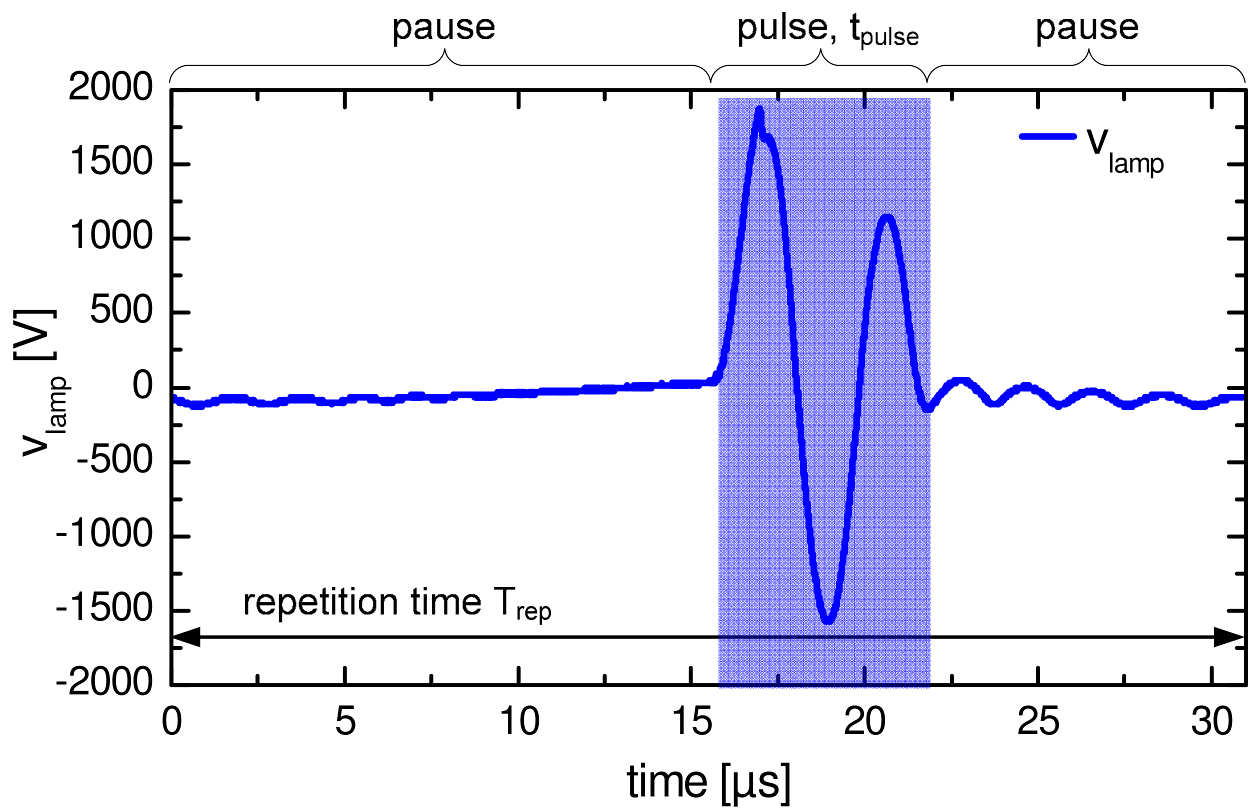
Characterization:

- low power factor – capacitive loads

Requirements:

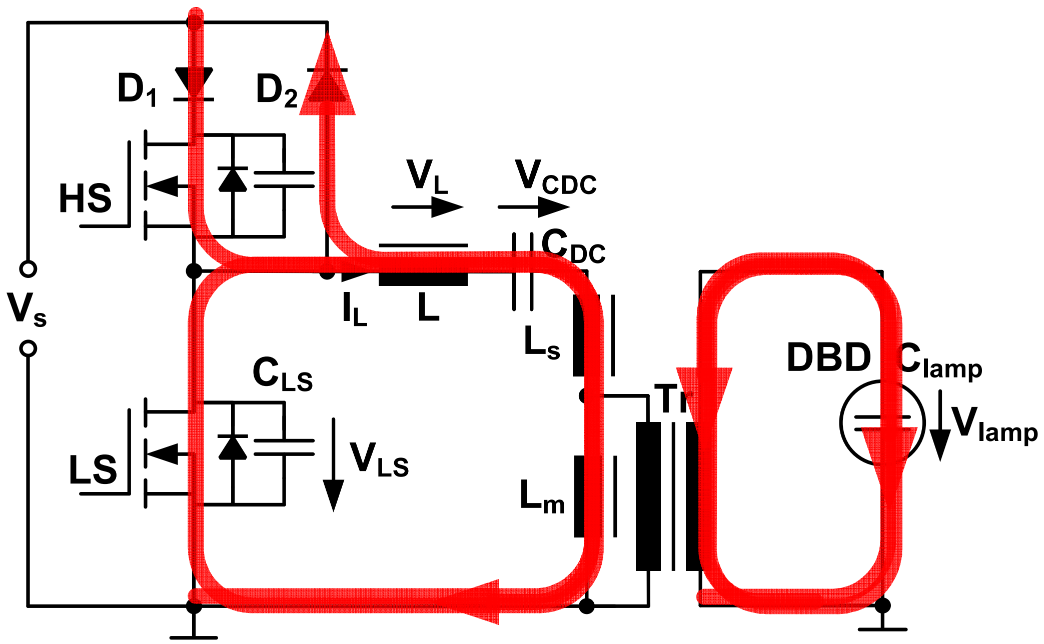
- high AC voltage
- pulsed operation
- energy recovery

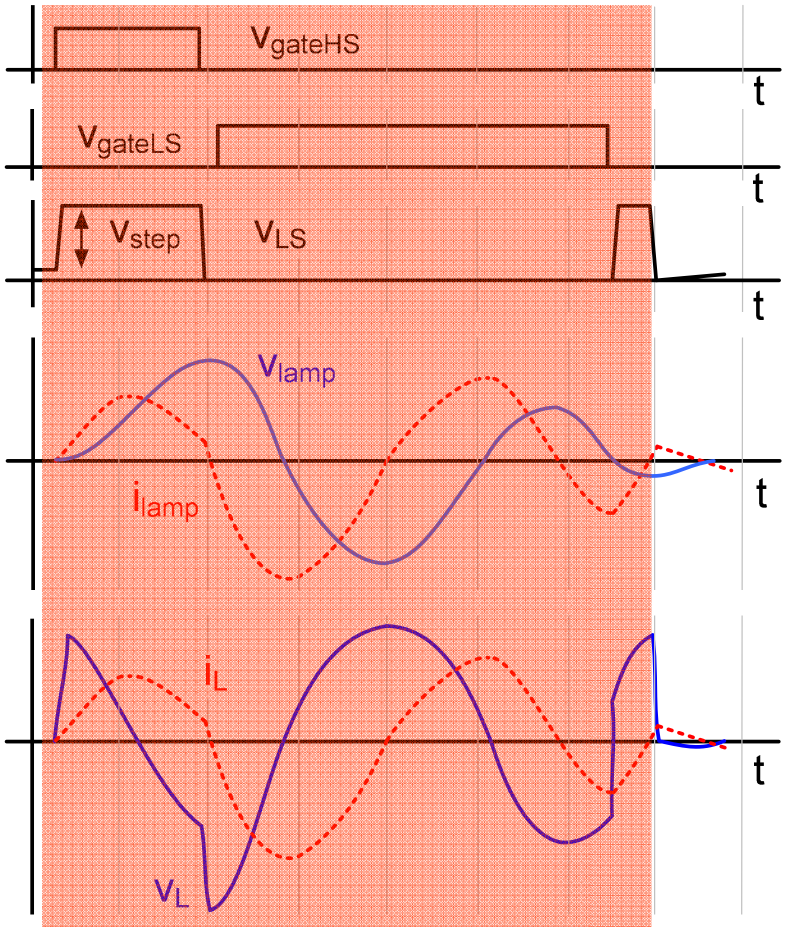
Pulsed Operation Mode With Resonant ECG



- 3 half-wave sinusoidal pulse lamp operation
- one lamp ignition per half-wave
- $f_{pulse} \approx 200$ kHz, $f_{rep} = 32$ kHz

Schematic and Operation Mode

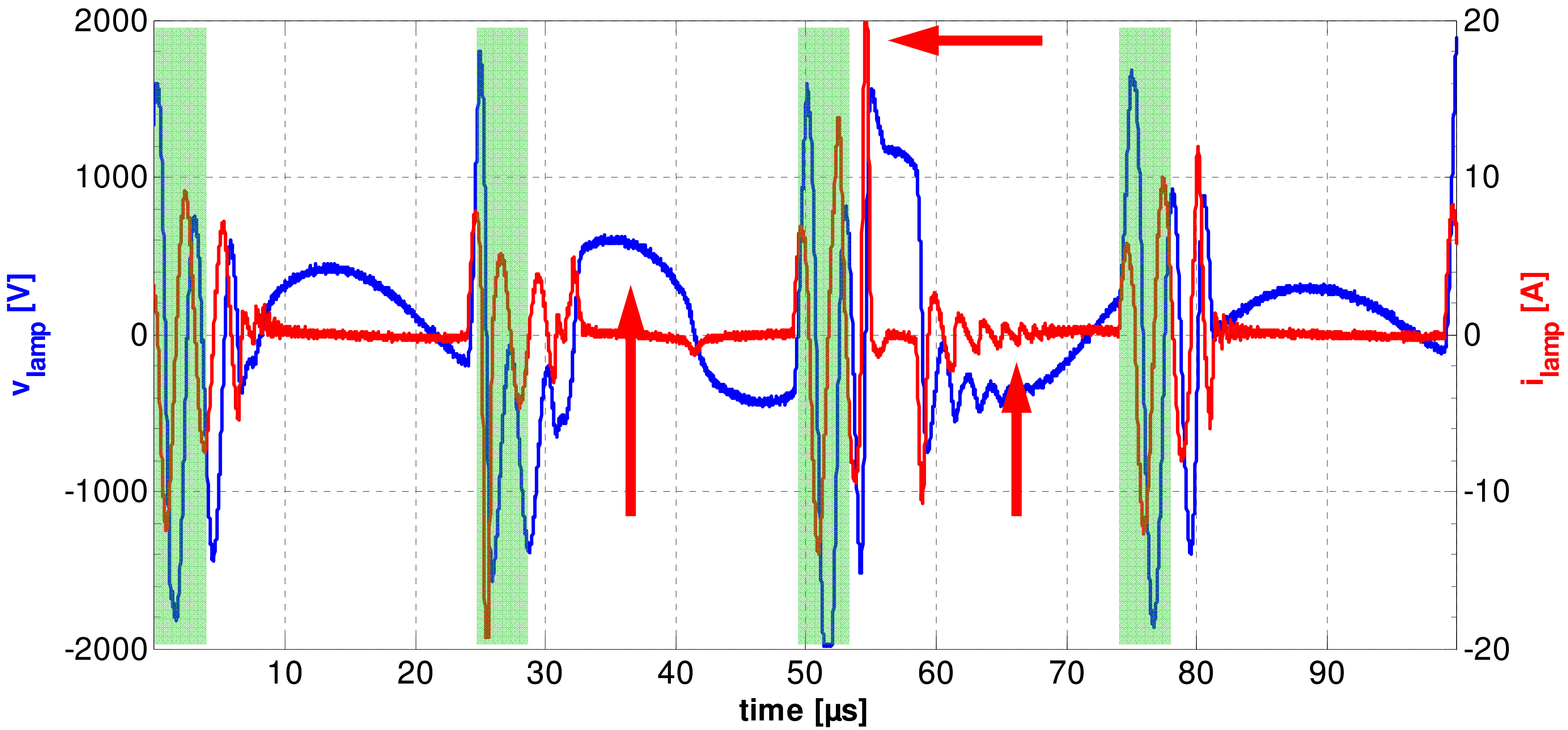




- resonant tank excited by half-bridge
- waveforms resulting from step answer of RLC-circuit

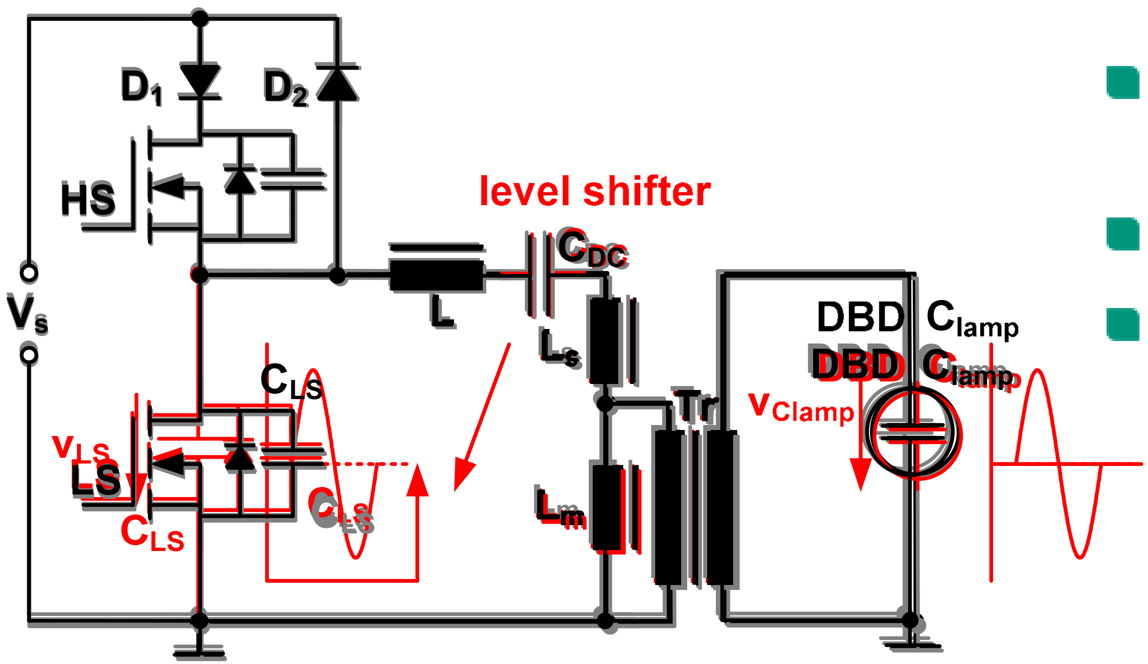
Paravia, M. et al "*Threshold current density for homogeneous excitation of pulsed xenon excimer DBD.*" *Int. Conf. on Plasma Science, ICOPS*, 2008

Problem of Parasitic Parallel Resonance



- excessive v-t products
- magnetic runaway of magnetic components
- peak currents may destruct half-bridge

Origin of Parasitic Parallel Resonance



- parasitic parallel resonance between L_m and C_{lamp}
- remaining v-t product in transformer
- charges on switch output capacitances
- stored energy on C_{DC}
- level shifting: free swinging

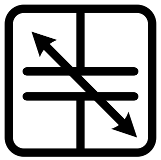
Managing Parasitic Parallel Resonance

- energy left in circuit
- circuit not clamped

free swinging of damped multi-resonant circuit

↓

damping by adjusting

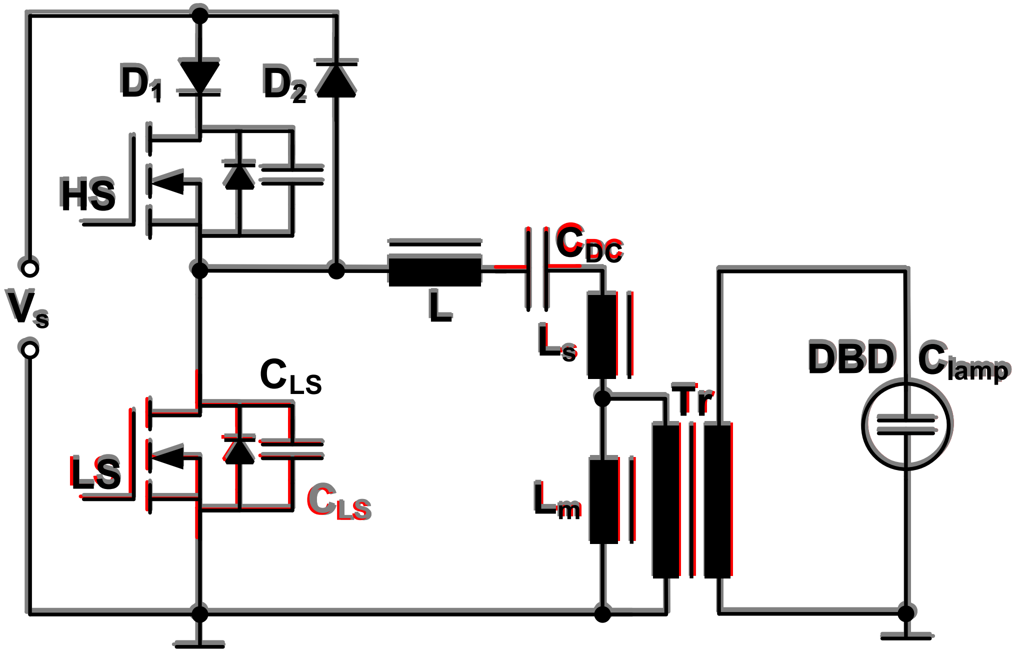


component parameters

T_{rep} **timing**

Damping by Parameter Variation

- **reduction of quality factor of parasitic parallel resonance**



- lamp capacitance fixed by application
- transformer optimized and fixed by v-t rating
- transistors fixed by max currents
- DC-blocking capacitor
  - low damping possible to cost of reduced ignition support

Alternatives

parameter variation not an option

repetition period

switching pattern

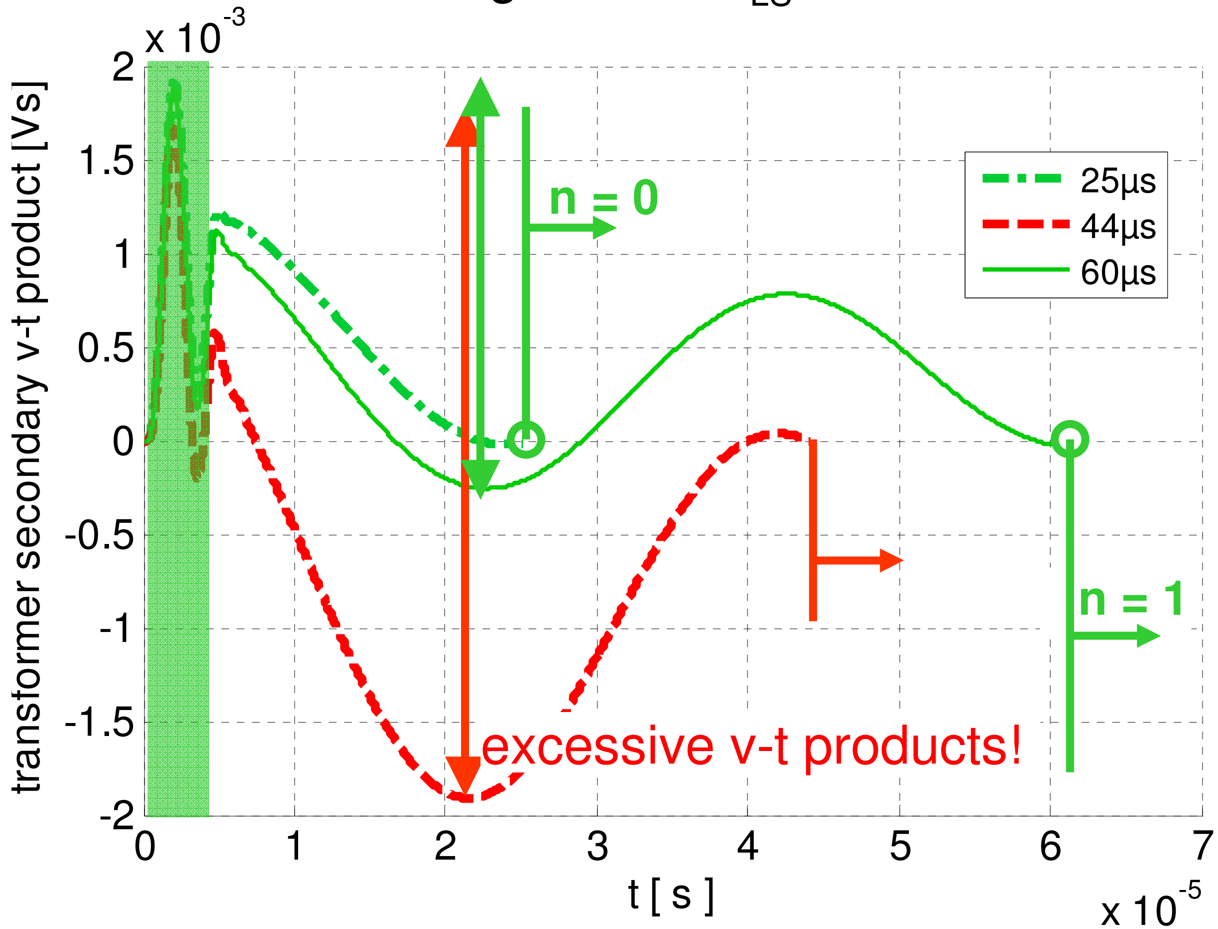
Adjusting Repetition Period

- optimize preconditions for next pulse
- pulse start in minimum of volt-second swing – initial V_{LS} minimal

therefore meet:

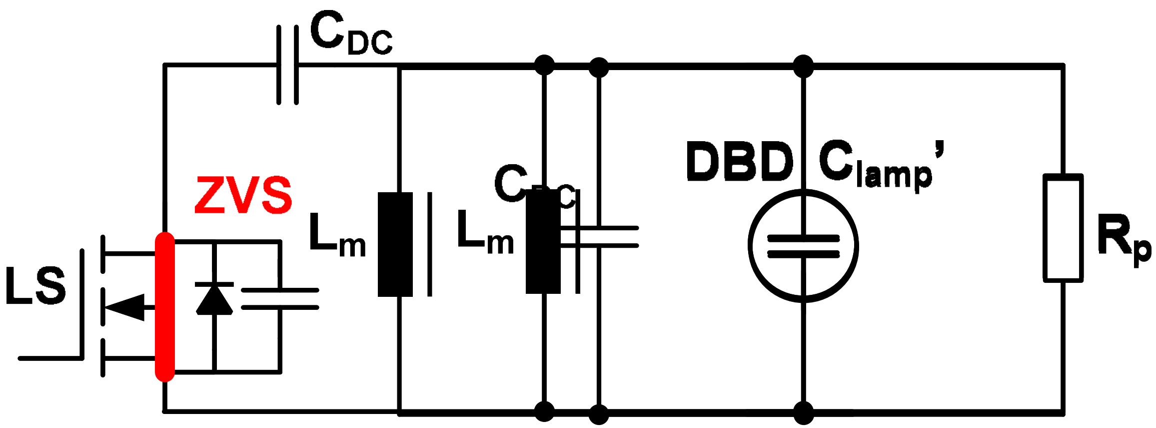
$$T_{rep} \approx \frac{1+2n}{2 \cdot f_{pp}} + t_{pulse}$$

- reduced v-t product swing
- reduced amplitude of resonance



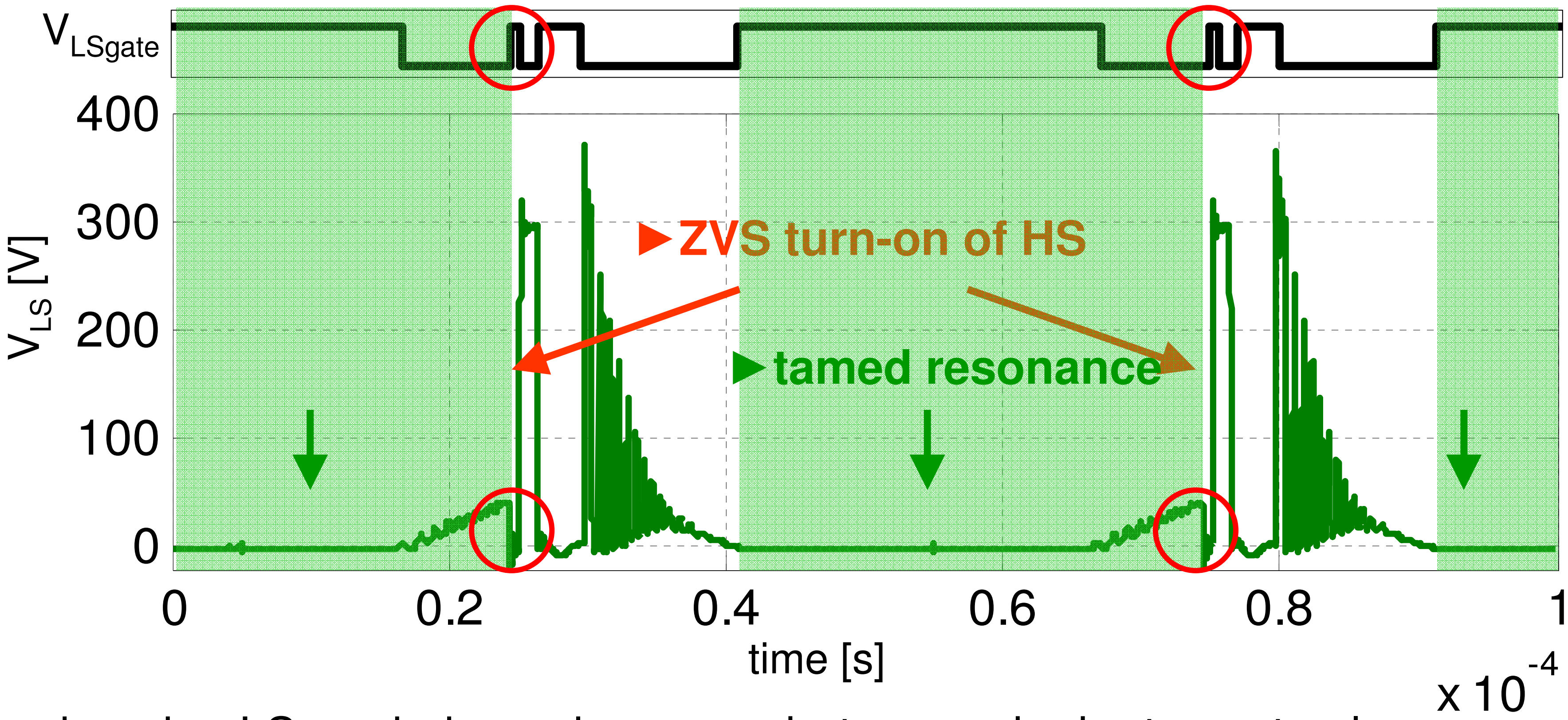
Variation of Switching Pattern

- keeping LS on during pulse pause



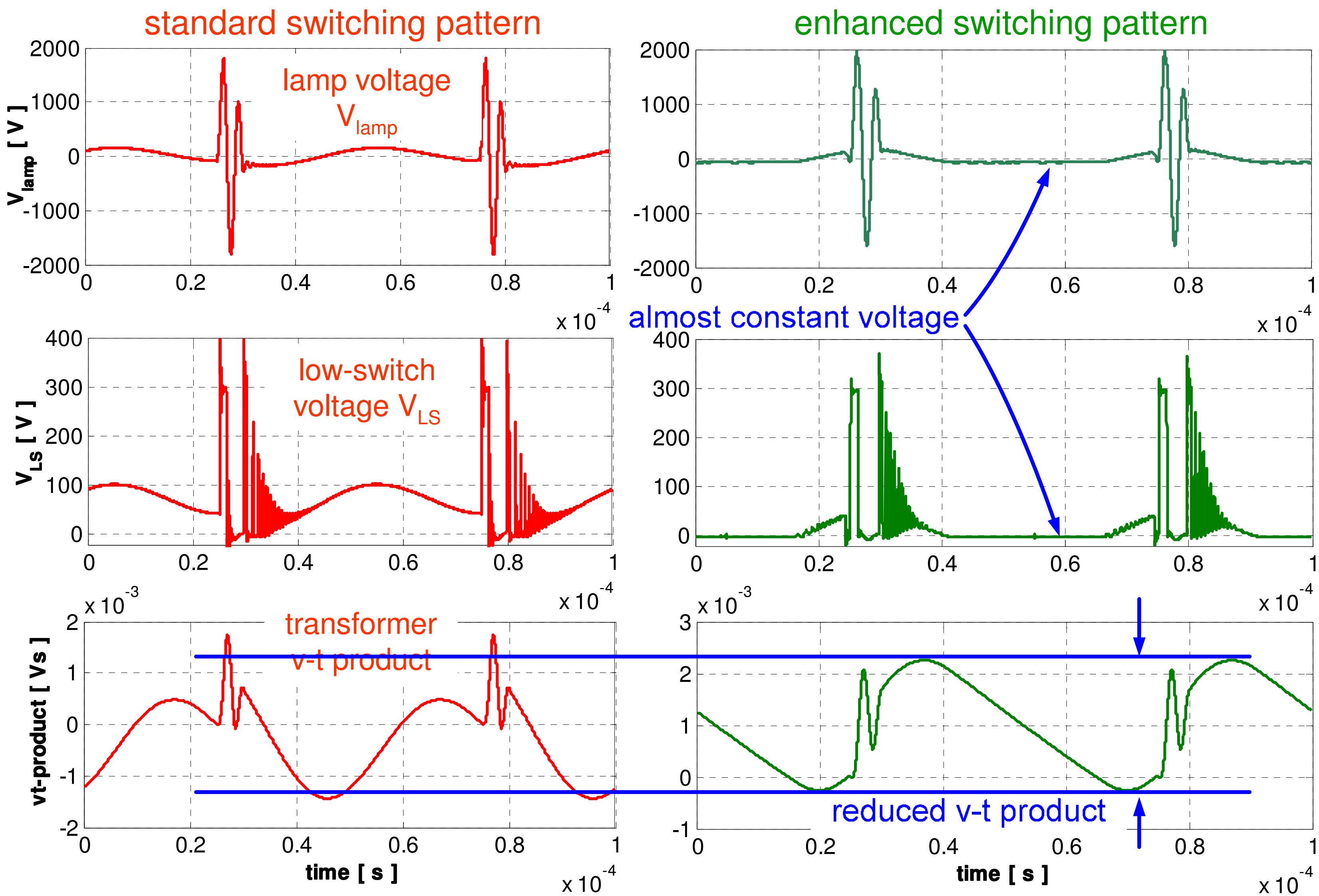
- result:
  - reduced resonance frequency
  - v_{CDC} constant and adequate to compensate v-t product
- benefits:
  - lower v-t products reduce losses & prevent saturation of transformer
  - parasitic parallel resonance tamed

Additional Benefit: ZVS for HS On-Transition



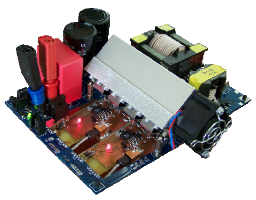
- keeping LS on during pulse pause but opened prior to next pulse
- short closing directly before pulse stores energy in L
- utilization of E_L to charge C_{HS} **►efficiency increase from 80 % to 82 %**

Comparision of switching patterns

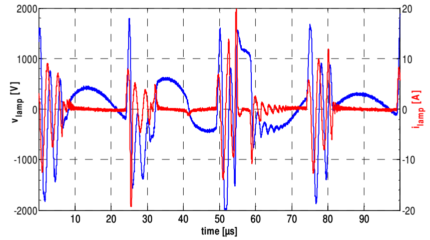


To Conclude

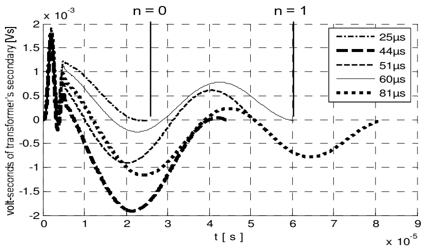
- resonant ECG drives DBD lamp



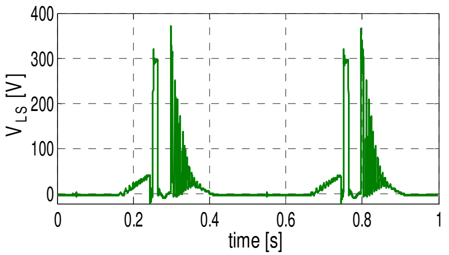
- serious problem of parasitic parallel resonance



- adaption of repetition period T_{rep} shrinks resonant amplitude



- advanced switching scheme tames negative effects and brings additional benefit
  ►**increased reliability & efficiency + 2 %**



Question and Answer Part

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